A Review of the Accomplishments and Plans of the NOAA Coastal Ocean Program (1994)

Panel on the NOAA Coastal Ocean Program
Ocean Studies Board
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Cover art was provided by Eileen Kiliman, a native of White Plains, New York, now living in Front Royal, Virginia. She earned a BBA in Marketing and a Certificate in Commercial Art from Pace University in New York. After eight years of representing a graphic design firm, she has made her lifetime love of art a full time profession, receiving a variety of commissions. Her style projects childhood observations combined with adult introspection.

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PANEL ON THE NOAA COASTAL OCEAN PROGRAM

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EXECUTIVE SUMMARY

Since its inception in FY 1990, the Coastal Ocean Program (COP) of the National Oceanic and Atmospheric Administration (NOAA) has filled a unique niche in the U.S. marine sciences community by supporting activities designed to improve our understanding of, and ability to manage, coastal fisheries ecosystems, coastal environmental quality, and coastal hazards (the three thematic foci of the program). In fisheries and environmental quality, COP has funded three major field programs, each lasting 5 years and focused on fundamental regional research that could contribute to the understanding of societally important issues. In coastal hazards, COP has added incremental funding that has made possible the development of new systems and products that probably would not have been developed without COP support. COP funding differs from that provided by other NOAA programs, such as Sea Grant and the National Marine Fisheries Service, in that it explicitly encourages NOAA-academic partnerships in coastal research. The synergistic effects of these partnerships are evident within NOAA and academia. Also, focusing a part of COP's budget on a few relatively large initiatives has enabled COP to apply a critical mass of effort on important problems.

The Panel on the NOAA Coastal Ocean Program of the National Research Council's Ocean Studies Board has followed COP progress almost since the formation of the program. At the request of the COP Director, Dr. Donald Scavia, the panel conducted its second in-depth review of the program. The detailed findings of the panel are presented in this report. The panel found that COP funding has advanced understanding and created useful products in a number of areas. In many cases, however, because research is still in progress the utility of COP-supported research for addressing important coastal issues is uncertain. The greatest program-wide need is to develop a program that can be conducted under a situation of level funding, streamlining COP's management and advisory structures to reflect this probability. Other recommendations discussed throughout the report advise COP about other changes the panel believes COP and its components should adopt.

Coastal fisheries are important to the economy of the United States, ranging from the employment of individual fishermen in coastal towns to the national balance of trade in seafood products. Fisheries are regulated in the United States, yet many are still declining due to a variety of causes (NRC, 1994). COP is funding three programs focused on coastal fisheries ecosystems. These studies—targeting some of the most productive fisheries and U.S. fishing grounds—seek to understand the factors that control abundance of fish populations, including recruitment variability, compensatory mechanisms, and species interactions. Understanding these factors could lead to better management of U.S. fishery resources.

The panel supports COP in its choice of research supported under the Coastal Fisheries Ecosystems (CFE) theme, carried out cooperatively by NOAA and academic scientists. It is too early for major breakthroughs to have been achieved, but the programs have advanced sampling technologies, conducted innovative modeling efforts, and applied new methods of molecular biology and biochemistry to fisheries research. The NOAA-academic partnerships and possibilities for long-term funding through CFE are providing opportunities to conduct fishery oceanography programs that promote fundamental science, but maintain regional, resource, and mission-oriented emphases. The CFE theme supports the NOAA Strategic Plan (NOAA, 1993) and is a positive step toward understanding coastal fisheries ecosystems that, if successful, will assist managers in attaining sustainable harvests of fish.

The panel recommends that the CFE theme maintain its present goals and objectives through FY 1995. To develop plans for its next 5 years of research, CFE should convene workshops and planning meetings, taking into account related research programs, and perhaps in conjunction with professional meetings, to include a broad cross-section of fisheries scientists. The panel recommends that the CFE theme begin planning for the FY 1996 to 2000 period, with due consideration given to new programs and possible continuation of existing ones. It is important to communicate CFE's future plans to the scientific community as soon as possible.

CFE should reconstitute its Program Management Committee (PMC) and Technical Advisory Committee (TAC).[1] The membership of each should be balanced among member scientists from the National Marine Fisheries Service, the Office of Oceanic and Atmospheric Research, and academia. The TAC should be of appropriate size and its members should not be involved in the constituent programs. The PMC and TAC are needed to plan, manage, and promote interactions and collaborations among CFE programs. The panel recommends that CFE standardize the processes by

[1]See pp. 22 and 23 for a more detailed description of the responsibilities of the Program Management Committee and the Technical Advisory Committee.

which proposals are solicited and reviewed, at both the theme and program levels, and that the same processes be used for NOAA, academic, and joint NOAA-academic proposals. COP should encourage interactions on relevant issues between CFE and the Coastal Ecosystem Health (CEH) theme (e.g., to study the relationship between habitat quality and fisheries productivity) and between CFE and the Coastal Hazards theme (e.g., to study the relationships among coastal winds, ocean color, and fisheries).

Collaborations between academic and NOAA scientists have contributed to progress in the Coastal Ecosystems Health (CEH) theme by bringing new perspectives to old problems and by helping to focus the attention of academic scientists on critical problems in the coastal zone. Examples of successful ventures include: a major field effort that addressed the impacts of the upper Mississippi floods on the lower Gulf watershed (the Nutrient Enhanced Coastal Ocean Productivity-Mississippi-Atchafalaya Rivers study); the recent evaluation of atmospheric nitrogen deposition to Great Waters;[2] the development of bioindicators for assessing toxic contamination; new research on marsh restoration; improved procedures for assessing change in wetland habitats; and development of a data management system for coastal managers.

CEH is the result of merging several themes that examined the effects of anthropogenic impacts such as nutrient enrichment, the discharge of toxins, and habitat loss, on coastal ecosystems. By merging these themes, COP hopes to be able to examine the integrated effects of both natural and anthropogenic stressors in the coastal zone. As COP further consolidates the new CEH theme, the major focus should continue to be on the processes and mechanisms by which these stressors act at a number of scales ranging from the individual animal, to the population, community, and whole ecosystem levels. The innovative nature of the new "multiple stressors" initiative will require close monitoring by COP to determine if this approach produces high quality research. As the theme evolves, its leaders (with the help of COP management) should also promote interactions with the CFE theme to design joint research to study relationships among environmental quality, secondary production, and fisheries recruitment.

CEH should establish programs of pre-determined durations and should develop mechanisms to allow its mixture of programs to evolve over time as needs change. This will require the formation of an objective PMC and TAC consisting of individuals not directly involved in any of the research programs, who can recommend the

[2]The Great Waters are a series of large bodies of water that the Environmental Protection Agency has designated for monitoring. The Great Waters originally included the Great Lakes, Lake Champlain, and Chesapeake Bay, but have been expanded to include many other lakes and all coastal waters.

elimination of programs when necessary. The panel recommends that CEH continue to work with related programs, such as NOAA's National Status and Trends Program and the Environmental Monitoring and Assessment Program of the Environmental Protection Agency. COP should play a role in developing new ways to assess and inventory the health of the coastal zone but should not undertake routine monitoring activities once these techniques have been developed.

Significant scientific and technical progress has been achieved by programs under the Coastal Hazards theme. These include: (1) development of an operational demonstration data acquisition and distribution system in the CoastWatch program; (2) derivation and testing, as part of the Coastal Winds program, of refinements that will significantly improve the accuracy of operational coastal wind products; (3) acquisition by the Tsunami program of bottom pressure data in key regions needed to improve physical understanding of tsunami processes; and (4) the first successful demonstration of a regional Great Lakes Forecast System utilizing inputs from CoastWatch, the NOAA National Ocean Service, and National Weather Service operational models, and providing products to a wide variety of users.

The panel recommends that the Coastal Hazards theme should adopt as its overall goal the development of a scientifically valid, operationally useful, and programmatically relevant coastal forecast and analysis system that combines the various activities of the theme. The operational portions of programs that have moved beyond the demonstration stage (e.g., CoastWatch) should be transferred to NOAA line offices, with responsibilities for further research and development retained by the Coastal Hazards theme. This is in keeping with recommendations of a previous Ocean Studies Board report that highlighted the need for academia and federal agencies to work together to ensure the development of mechanisms “to provide smooth transition from research activities to operational measurements” (NRC, 1992). COP must support the acquisition of SeaWiFS ocean color data for the Alaska coastal region, to prevent significant data gaps and to contribute to the goals of other studies, such as the Bering Sea Fisheries Oceanography Coordinated Investigations program. The panel recommends that formal technical review and advisory procedures be incorporated as soon as possible at the theme planning level and, when appropriate, within individual programs.

After 5 years, COP's budget is lower than expected by program managers. At its inception, COP formulated ambitious plans to address a wide range of topics in coastal ocean science that are relevant to societal needs. As budget increases failed to materialize, many of the multi-year activities have been scaled back. COP has responded with a program-wide process of consolidating and integrating many of its activities. Some programs, particularly in CEH, still have not incorporated realistic budget expectations into their plans. COP needs to improve its long-range planning,

taking into account funding uncertainties and requiring its themes to react more quickly and realistically to budget shortfalls. Given the future budget limitations that may be faced by COP, program managers must define COP's role in the national research effort carefully. Part of this process should include an examination of COP's review and advisory structure with the goal of streamlining it, and developing effective mechanisms to transfer monitoring and prediction activities out of COP when they pass from research to operational status. The panel also noted the serious effect of congressional earmarks on COP funding decisions. Congress has required COP to spend an increasing portion of its appropriations on congressionally-mandated projects. This short-circuits COP's normal planning and peer-review processes, and does not result in the most important and scientifically defensible projects. COP should continue to articulate the negative consequences of earmarking, and at the same time make a greater effort to communicate its successes.

The panel endorses the present three COP themes and believes that the program should maintain a multi-theme approach. The panel also endorses the decision that consolidated the former seven themes into the present three themes; it is likely that increased coordination of programs within the new themes will yield new approaches and insight into coastal fisheries ecosystems, coastal environmental quality, and coastal hazards. In addition, COP should develop clearer communication and integration among its three themes. Developing cross-theme connections will promote coherence in COP activities.

Effective technical advisory groups should be formed now for each of the themes and should begin planning now for COP's next five years. These advisory groups should be composed of individuals who do not have a stake in the outcome of the advice, so that they can make objective recommendations about changing or eliminating programs and projects within a theme and can avoid conflicts of interest.

Finally, the panel recommends that the procedures for proposal solicitation and review, as well as advisory structures, should be standardized among themes and programs so that investigators supported by each program are treated similarly and program management is streamlined. All themes should maintain a significant NOAA-academic partnership, even when funding levels are lower than expected because of the benefits that result from the sharing of intellectual and physical resources. NOAA should continue to use its resources—personnel, research vessel support, computer time, and equipment—to help COP conduct its programs. The panel recommends that COP management continue to stress the benefits of NOAA-academic collaboration in all aspects of COP research and development. Timely publication of results in the open literature is important for evaluating the quality and significance of COP-supported research and to publicize COP research activities. The recommendations

contained herein should be implemented expeditiously (beginning in FY 1996 budgets where possible) to have maximum impact.

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CHAPTER 1

INTRODUCTION AND BACKGROUND

OBJECTIVE OF THE REPORT

In May 1993, managers of the Coastal Ocean Program (COP) of the National Oceanic and Atmospheric Administration (NOAA) began planning with the NRC Panel on the NOAA Coastal Program to review COP achievements and progress over its lifetime and to assist COP in charting its future course. This evaluation included activities within the three themes of the program—Coastal Fisheries Ecosystems (CFE), Coastal Ecosystem Health (CEH), and Coastal Hazards—as well as general program review. COP requested that special attention be given to CFE because its projects had reached mid-life and decisions about their continuance and direction were necessary. The objective of this document is to report the findings of the panel's review of COP and to provide an objective assessment of program activities and its future directions.

HISTORY OF THE PROGRAM

The original goal of COP was to provide information to decisionmakers that would enable the nation to achieve the full potential of its coastal resources and to protect them for the future. “A unifying concept for the COP is improving predictions. The comprehensive science-based goal is to improve predictions of human impacts on: fisheries productivity, environmental quality, and coastal hazards, within the context of natural variability” (COP, 1993). It is clear that many of NOAA's legislative mandates are in science, resource management, and policy for coastal areas. COP-funded research is thus of great importance to NOAA as it attempts to refine and

implement the NOAA strategic plan (NOAA, 1993). It is significant that COP's goals are central to the activities described in the strategic plan. COP has encouraged new partnerships between NOAA and academic scientists for research on important coastal issues (Wenzel and Scavia, 1993).

COP had three subordinate goals:

1. Environmental Quality—Improve predictions of coastal pollution to help correct and prevent degradation.
2. Fisheries Productivity—Improve predictions of fish stocks to better conserve and manage living resources.
3. Physical Impacts—Improve predictions of physical impacts on coastal areas to protect life and property.

COP proposed to make progress by "capitalizing on resources from all NOAA line offices and the academic community" (COP, 1993). By creating COP as an entity outside the five NOAA line offices, NOAA hoped to support effective coordination and integration of relevant NOAA programs and to provide high level management to the program.

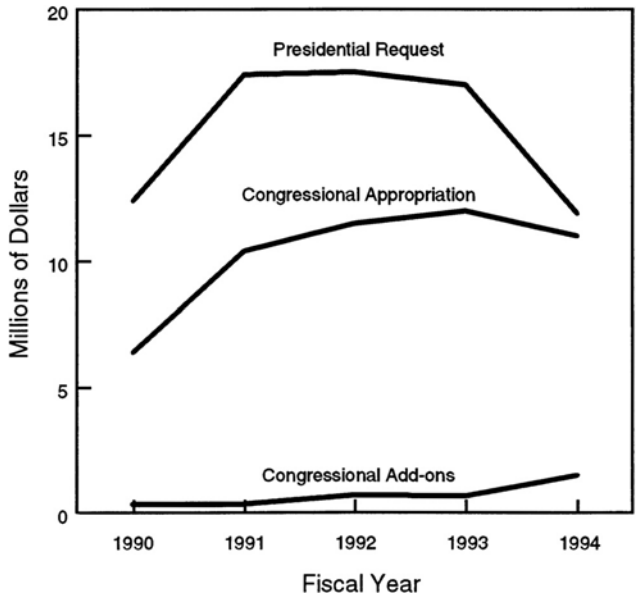

Figure 1.1
Coastal Ocean Program Funding History

BUDGET HISTORY

COP was formed in 1989 with a budget of $6.4 million. At the time, it was the second cross-line office program to be established within NOAA, following the Climate and Global Change Program. The purpose of these cross-line office programs is to coordinate activities within a subject area among the five NOAA line offices. The two programs mentioned are characterized by an emphasis on high-quality research by joint NOAA-academic groups; a high percentage of their research funding is awarded to scientists outside the agency. Since its inception, COP's budget has grown to $12 million. In FY 1993, 43.5% of its research funding was awarded to academic scientists (see Table 1.1).

COP's budget history is shown in Figure 1.1. COP has been ambitious in its plans and these generally have been supported by NOAA, the Department of Commerce, and the Office of Management and Budget. As Congress has evaluated the NOAA budget and overlayed congressional priorities on it, they have increased the COP budget over the years, but to a lesser extent than recommended by the Administration.

PANEL'S INTERACTION WITH THE COASTAL OCEAN PROGRAM

Early in its history, COP asked the National Research Council's Ocean Studies Board (OSB) to provide advice about program structure and function. The Panel on the NOAA Coastal Ocean Program (PoCO) was formed by the OSB in 1990 to make recommendations aimed at strengthening the coastal ocean activities of NOAA in general, and to assist COP specifically. The panel's terms of reference are to:

1. Recommend broad scientific programmatic guidelines for NOAA programs focusing on coastal ocean pollution and degradation, living marine resources, and the protection of life and property in coastal areas.
2. Assist in identifying the science and information needs of coastal public decisionmakers.
3. Assist in defining an efficient and cost effective program for NOAA that will complement programs of other agencies in the coastal ocean.
4. Examine and assess ongoing NOAA activities, short- and long-range plans, and institutional arrangements relative to the goals and objectives of the NOAA Coastal Ocean Program.

In its first year (from August 1990 to September 1991), the panel met three times to review and evaluate the objectives and the proposed implementation plans for FY 1991 and FY 1992 for all COP elements. A report of the panel's findings, *A Review of the NOAA Coastal Ocean Program* (NRC, 1991) summarized the conclusions of the panel after its first year of deliberation. In the period between September 1991 and May 1993, the panel met twice to be informed about the progress of COP activities and to receive follow-up briefings on issues of concern raised in the 1991 panel report. No reports were issued during this period.

EVOLUTION OF THEMES

COP originally included eight major themes—Observations and Predictions; Physical Impacts; Toxic Chemical Contaminants; Nutrient Over-Enrichment; Estuarine Habitats; Coastal Fisheries Ecosystems; CoastWatch; and Resource Information Delivery. *A Review of the NOAA Coastal Ocean Program* (NRC, 1991) recommended that the Observations and Predictions and Physical Impacts themes be combined. COP followed this advice and by 1993 had begun to combine its remaining elements into three broader themes: Coastal Fisheries Ecosystems, Coastal Ecosystem Health, and Coastal Hazards[3] (Figure 1.2).

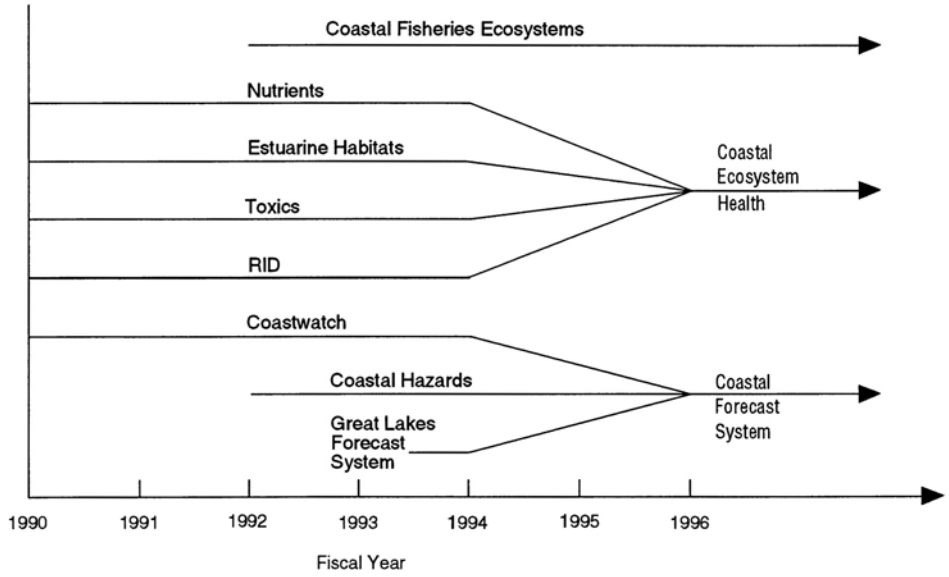

Figure 1.2
Evolution of the Coastal Ocean Program

[3]The Coastal Hazards theme was recently renamed "Coastal Forecast System."

CFE includes three programs: Bering Sea Fisheries Oceanography Coordinated Investigations (FOCI), the South Atlantic Bight Recruitment Experiment (SABRE), and the Predation and Structure of the Georges Bank Ecosystem program. CEH includes activities in nutrient-enhanced productivity, toxic chemical contaminants, estuarine habitats, and economic valuation. The Coastal Hazards theme includes activities on coastal winds, hurricane winds, tsunamis, sea level rise, CoastWatch, and ocean color. It also includes developing coastal forecasting systems for the Great Lakes and the U.S. east coast that could potentially be expanded to apply to the entire U.S. coastal ocean.

Some of the original themes fit neatly into the present three themes. The original Resource Information Delivery theme overlaps all three new themes and has been applied to each. COP has only begun to integrate programs within themes. The most developed example is the beginning of a transformation of activities in the Coastal Hazards theme into an integrated Coastal Forecasting System.

IMPORTANCE OF NOAA-ACADEMIC PARTNERSHIPS IN COP

COP was created to promote cooperation among the NOAA line offices in the area of coastal ocean research, and encourage cooperative projects between NOAA and academic scientists. Early in COP's evolution, former NOAA Administrator, Dr. John Knauss, directed COP to award a significant percentage of the program's funds to external scientists. As previously mentioned, COP presently awards 43.5% of its research funds to scientists outside NOAA (see Table 1.1).

COP has brought NOAA and academic resources together in a number of ways. As the subgroups of the panel examined COP activities, it became obvious that NOAA base support, in addition to COP research funds, has been very important to conduct several COP projects. This additional NOAA support has been primarily in the form of NOAA personnel salaries, research vessel support, and equipment. Without this support, the accomplishments of some programs, such as the Bering Sea FOCI and SABRE in CFE and Nutrient Enhanced Coastal Ocean Productivity-Mississippi-Atchafalaya Rivers (NECOP-MAR) in CEH, would not have been possible. **NOAA should continue to use its resources—personnel, research vessels, computer time, and equipment—to support COP programs.** This policy leverages existing NOAA resources and strengthens the partnerships and positive interactions among NOAA scientists and between NOAA and academic scientists. COP encourages a positive synergy when NOAA and academic scientists are brought together to conduct science that addresses NOAA problems.

Finally, COP has involved both NOAA and academic scientists in various advisory activities. At any given time, there are 50 to 100 scientists advising COP at the COP, theme, program, and project levels. The panel believes that advice from external scientists has improved many aspects of COP. The majority of these advisors serve on program- or project-level Technical Advisory Committees. **COP should seek more external advice at the theme level, while streamlining its program- and project-level advisory structures to decrease overhead costs.**

NOAA STRATEGIC PLAN

The NOAA strategic plan (NOAA, 1993) provides a context within which NOAA will evaluate its future activities and rationalize its many and varied responsibilities. The great emphasis of the NOAA strategic plan on coastal issues provides a clear rationale for a strong COP that performs a valuable service to NOAA by sponsoring research that lays a scientific foundation for future prediction, management, and mitigation activities. The NOAA strategic plan has major sections on coastal ecosystems health (p. II-3-1), building sustainable fisheries (p. II-1-1), and advancing short-term warning and forecast services (p. III-1-1), which relate directly to present COP themes.

PLANNING, REVIEW, AND ADVISORY STRUCTURES

COP initially performed planning and evaluation through its National Office staff, and later some aspects were carried out by PoCO. As time passed, COP implemented a management and review structure to provide objective, detailed advice on each theme. PoCO encouraged this development and provided advice to COP about the structure of its advisory mechanism and composition of its various advisory groups. At present, these advisory groups do not interact with each other.

PROGRAM CHARACTERISTICS

The National Coastal Ocean Program Office (NCOPO) is responsible primarily for conducting COP-related activities, but also has other responsibilities related to NOAA coastal ocean science, such as the Regional Marine Research Program, staffing the Water Resources and Coastal and Marine Environments Research Subcommittee of the White House Committee on Environment and Natural Resources Research, and NOAA-wide oversight for the new Center for Coastal Ecosystem Health at Charleston, South Carolina. Of the staff employed by NCOPO, approximately seven full-time equivalents (FTEs) are required to provide direct support for COP-specific activities.

This yields a value of $1.7 million per FTE, midway between the values for the National Sea Grant College Program ($1.2 million per FTE) and the Office of Naval Research (ONR) ($2.2 million per FTE), and lower than the National Science Foundation (NSF) ($4.4 million per FTE) (NRC, 1994). COP has a less extensive review structure than Sea Grant, being more comparable to NSF and ONR, but NCOPO staff are heavily involved in managing themes and coordinating activities of investigators they support. If dollars per FTE is negatively correlated with grant size, however, this would confound comparisons among agencies whose median grant size differs.

COP provided quantitative information about the accomplishments and productivity of the program (Table 1.1). Differences in the numbers of publications and number of investigators among the themes were attributed by COP staff to the different natures and relative maturities of the themes. For example, much of the research funded in CEH is performed by single investigators in projects with durations of one to two years, so that several project cycles have been completed and results have been published. In contrast, CFE supports large multi-investigator projects that have not yet completed a project cycle.

OUTLINE OF REPORT

The three COP themes are evaluated in detail in the following chapters. For each theme, the review includes:

- Goals and Objectives—Reviews the evolution of the goals and objectives and the extent to which they address fundamental questions.
- Progress and Quality—Outlines progress toward the goals and objectives, and the quality of research and development efforts from the beginning of COP to the present. Evaluates the extent to which results from scientific tasks have been synthesized to achieve progress toward objectives and goals.
- Utility of the Research—Reviews the extent to which each program has identified and interacted with target audiences or users of the information, both NOAA managers and external users.
- Theme Management—Outlines the planning process as well as future plans for COP programs, with an emphasis on the processes by which the plans are being developed.

- Responsiveness to Past Reviews—Discusses how responsive COP themes have been to any previous reviews.
- Future Plans—Evaluates future plans and makes recommendations for the future of themes and programs.

Table 1.1 Performance Measures for the Coastal Ocean Program, by Theme.

Performance Measure	CFE	CEH	Coastal Hazards	Total COP
Peer-reviewed Publications[1]	20	81	27	128
Academic Investigators Supported[2]	34 (of 51 total)	115 (of 183 total)	7 (of 34 total)	156 (of 268 total)
Percent of Funding for External PIs[3]	46%	51%	24%	43.5%
Percent of Total COP Research Funding[4]	25%	52%	23%	100%

[1]Printed or in press, over the life of the program
[2]Number of individual academic scientists who have received support over the life of the program
[3]Exclusive of NCOPO overhead (5% of total COP appropriation), FY 1993. Actual NCOPO overhead rate is 8%, being funded through the variety of activities for which COP is responsible.
[4]In FY 1993

The panel divided into three subgroups, one devoted to each theme, and specifically responsible for one chapter of this report. In addition, three outside experts were invited to provide input on the Coastal Fisheries Ecosystems themes.[4] The report also includes a discussion of other, cross-cutting issues. Because the

[4]George Boehlert (National Marine Fisheries Service), Donald Olson (University of Miami), and David Townsend (University of Maine).

nomenclatures used by the various COP elements are not always consistent, the panel chose to use a common nomenclature for this report. Thus, the report reviews the three themes, the programs that are sub-theme elements, and projects that are sub-program elements. Moreover, some themes and program names have been changed since the review, as indicated where appropriate.

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CHAPTER 2

COASTAL FISHERIES ECOSYSTEMS

INTRODUCTION

Fisheries in coastal and estuarine ecosystems are experiencing increasing pressures. Stocks have been overfished and estuarine habitats degraded to the extent that potential productivity and fishery yields are reduced below optimum sustainable levels. Some stock declines and collapses have occurred because scientists have insufficient knowledge to predict future trends in abundance or to advise managers with regard to sustainable yields, whereas others have occurred because of a failure to apply available knowledge.

Declines of fish stocks and their productivity are associated with declines in recruitment of catchable-size fish to the populations and high temporal variability in recruitment, eventually limiting harvests. Predicting recruitment success, the total number of catchable-size fish added to a population in a given year, has been a goal of fisheries science for many decades. Results of recruitment research may eventually lead to reliable forecasts of future productivity and abundances of fished stocks.

The decline of U.S. fisheries, the lack of understanding of mechanisms that control and regulate fish stocks, and a need for a predictive capability to forecast future trends in abundance led to the development of the Coastal Fisheries Ecosystems (CFE) theme. Fisheries ecosystems are biologically and physically complex systems that can only be understood as a result of long-term research carried out by interdisciplinary teams. In CFE, NOAA and academic scientists have collaborated to conduct multi-year programs that include the expertise of fisheries biologists, physical oceanographers, ecologists, animal behaviorists, molecular

biologists, biochemists, and others. These collaborations have promoted intellectual exchange and the development and application of new technology.

The CFE theme focuses on regional, resource-specific problems and supports research into the mechanisms that regulate or control abundances of important fishery resources (COP, 1993a). It promotes mission-oriented fisheries oceanography, distinguishing CFE programs from other evolving programs on fishery ecosystems [e.g., Global Oceans Ecosystems Dynamics (GLOBEC); see GLOBEC, 1992], which also pursue fundamental science goals, but which do not necessarily focus on specific regions or on particular exploited species. The potential for long-term funding (≥5 years) through CFE offers an opportunity to solve oceanographic and ecosystem-level problems that have not yielded to lesser efforts over the past 50 years. Long-term funding at a high level (about $500,000 to $ 1 million annually per program), the team approach of CFE, and regional projects distinguishes it from research funded by Sea Grant and other extramural fisheries research programs.

A major goal of the NOAA strategic plan (NOAA, 1993a) is the restoration of sustainable fishery resources. The CFE theme is highly visible as a cross-cutting element within NOAA that will help to address this strategic goal, as well as a second goal, the promotion of ecosystem health.

The concept of CFE research was included in COP from its outset (NOAA, 1991). Regional projects were envisioned, to be focused on problems associated with valuable exploited fisheries. As COP was implemented, CFE concept papers and proposals were considered. Two initial projects were accepted and funded in FY 1991. These were Bering Sea Fisheries Oceanography Coordinated Investigations (Bering Sea FOCI) and the South Atlantic Bight Recruitment Experiment (SABRE). The original COP intent was to expand the CFE theme in a deliberate way by adding at least four additional programs, perhaps one or two per year, during the 1990s (COP, 1991; 1993), as additional funds were appropriated by Congress for COP. A third program, Predation and Structure of the Georges Bank Ecosystem, initially was funded in FY 1993. Two additional programs were accepted in principle as possible future additions to CFE. They are Fishery Oceanography Research and Groundfish Ecology (FORAGE), a proposed study of groundfish recruitment variability on the U.S. west coast, and Salmonid Ecosystems Analysis (SEA), a proposed study of ocean survival of salmon (COP, 1991). Several additional concept papers have been considered by CFE during the past 4 years (COP, 1990; 1991a; NOAA, 1991).

Budgets of accepted CFE programs did not reach requested or anticipated levels (COP, 1991a; 1993a), in some cases making original goals of CFE programs unrealistic. Reductions in sampling efforts and other adjustments to proposed research were made by CFE program managers to accommodate budget shortfalls. No new programs

were to be funded in FY 1994 (COP, 1993a). The budget shortfalls are a major concern of presently funded programs and cloud future possibilities for expansion of CFE research.

As part of its overall responsibility to COP, the panel has previously provided advice regarding CFE, in particular its development, inclusion of elements, management structure, and review and selection procedures. In the present review, the panel evaluates CFE accomplishments since FY 1991 and provides advice on future development and evolution of the CFE theme. The present review included site visits and in-depth examinations of the Bering Sea FOCI and SABRE programs. These two programs had been funded for 3 years at the time of the review. The PoCO fisheries subgroup carried out the site visits in January 1994. Detailed evaluations of progress, achievements, utility, and planning for each program, as well as recommendations for future research directions, are provided in Appendix 1 and Appendix 2.

GOALS AND OBJECTIVES

The goals and objectives of CFE have remained essentially unchanged since the implementation of the theme in FY 1991. They are far-reaching and comprehensive (NOAA, 1991; COP, 1993a) and focus on problems that impede or prevent progress in understanding fundamental mechanisms which control fish population abundances and thus limit effectiveness of management.

The CFE theme supports mission-oriented, ecosystem research on fisheries ecosystems. The goal of CFE is to reduce uncertainty in resource management decisions through ecological research (NOAA, 1991; COP, 1993a). This goal is appropriate for a COP theme because it promotes cross-cutting research activities and provides opportunities that involve two NOAA line offices [the National Marine Fisheries Service (NMFS) and the Office of Oceanic and Atmospheric Research (OAR)] and many academic partners. The theme and its goal are supportive of interdisciplinary research that may be funded for 5 or more years. Prior to CFE, there were few mechanisms within NOAA or other agencies to undertake research in fisheries oceanography at the ecosystem level. A notable and unique exception is Shelikof FOCI, which is jointly supported by NOAA's NMFS and OAR, and which includes academic partners (COP, 1991a; NOAA, 1993b).

CFE has three objectives. Each is phrased as a question and highlights a major scientific issue related to understanding variability in fish stock abundances (COP, 1993a).

1. Recruitment variability: What are the processes that control recruitment, and to what degree can a better understanding of these processes be used for improved management decisions?
2. Compensatory mechanisms: What are the mechanisms that lead to biological feedback (e.g., compensation) that control marine populations, and how can these mechanisms, which stabilize populations, be quantified?
3. Species interactions: To what extent do resource populations interact, both within and between trophic levels as predators and prey (i.e., does the abundance of one affect the abundance of another), and how can these interactions be considered in management strategies?

The panel supports these objectives which are focused on three central issues in fisheries science. The objectives focus on fundamental yet complex processes that, if understood, could provide predictive capabilities of clear benefit to fishery management. The objectives and the issues that they represent have been largely intractable in the past, but CFE partnerships and long-term support promise to enable significant progress. CFE programs such as Bering Sea FOCI may develop effective models to predict recruitment of single year classes. Results from the similar Shelikof FOCI, which has been operational since 1986, are being used as one of several approaches to forecast trends in pollock recruitment and population abundance in the Gulf of Alaska. Shelikof FOCI data have added a new dimension to the general understanding of the oceanographic processes that impact recruitment.

Emphasis on the three objectives varies among programs supported by CFE. Both Bering Sea FOCI and SABRE emphasize the complex interactions between biology and physics that act on early life stages and which can lead to recruitment variability. The Georges Bank program emphasizes species interactions within the fish community and compensatory relationships that may regulate population and community structure. Species interactions, particularly trophic relationships, are elements of research in each of the funded programs. Other aspects of species interactions, including complex behavioral or habitat-mediated interactions, could be included in the future because they also can have important consequences for population regulation.

The panel believes that the CFE goal and objectives are relevant to NOAA's mission as elaborated in the NOAA strategic plan (NOAA, 1993a). **Although suitable now, CFE's goal and objectives should be examined periodically to insure that they retain their relevance, permit innovative and rigorous research within available budgets, and allow new concepts or ideas to evolve.**

PROGRESS AND QUALITY

The three CFE programs are in relatively early stages of their development. At the time of this review, Bering Sea FOCI and SABRE had completed three years of their projected 5-year durations while the Georges Bank program had completed its first year.

The successful planning and implementation of the CFE theme represents a significant achievement. Opportunities to support fishery oceanography programs that are truly interdisciplinary and which emphasize ecosystem-level science are rare. The panel commends NOAA and COP for their foresight in instituting the CFE programs, which not only include expertise from various NOAA line offices but also attract academic scientists to fundamental science programs which will benefit fishery management. CFE has successfully launched three major programs on important regional fishery ecosystems and has forged partnerships which are unusual in NOAA. Without COP and CFE, it is unlikely that NOAA would have made such significant investments in fisheries oceanography.

It is too early, after only three years of CFE research, to expect major breakthroughs in understanding ecosystem-level processes that affect recruitment variability. Successful implementation of three programs and the formation of NOAA-academic partnerships are regarded by the panel as significant CFE achievements. Among other notable achievements that were recognized are: advances in sampling technology (e.g., optical egg counters in SABRE), innovative modeling efforts (e.g., three-dimensional models to narrow the search for menhaden spawning areas, in SABRE), and application of new biomolecular methods to classical fishery problems (e.g., molecular stock identification in Bering Sea FOCI and biochemical measures of condition index in SABRE). The investment in CFE of additional non-COP NOAA resources (e.g., research vessel time, instrumentation, and salary support) has augmented CFE funding. Such investments are especially important to program quality because CFE budgets did not grow to expected levels. The panel noted that a significant number of refereed journal papers (see Table 1.1) already have been published by CFE investigators, indicating that CFE investigators are making serious attempts to transfer information to the scientific and management communities.

UTILITY OF THE RESEARCH

Research supported by CFE will provide knowledge that, if successful, will be useful for resource management and is supportive of the NOAA strategic plan (NOAA, 1993a). Developing a predictive capability to forecast recruitment and to understand how environmental factors and adult stock abundances interact to control recruitment

levels are major goals of fishery managers. Evaluating species interactions, especially predator-prey relationships, is particularly important to managers who are concerned about the effects of fishing on fish community structure, productivity, and recruitment. If CFE programs are successful in improving fisheries forecasts, they may benefit the harvesting sector which often must contend with fluctuating stock levels and reactive management decisions. Better forecasts, based on CFE research results, would allow harvest adjustments to ensure maintenance of selected ecosystem management goals, at least in the short-term.

Fish stocks fluctuate in response to fishing and to variability of the coastal and open ocean environments. CFE addresses the ocean variability issue. Development and application of regional models and new methods by CFE programs to sample the ocean will provide new tools for fishery scientists and managers. The panel saw evidence of technology transfer among CFE programs, for example the sharing of models and optical sampling techniques between SABRE and Bering Sea FOCI. Development and sharing of technology should be encouraged in CFE, to increase the utility and benefits of the research.

THEME MANAGEMENT

A hierarchy of management exists within the CFE theme (COP, 1993a; NOAA, 1993c). The top level administration of CFE is conducted through the National Coastal Ocean Program Office (NCOPO) and a Coastal Ocean Council consisting of senior representatives of the Assistant Administrators of NOAA's line offices. Below this level, the theme and each of its programs have parallel structures of small management committees composed of representatives from NMFS, OAR, and academia, and larger technical advisory groups with diverse representation.

Primary responsibility for managing CFE lies in the Program Management Committee (PMC). Working with the COP Director, the PMC is responsible for top-level review and analysis, long-range planning, setting priorities, oversight, and ultimately for implementations of plans and programs. Recommendations to NCOPO with respect to selection of CFE programs and funding levels are made by the PMC. It also has responsibilities to insure that individual programs are managed well and reviewed properly.

Initially, the PMC consisted of three persons, one representative each from NMFS and OAR, and one academic representative. Recently, the PMC was supplemented with an additional representative (COP, 1993a), from COP. There is little evidence that the PMC presently is an active body providing necessary leadership and oversight to CFE programs. The recent resignation of the academic representative has

left the academic component of the partnership unrepresented on the PMC. The PMC could be more effective if it had a chairperson, who would take primary responsibility for its activities. At present it is a "troika," and responsibilities for action are not defined sufficiently to assure the committee's effectiveness. **It is essential that the PMC be active to promote future CFE planning and coordination of CFE.**

Each CFE program has a Project Management Committee with representatives from NOAA and academia. These committees are critical to the success of CFE programs because they constitute the leadership within a CFE program and will, to a large degree, determine the course of action of each program. It is intended that the Project Management Committees interact regularly with the Program Management Committee (COP, 1993a, NOAA, 1993c), although interactions are neither regular nor formal.

A Technical Advisory Committee (TAC), which consists of 29 NOAA and academic scientists, was formed to provide advice and guidance to the PMC on concepts, proposals, research plans, and other technical aspects of CFE programs or program planning (COP, 1993a; NOAA, 1993c). The TAC has met three times since FY 1991 and played an active role when CFE programs were being proposed and selected. The committee has been inactive for nearly two years, a consequence of reduced budgets and the inability of CFE to add new programs. This inactivity also reflects the evolution of CFE from a planning to operational mode. The panel believes that the TAC is too large and includes members with perceived or real conflicts of interest.

Program Technical Advisory Groups (TAGs) have been appointed by each of the CFE programs. These groups presently include members from academia, NOAA, industry, the national laboratories of other agencies, and state agencies. They review progress and provide advice regarding research plans. CFE programs have included investigators from other CFE programs on their TAGs; this is a desirable way to promote cross-fertilization among CFE programs.

Each CFE program has used ad hoc reviewers to review proposals and to offer advice from time to time on projects or plans. The use of ad hoc reviewers is especially important to obtain independent peer review of proposals for new projects. There does not appear, however, to be a standardized CFE process to select or use ad hoc reviewers; CFE and COP should remedy this deficiency.

External review of CFE is provided by PoCO, which has devoted its attention to the quality of science, management, and the planning process (NRC, 1991; NOAA, 1993c). External review also was provided by the Coastal Ocean Policy Roundtable (COPR), an ad hoc group of experts in management and policy who reviewed COP and

the CFE theme with an emphasis on utility and applications of research (COPR, 1992; NOAA, 1993c). COP is planning to commission a subsequent review of the utility of its research.

When CFE was initiated in FY 1990, requests for concept papers were widely advertized (COP, 1990; 1991a; NOAA, 1991). The desirability of NOAA-academic partnerships was emphasized in the request for proposals. Several concept papers were received by NCOPO (NOAA, 1991) and were reviewed by the CFE TAC. Recommendations for funding were made by the PMC. Initially, two programs were selected for funding, and a third was subsequently selected.

Solicitation, review, and selection of proposals were conducted separately by each of the funded programs and processes apparently differed somewhat among programs. In some cases, NOAA and academic proposals were reviewed similarly. In other cases, the review criteria and process seemed to differ. A variety of procedures has been used by CFE programs to terminate or add projects after a program has started. Procedures used in CFE need to be standardized and need to ensure that the review process has integrity.

In retrospect, the CFE planning process was too optimistic about presumed levels of funding in later years of the theme. As a consequence, initial plans by funded programs have required revision and the directions of research modified to adjust to lower funding levels. Additional programs that were approved in principle, and might have been implemented, were not funded.

RESPONSIVENESS TO PAST REVIEWS

There was little formal review of the overall CFE theme or its programs prior to this effort. An earlier review by PoCO endorsed the selection of SABRE and Bering Sea FOCI (NRC, 1991). It also expressed concerns and provided advice about feasibility or directions of those programs and other nonselected programs. NCOPO and representatives of CFE programs considered and responded to panel recommendations in 1991.[5]

The CFE TAC met three times and provided advice to the CFE PMC. The CFE TAC recommended that SABRE and Bering Sea FOCI be funded. The TAC also made

[5]COP Review comments related to 1991 PoCO review report, accompanying a March 18, 1992 letter from Under Secretary John Knauss to OSB Chairman Carl Wunsch.

numerous other recommendations (COP, 1993a) with respect to plans, implementation, and guidance for CFE programs.

Program TAGs are potentially valuable sources of advice and review. It is not clear that they have played a significant role yet in advising Bering Sea FOCI and the Georges Bank program because they were only recently formed, but the SABRE TAG has been well utilized as a valuable source of objective and critical advice.

FUTURE PLANS AND THEME RECOMMENDATIONS

The CFE theme has not grown and evolved as planned because of near-level COP funding. Both SABRE and Bering Sea FOCI had expected to receive funding at approximately twice their initial levels (COP, 1991a; 1993a) in succeeding years, and the Georges Bank program has been funded at a level far below expectations. Plans should be developed by the CFE theme within the next 2 years, regarding new research or continuations of present programs. A planning process should be instituted now. It must assume realistic budget levels in the future. Several recommendations from the panel on future CFE management, planning, and implementation are listed below.

It is appropriate that CFE maintain its present goals and objectives, at least through its first 5 years, until FY 1995. Goals and objectives for CFE in succeeding years should evolve through a planning process led by the PMC and including the active involvement of NOAA and academic scientists in workshops or other planning meetings.

CFE must communicate to the scientific community, both within NOAA and in academia, plans regarding CFE evolution and mechanisms for future program selection. Revitalized strategic planning must be initiated now, to provide a vision for the CFE theme in its second five years. The panel's recommendations fall into two general categories: 1) science planning and 2) program management.

Science Planning

1. **The goals and objectives of the CFE theme should be assessed before the second 5 years of the theme is planned.** A workshop involving the PMC and a reconstituted TAC (or other reviewers) could accomplish this task. The scientific community must know soon what emphasis CFE will have in the future.

2. **The NOAA-academic partnership and the mission-oriented nature of CFE must be maintained, and opportunities to enhance scientific efforts, to improve quality, or to leverage resources through collaborative efforts with related programs should be pursued. Future plans and directions of CFE should indicate an awareness of related fishery oceanography programs funded by other agencies or mechanisms, such as GLOBEC, Shelikof FOCI, and the South East Florida and Caribbean Recruitment Studies (SEFCAR).**
3. **Interaction and collaborations among CFE programs should be required in the future.** This requirement will improve resource sharing, technology development, and information transfer. **Mechanisms to assure interactions should be specified.** The Program Management Committee and Project Management Committees should work together to facilitate interactions among programs.
4. COP should seek to integrate CFE programs with other COP activities in Coastal Ecosystem Health and Coastal Hazards, where feasible. There are obvious relationships among environmental quality, physical oceanography, and coastal fisheries.
5. Fisheries management goals should be fully considered in scientific studies throughout CFE programs, rather than insulating science from management until the science is completed.

Program Management

1. The NOAA-academic partnership and the approximately equal sharing of COP budget support (see Table 1.1) is a unique strength of CFE that draws together highly competent researchers. **This strength should be maintained in future plans.**
2. The Program Management Committee is the major oversight/planning entity of CFE. **It needs to be reconstituted and to assume a leadership role for the theme. At least one academic scientist should be appointed to fill the vacancy left by the resignation of the previous academic representative.** The PMC's responsibilities must be reconsidered in light of the existence of functioning Project Management Committees. A PMC Chair should be designated to insure leadership, direction, and coordination of this top management body.

3. **The CFE Technical Advisory Committee should be reconstituted and its membership reduced from 29 individuals to 8 or fewer. Members should represent NOAA, academic, and other institutional perspectives. Members should not have either perceived or real conflicts-of-interest with ongoing or proposed CFE programs.** It is desirable that a member of PoCO be invited to TAC meetings to facilitate communication between the two review groups. The Program Management Committee should consider the possibility of using the CFE TAC in place of individual program advisory groups for future programs, which would improve the linkages among programs. The TAC should remain active during the operational phases of programs to assist the PMC.
4. **Because of budget limitations, alternative funding mechanisms should be considered in CFE's second 5 years.** Under an alternative scenario, the CFE PMC might phase planned annual activities of each program and allocate funding accordingly. For example, major field efforts or experiments by a program would draw augmented support in a given year, with lower support provided in other years for planning and/or analysis activities. Under this alternative mechanism, budget levels and levels of research activity of each CFE program would change significantly from year to year, but sufficient levels of funding for programs in their sampling or data collection phases would be ensured. This approach is not without difficulties, however, and to be successful would require contingency plans if funding were delayed or projects progressed more slowly than anticipated.
5. **Contingency funds (perhaps 5-10% or total CFE funding) should be made available on an annual basis for unanticipated CFE program emergencies and scientific opportunities. The PMC should recommend to the COP Director how to allocate such funds in each year.** These funds could be used to augment the budgets of individual CFE programs or to promote program interactions through workshops or working group meetings among program scientists.
6. **The processes by which proposals are solicited and evaluated by CFE at both the theme and program level should be standardized.** At the program level, these processes have been variable. **NOAA, academic, and joint NOAA/academic proposals should be treated similarly. Peer review should be applied equally to all proposals.**
7. Guidelines for research proposals must be developed soon, in anticipation of a new call for proposals by CFE in FY 1996-2000. **Both new and**

continued (renewal) proposals should be considered. Proposals and concept papers that were evaluated previously, but not funded, must be resubmitted if their planners wish to compete for CFE resources. These proposed programs would be evaluated again in competition with other, new, concept papers. **Renewal proposals should be reviewed fairly, with continued funding contingent upon past progress and the strength of a newly proposed scientific program.**

8. **The planning task for the second five years of CFE should be underway before FY 1995 to inform the scientific community of CFE plans and scientific opportunities.** The PMC and TAC, working with the NCOPO, can coordinate this process. The panel could review plans that may evolve.

Finally, the panel reiterates its support for the CFE concept. The NOAA-academic partnerships and possibilities for long-term funding through CFE are providing rare opportunities to institute research programs in fishery oceanography that promote fundamental science, but which maintain regional, resource, and mission-oriented emphases. The CFE theme is supportive of the current NOAA strategic plan and is a positive step toward understanding coastal fisheries ecosystems, a step that could assist managers in attaining sustainable fishery harvests.

INDIVIDUAL PROGRAMS—ASSESSMENTS AND RECOMMENDATIONS

Bering Sea FOCI

Bering Sea FOCI had its origins in the "Sitka Conference" (Sitka Symposium, 1988; COP, 1991b), held in 1988, in response to concerns over unregulated international fishing for walleye pollock (*Theragra chalcogramma*) in the "doughnut hole" of the Bering Sea. Poor knowledge of stock structure and causes of recruitment variability were identified as two areas in need of scientific investigation. An earlier, and continuing, program on pollock recruitment processes in the Gulf of Alaska (Shelikof FOCI) provided a background of scientific expertise and experience (NOAA, 1993b) to develop the Bering Sea FOCI research plan, which was implemented in FY 1991. Bering Sea FOCI has been supported annually with a budget of $0.95 million. Principal scientists are from NOAA's Pacific Marine Environmental Laboratory and Alaska Fisheries Science Center in Seattle. In addition, several academic scientists are partners in the research. A site review and evaluation of Bering Sea FOCI was carried out by the panel in January 1994 (Appendix 1) in response to the CFE requirement that its programs be reviewed after their third year of support (COP, 1993a).

The stated goal of Bering Sea FOCI (COP, 1993b) is "to provide information which will lead to an increased yield of the walleye pollock fishery while maintaining the resource." The program (COP, 1990; 1993a; NOAA, 1991) has two explicit objectives:

1. Stock structure—define it by using genetic probes to examine the structure and its relationship to the physical environment.
2. Recruitment Processes—study the biophysical environment of the shelf and slope of the eastern Bering Sea to examine processes critical to survival of eggs, larvae, and juvenile pollock.

The efforts of Bering Sea FOCI are directed primarily at the recruitment variability objective of the CFE theme. Planned projects will also address the species interactions objective, and the possible regulatory role of cannibalism offers the potential to study compensatory mechanisms in the program. Research on transport processes from the Aleutian Basin to the slope-shelf environment in the eastern Bering Sea is a prominent part of Bering Sea FOCI. Larval sampling, plankton studies, and food-chain modeling are included in the research. Stock structure is being investigated by DNA analysis of adult pollock from five areas of the Bering Sea.

The panel believes that one stated goal of Bering Sea FOCI should be reconsidered. Rather than "increase the yield of the walleye pollock fishery in the Bering Sea," a better goal of the research program is to "increase understanding of production and recruitment processes, to ensure sustainable yields." The panel endorses the two objectives of Bering Sea FOCI. **The panel recommends that Bering Sea FOCI's objectives should evolve to focus on an ecosystem-oriented view of pollock population dynamics, if the Bering Sea FOCI budget increases.**

Bering Sea FOCI has made significant progress in: understanding the basinwide circulation of the Bering Sea and its hypothesized relationship to transport of pollock larvae; identifying important spawning and nursery areas of pollock; determining that food for larvae may be limiting; obtaining evidence that eddies may be important to larval pollock; and developing a food-chain model relevant to the larval pollock environment. Studies are underway on the dynamics of pollock early life stages and on their food resources. These studies will be coordinated with research on ocean physics in the 1994 field season. Bering Sea FOCI should increase its emphasis on coordinated biological and physical observations. More intensive and better planned sampling of pollock early life stages also are needed, which is a goal of the program in 1994. Initial results of genetic probe analyses have suggested that there are distinct stocks of pollock in the Bering Sea. A food chain model of lower trophic levels has been developed and is helping to direct the research on plankton.

Research not supported by Bering Sea FOCI, but which contributes to it, plays a valuable role in this program. For example, studies on stock structure and dynamics, and on behavior of larval and juvenile pollock by NMFS biologists are very relevant to Bering Sea FOCI. This NMFS research is an important NOAA contribution to CFE success. CFE research would be imperiled if NMFS funding for pollock research and stock assessments were diminished.

Walleye pollock is the largest U.S. fishery (by weight of harvest), with harvest levels in excess of 1.0 million tons annually. The Bering Sea FOCI program investigates processes that are important to insure sustainability of that resource and to understand factors that can cause fluctuations in its abundance. Defining stock structure and its relationship to management of walleye pollock is a critical issue in the Bering Sea that the program is addressing. It is hoped that accurate forecasts of pollock recruitment will be products of Bering Sea FOCI. The critical examination of the Bering Sea environment (physics and biology) by Bering Sea FOCI will produce long-term benefits and knowledge of the region's oceanography and ecosystem, which harbors threatened marine mammal resources and is subject to intense fishing effort.

The Bering Sea FOCI Management Committee (their “Executive Council”) consists of six scientists, representing PMEL, NMFS, and academic institutions. Planning and coordination of the program is directed by the Executive Council. A Bering Sea FOCI Technical Advisory Group was appointed recently, consisting of academic and industry representatives. The TAG's role is uncertain at this time, but it could play a significant role in future plan and project development. The Technical Advisory Group is strong and potentially useful. **It should be called upon to review plans and project results. The panel also recommends that small working groups of program scientists be organized to develop hypotheses, plan research, evaluate progress, and assess needs to change directions in specific research areas.** Leadership will emerge within the working groups that will benefit the projects and the program.

Project solicitation, selection, and review have not been standardized in Bering Sea FOCI, although overall resources have been shared well between NOAA and academic partners. The method for proposal review and selection apparently has differed for NOAA and academic submittals. Projects have been terminated and new ones initiated as the program's perceived needs have changed and as projects have been completed. **The panel believes that the proposal solicitation and review process should be standardized in Bering Sea FOCI. Proposals from NOAA and academic scientists should be treated similarly. Both should receive objective peer review.**

The panel believes that successful management and leadership of a CFE program requires equal and communicative participation by the three partners, i.e., OAR, NMFS, and academia. The present Executive Council may not represent the academic partners sufficiently, having only a single academic member on the six-member council.

It is desirable for the program to think beyond its present objectives and look toward studies of the Bering Sea ecosystem, in which pollock is only one major resource. Future research might examine recruitment processes of Bering Sea fishes, with respect to important variables in this complex environment. For example, effects of sea ice, which can affect circulation, productivity, and probably fish recruitment in the Bering Sea, is not considered in the present Bering Sea FOCI. Additionally, complex trophic relationships, including interactions among fishes, sea birds, and mammals, must play a regulatory role with respect to recruitment of fishes but the relationships are little understood or studied at present.

South Atlantic Bight Recruitment Experiment (SABRE)

The concept of the South Atlantic Bight Recruitment Experiment (SABRE) had been nurtured during the 1980s by NOAA and academic scientists. With the advent of COP, SABRE became one of the two original programs that were supported (COP, 1990; 1991a; 1993a; NOAA, 1991). It has been supported with a budget of $1.0 million annually. SABRE targets Atlantic menhaden (*Brevoortia tyrannus*) in the South Atlantic Bight (the zone between Cape Hatteras and Cape Canaveral), and focuses on recruitment processes that operate from the egg through juvenile stages. Menhaden, which is the largest tonnage fishery on the U.S. east coast, is representative of many coastal fishes that are estuarine-dependent during the juvenile stage of their life cycle.

SABRE emphasizes the recruitment variability objective of the CFE theme. The approach of SABRE is to study the characteristics of survivors at “critical junctures” in their life history (COP, 1990; 1991a; SABRE, 1994). This approach is an alternative to more traditional approaches that depend on estimating mortality of early life stages. Birthdate distributions will be established by analyzing otolith ages of surviving fish at several life stages during their first year of life. Shifts in apparent birthdate distributions among life stages will allow SABRE investigators to judge how habitat, environment, and life stages interact to control recruitment.

Participants in SABRE include scientists from the NOAA Atlantic Oceanographic and Meteorological Laboratory and the NMFS Southeast Fisheries Science Center, as well as academic scientists from several institutions. SABRE recently completed its

third year of support by CFE. A site review of SABRE was carried out in January 1994 (Appendix 2).

The goal of SABRE is to understand the relationship between variation in environmental factors and the variable recruitment of estuarine-dependent fishes in the South Atlantic Bight (COP, 1993a). The overlying philosophy of the program is that detailed investigation of survivors at several life stages will reveal how stage-specific and size-specific processes operated to control the resulting recruitment (COP, 1990). This "alternative approach," as stated, would allow SABRE investigators to concentrate on habitats and life stages that are critical to survival or the recruitment process. The approach incorporates measurements and models of coastal ocean circulation to elucidate transport mechanisms. It depends on otolith-aging analyses of larvae and juveniles to characterize survivors.

As SABRE has evolved, its emphasis has shifted toward the estuarine juvenile life stage. The shift is a consequence of program budgets that limit offshore sampling effort and the result of information in life-stage models, which suggest that a large fraction of the variability in menhaden recruitment occurs during the juvenile stage.

The panel endorses the goal of SABRE and acknowledges that the alternative approach which SABRE has taken can make important contributions toward understanding recruitment variability in menhaden. A caveat is necessary: the emphasis now directed at estuarine-phase juveniles may not be balanced sufficiently by offshore efforts to characterize the little-known egg and youngest larval stages. However, given the existing logistical and budget constraints of CFE, the approach being taken by SABRE is a good alternative in the short term.

SABRE has made significant progress. A strong management team and NOAA-academic partnership have been developed. Considerable progress has been made in characterizing late-stage larvae that enter estuaries in the study area. Studies on juveniles are progressing. Development of new sampling technologies (e.g., an optical egg sampler) and application of new larval condition indices based on biochemical measurements have been successful. The application of a three-dimensional (3-D), finite element circulation model shows promise to describe how larvae are transported from offshore to estuarine inlets. Otolith-aging of larvae and juveniles has been successful, which will allow the life-stage analyses to proceed. Biological modeling, including life-table approaches and individual based models, are being developed and applied.

Offshore sampling has not been as intensive as originally planned and the egg and offshore larvae distributions are not well defined. Budget constraints and temporal patchiness of eggs have frustrated offshore sampling, although recent

successes with the optical egg counter show promise. **The panel recommends that SABRE determine if menhaden eggs are present in historical samples of ichthyoplankton from the region, to compensate partially for the limited sampling effort.** Other collecting gear (e.g., CalVet nets), which are rapid and efficient, also might improve the offshore sampling effort for menhaden eggs.

Results from SABRE will improve understanding of recruitment processes in estuarine-dependent fishes by defining life stages and habitats that are critical. Because menhaden is representative of many estuarine-dependent species, results may have broad applicability to recruitment processes in such species. The new sampling and analytical technologies that are being developed in SABRE should be transferrable to other fishery oceanography research. SABRE addresses issues that are highlighted in the NOAA strategic plan (NOAA, 1993a), specifically the need to advance fisheries predictions.

Leadership in SABRE is by a three-member Project Management Committee comprised of one individual each from NOAA/AOML, NOAA/NMFS, and from an academic institution. Thus, all partners are represented equally and complement each other. Project proposals from NOAA and academic scientists were reviewed similarly. Decisions made in workshops and by the Management Committee have led to changes in direction of SABRE. Some projects have been phased out and new projects added through a standardized proposal solicitation and review procedure that has involved SABRE's TAG and outside peer reviewers. The TAG consists of five academic and NOAA scientists who, in addition to reviewing project proposals, meet once each year with SABRE to provide advice to the program.

Lower than expected budgets and logistic support have resulted in changes to the original work plan. Increased emphasis is being placed on sampling late-stage larvae entering the inlets and on estuarine juveniles. This shift in emphasis has been justified by citing a life-table model which indicates that a large fraction of the variability in recruitment may be generated in the juvenile stage. The panel sees a continuing need for offshore egg and larval sampling but realizes that substantial NOAA resources must be committed to achieve it. In this respect, SABRE and Bering Sea FOCI differ, because the latter program can draw on substantial NMFS resources already in place to study pollock, independent of CFE.

Despite SABRE's shift toward estuarine studies of the juvenile stage, offshore investigations, including physical modeling, moorings, and ichthyoplankton surveys, will continue but are constrained by budget limitations. Continued, or enhanced, effort in inlet sampling to define characteristics of late-stage larvae entering the estuaries is planned.

The panel endorses the shift in emphasis toward estuarine juveniles, recognizing the budgeting and logistic realities that SABRE faces. In offshore investigations, it is important for SABRE to deliberate over how they can best define where and when menhaden spawn. This information is necessary to establish initial birthdate distributions and also to provide input data for models that attempt to describe larval transport to the inlets. This will require careful sampling design. It also may require new sampling gear and examination of previously collected ichthyoplankton material from the South Atlantic Bight. With SABRE's increasing effort on juvenile menhaden biology, new emphasis on predator-prey interactions also will be necessary. **In the long term, SABRE should consider broadening the scope of its research to include other abundant, estuarine-dependent species (e.g., spot, croaker, and flounders).** The panel believes that to make important strides in understanding recruitment processes in menhaden and other estuarine-dependent species it will be necessary eventually to sample and characterize all early life stages. The causes of recruitment success or failure probably will differ from year to year in their dependence upon either offshore processes that affect eggs and larvae versus inshore processes that affect estuarine juveniles.

Predation and Structure of the Georges Bank Ecosystem

The Georges Bank program is the third and most recently funded of the CFE programs. It was implemented in FY 1993 with a budget of $0.4 million, well below its planned level of support; it was level-funded in FY 1994 (COP, 1993a). The Georges Bank program addresses the three overall objectives of CFE, but concentrates on species interactions, and is the only CFE program that explicitly addresses the compensation objective. The Georges Bank program also differs from the other CFE programs in that it emphasizes the Georges Bank ecosystem and community-level dynamics, rather than having a single-species focus. The Georges Bank program includes the least physics of the CFE programs, in the sense that no studies of ocean physics are included explicitly at this time.

It is hypothesized that predation, by both man (i.e., fishing) and natural predators, has shaped the recent structure of the Georges Bank ecosystem. Heavy and selective fishing has caused drastic declines in valuable cod, haddock, and flounder resources, while biomasses of less valuable piscivores (e.g., sharks and rays) have increased (COP, 1992; 1993a). It is not clear whether the present community structure is stable or whether changes in fishing strategies or ocean conditions could cause the system to shift back toward its former condition.

Primary species of interest are the gadids (haddock and cod), the flounders, and the elasmobranchs (spiny dogfish and skates). Pelagic species, for example herring

and mackerel, also are of concern. Species interactions among these groups, principally predator-prey relationships, will be the focus of the Georges Bank program research.

Scientists from the NMFS Northeast Fisheries Science Center have formed partnerships with five university scientists in the program. Collaborative arrangements with other programs that include fishery oceanography components and have activities in the Georges Bank area (e.g., the NSF/NOAA Climate and Global Change Program, GLOBEC, the Canadian Ocean Production Enhancement Network (OPEN), and Cod and Climate), have been developed (COP, 1992), promising to produce economies of scale for the low-budget Georges Bank program and ultimately to increase its utility to scientists and managers. The Georges Bank program will depend upon the other programs to provide data on ocean physics and larval ecology (e.g., GLOBEC) (COP, 1992). If these programs are underfunded, the Georges Bank program may be diminished in value.

The overall goal of the program is to quantify the combined effects of predation and exploitation on fish community dynamics on Georges Bank (COP, 1992). There are three major and overlapping phases of research in the Georges Bank program (COP, 1993a). These are: (1) to undertake retrospective analysis of feeding interactions among fishes on the Bank, (2) to undertake field and laboratory studies to improve consumption estimates, and (3) to develop multispecies models of Georges Bank to evaluate production potential of cod and haddock under different levels of predation stress. Six specific tasks are identified (COP, 1992):

1. Refine estimates of diet composition and intake of key predators.
2. Estimate predation mortality rates of prerecruit cod and haddock.
3. Refine estimates of gastric evacuation rates of key predators.
4. Determine functional feeding responses and selectivity of key predators.
5. Examine importance of compensatory mechanisms in haddock and cod.
6. Evaluate how above factors influence the form of stock-recruitment models.

The panel endorses the ambitious goals and objectives of the Georges Bank program. There is considerable evidence that fishing and predator-prey relationships have shaped the structure of fish communities on the Georges Bank. Given the limited budget of the program, retrospective analyses, limited experimental and field work, and model development are appropriate emphases that can lead to important

gains in knowledge of this ecosystem. This is particularly likely, if meaningful collaborations with other fishery oceanography programs materialize as anticipated.

The program was implemented just one year ago and accomplishments have not yet been reported. The program has been organized, partnerships between NOAA and academia have been established, and research proposals were funded. Links with GLOBEC have been formed. The panel endorses plans of the Georges Bank program to collaborate with other fishery oceanography programs as one way to increase program effectiveness. It is unclear if any formal agreements have been made between Georges Bank and GLOBEC or other programs, although such agreements would be desirable, and joint management teams should be considered.

A three-member Management Team of NMFS and university scientists has been assembled and a 6-member TAG formed (COP, 1992). Research proposals were solicited from universities, research laboratories, and from the NMFS Northeast Fisheries Science Center.

Knowledge from the Georges Bank program can be applied to advise fisheries managers on best methods to achieve sustainable harvests to promote productive fish communities of high economic value. The predation process and the role of compensatory mechanisms, which are major ecosystem-level regulators of structure and productivity, are poorly understood by fishery scientists. Knowledge gained about these processes by the Georges Bank program will have utility both for that system and for other ecosystems where fishing and predation are dominant factors.

The Georges Bank program is constrained by lower than expected budgets, with uncertain prospects for increased funding. The emphasis on retrospective and modeling studies, and limited field or experimental research, is appropriate under the circumstances.

The Georges Bank program is now in its second year. It is anticipated that products and progress will be evident during the next several months, which may shape future directions of the program. The panel noted that the principal product of the program is proposed to be a multi-species model of the Georges Bank ecosystem, which can be used to guide management decisions (COP, 1992). A proposed adaptive management strategy, in which predator populations are manipulated by selective fishing, will be proposed by the Georges Bank program for future application. As the Georges Bank program unfolds, careful planning and selection of projects are essential to meet its goals under the limited budgets that likely will be available. Effective management and coordination with other fishery oceanography programs also are essential.

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CHAPTER 3

COASTAL ECOSYSTEM HEALTH

INTRODUCTION

The coastal zone is subjected to a wide range of stresses, from increased nutrient inputs to loss of habitat. To manage and protect the coastal zone, it has become necessary to develop an understanding of the effects of multiple impacts on coastal ecosystems and to adopt a more integrated approach to ecosystem management (NOAA, 1993a). The goal of the Coastal Ecosystem Health (CEH)theme is to be able to predict the effects of multiple stressors on coastal resources. CEH is being established by the merger of three former themes: Nutrient Enhanced Productivity, Toxic Chemical Contaminants, and Estuarine Habitats (Figure 3.1). Elements of the Resource Information Delivery (RID) program also have been included in the new CEH theme. The new theme will examine the effects of stresses from eutrophication, toxins, and habitat loss on coastal ecosystems in an integrated way. The objectives of CEH are:

1. to quantify the magnitude and effects of specific natural and anthropogenic stressors and the combinations of those stressors;
2. to identify indicators of integrated stress at individual, population, and ecosystem levels; and
3. to evaluate the effectiveness of potential alternative mitigation approaches.

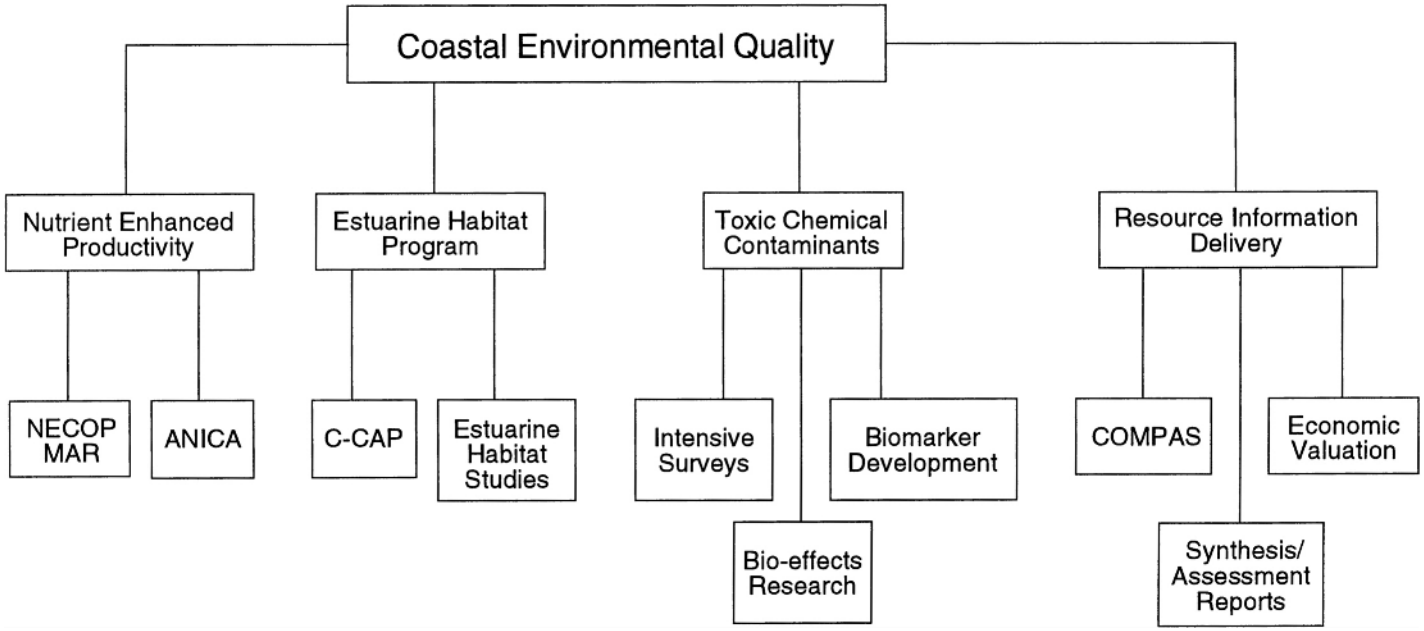

Figure 3.1 Coastal Ecosystem Health Theme Structure. NECOP-MAR is the Nutrient Enhanced Coastal Ocean Productivity-Mississippi-Atchafalaya Rivers program; ANICA is the Atmospheric Nutrient Inputs to Coastal Areas program; and COMPAS is the Coastal Ocean Management, Planning, and Assessment System.

The panel review of this theme took place over several months, beginning with a formal review held in Washington on November 1-2, 1993. Presentations were made to the panel on nearly all of the ongoing programs in the former themes except for the Resource Information Delivery (RID) theme. In-depth presentations were made on: Nutrient Enhanced Coastal Ocean Productivity-Mississippi Atchafalaya Rivers (NECOP-MAR), Atmospheric Nutrient Inputs to Coastal Areas (ANICA), Estuarine Habitat Program (EHP), Coast-Watch Change Analysis Program (C-CAP), and Toxic Chemical Contaminants.

The economic evaluation program of RID was discussed, but the panel was not briefed about the Coastal Ocean Management, Planning, and Assessment System (COMPAS). At this meeting, and shortly afterwards, many documents were reviewed by the panel, including the FY 1993 and FY 1994 implementation plans for most of the programs and projects, summaries of previous TAC reports and the responses from CEH investigators, journal articles, and technical reports. The panel evaluated all aspects of these programs. A summary review of the CEH theme will be presented next, followed by reviews of the individual programs.

GOALS AND OBJECTIVES

The CEH theme is now proposing to proceed beyond research on the effects of individual stresses (such as nutrient enrichment, toxins, and habitat loss) on ecosystem health, and to examine how the integrated effects of natural and anthropogenic stresses affect coastal ecosystems. This is an ambitious and important goal, but it has the potential limitation of becoming too diffuse and losing perspective on the basic scientific processes controlling coastal ecosystems. **The theme's major focus should continue to be on the processes and mechanisms by which stressors affect coastal ecosystems. This theme should continue to work closely with programs such as the National Status and Trends (NS&T) program of the National Oceanic and Atmospheric Administration (NOAA) and the Environmental Monitoring and Assessment Program (E-MAP) of the Environmental Protection Agency (EPA), to develop new ways to assess and inventory the health of the coastal zone.** Because overall coastal environmental quality is closely tied to secondary production and fisheries recruitment, this theme should also develop connections with the Coastal Fisheries Ecosystems theme.

PROGRESS AND QUALITY

CEH progress has been significant in those areas in which it has been able to make a significant financial investment. The quality of research activities has also

been high, and will become more generally recognized as the many internal technical reports are published in the refereed literature. The panel believes that the collaboration between academia and the NOAA labs has contributed to the progress of this theme by bringing new perspectives to old problems and by helping to focus the attention of academia on critical problems in the coastal zone.

UTILITY OF THE RESEARCH

The results of CEH research have been quite useful. Examples of successful ventures include: the major field effort of NECOP which addressed the impacts of the 1993 upper Mississippi floods on the lower Gulf watershed, the recent evaluation of atmospheric nitrogen deposition to Great Waters, the development of new bio-indicators for assessing toxic contamination, new research on marsh restoration, improved procedures for assessing change in wetland habitats, and the development of a data management system for coastal managers.

THEME MANAGEMENT

In general, planning has been successful but the theme has been limited due to shortages or postponements of funding and CEH has been slow to scale back its plans. Most programs in the CEH theme have planned four- to five-year projects with projected budget increases of two- to five-fold (COP, 1992; MACII, 1993; NOAA, 1993a). **COP needs to require that programs use realistic budget assumptions in their planning.** CEH has a large number of programs and is working at a fraction of its planned and required funding. Thus, a disproportionate amount of time and money has been spent on planning and review meetings, rather than in conducting research. Under limited funding, COP has justly appropriated research and field work to only a few of its programs. However, this means the choice of these priority programs needs to be made very carefully, in close consultation with its scientific advisory and review committees and in coordination with other federal coastal programs. CEH should establish a better balance among resources devoted to planning, review, and research.

Toxic Chemical Contaminants has an active TAC which meets frequently (June 1992 and August 1993). Nutrient Enhanced Productivity had a comprehensive meeting of both management and an external advisory review team in June 1992. Estuarine Habitats held a joint investigator, management, and TAC meeting in 1992, and C-CAP had a meeting of their TAC in September 1993.

The panel supports the decision to merge the former themes into a single CEH theme and to try to integrate research within this theme. However, unless COP's limited budget is greatly increased, initiating new programs will require that some of the old programs be eliminated (at least for now) or transferred to other parts of NOAA. **CEH should develop a strategy for "down phasing or shedding" some of its many programs, while initiating new programs. New programs should be given reasonable lifetimes in which to accomplish their goals and should not plan for indefinite funding.**

The former structure of multiple themes and a large number of programs was too compartmentalized to allow for integration of the results of the individual programs. Merging the former themes into a single new theme is a first step toward integration but is not sufficient by itself. Planning and program development need to take place at the theme level for this new structure to succeed. The present structure of assembling all the program heads to act as a "theme team" makes it difficult to eliminate or phase out programs. **A separate TAC for the entire theme is needed, consisting of individuals not directly involved in any of the individual programs.**

RESPONSIVENESS TO PAST REVIEWS

The former themes related to environmental quality have sought thorough and frequent outside evaluation and nearly all have had a comprehensive review since the overall COP review carried out by the panel in 1991. Most themes had technical advisory committees (TACs) which played active roles in shaping the different programs. COP has also responded to some of the broader thematic issues raised in the 1991 panel review (NRC, 1991). For example: the Nutrient Enhanced Productivity theme changed the focus of NECOP-MAR as a result of the 1991 panel review and recommendations made by external scientific advisers; COP suspended its program on the causes and effects of toxic algal blooms (CEHAB) in response to the panel's criticism that the program was too ambitious considering COP's budget; COP adopted the panel's suggestion to undertake a modeling and synthesis effort in the Estuarine Habitat theme; and COP has eliminated Resource Information Delivery (RID) as a separate entity and is trying to incorporate RID into each of the theme areas.

FUTURE PLANS AND THEME RECOMMENDATIONS

The new field initiative into multiple stressors is a bold approach to the problem of coastal environmental quality. However, it will be a new venture for both COP and the scientific community. **COP should follow the progress of this program closely to determine if this approach produces high quality integrated research.**

INDIVIDUAL PROGRAMS—ASSESSMENTS AND RECOMMENDATIONS

Nutrient Enhanced Productivity (NEP)

The goal of this program is to "improve the environmental quality of coastal waters by predicting the harmful effects of nutrient over-enrichment (eutrophication, oxygen depletion, harmful algal blooms, and effects on the global carbon cycle)" (NOAA, 1991). Most of this program's budget has been allotted to study the influence of the Mississippi/Atchafalaya river system on nutrient enhanced production in the Gulf of Mexico through the Nutrient Enhanced Coastal Ocean Productivity-Mississippi-Atchafalaya Rivers (NECOP-MAR) project. The NECOP-MAR project has also received some support from other branches of NOAA in the form of research vessel support. As originally envisioned, NECOP-MAR was to be one of several largescale ecosystem studies. Proposals for projects in the South Atlantic Bight and the Yukon-Kuskokwim rivers were received but the funding for expansion to other areas has not become available (Calder, 1992). A project on atmospheric nutrient inputs, entitled Atmospheric Nutrient Inputs to Coastal Areas (ANICA) has received funding from COP, but largely relies on other sources of funds within NOAA to meet many of its objectives.

Although COP developed plans for a large program on causes and effects of harmful algal blooms (CEHAB), only a small amount of funding was allocated to this project in FY 1992, and the effort was discontinued the next year due to the overall COP budget constraints. While the study of harmful algal blooms could clearly fall within the new CEH theme, its presence in the old NEP theme was somewhat controversial. External review teams felt that the assumption that harmful algal blooms were directly linked with nutrient enrichment was still unproven (Calder, 1992). An additional project, a National Assessment of Harmful Algal Blooms (NANO) was developed by COP, but has been moved to the NOAA National Ocean Service (NOS) because of complementary NOS activity on eutrophication.

Nutrient Enhanced Coastal Ocean Productivity-Mississippi-Atchafalaya Rivers (NECOP-MAR)—This project, when established, had four objectives: (1) to determine the degree to which coastal primary productivity has been enhanced in areas receiving terrestrial inputs, (2) to determine the impact of increased primary productivity on water quality (including dissolved oxygen), (3) to determine the impact of fixed carbon on living resources, and (4) to determine the impact of nutrient enhanced primary productivity on the global carbon cycle. In response to recommendations of outside review committees and the 1991 panel eview, NECOP narrowed its focus to shelf

productivity and hypoxia issues and dropped global carbon flux studies as a major objective.[6]

NECOP has been most active in: (1) determining specific nutrients that limit productivity and biomass of primary producers, (2) making direct measurements of nutrient recycling and "new productivity" in different seasons, (3) enhancing modeling efforts relative to direct measures of fluxes and physical linkages, and (4) examining the impact of hypoxia on socioeconomic conditions around the Gulf of Mexico. NECOP has conducted high quality research in these areas. The results of NECOP will be quantified in terms of a mass balance model to test the sensitivity of the Gulf of Mexico to changes in nitrogen and phosphorus inputs and on their rates of change. It will include a component to interpret sedimentary records for historical carbon flux, hypoxia, and other "biomarkers."

NECOP results have been useful for a number of purposes. NECOP has focused on understanding the basic biogeochemical processes involved in the mixing of riverine plume and shelf waters. This will be of great utility to other basic research programs with similar goals [e.g., the NSF Coastal Ocean Processes (CoOP) initiative and the Ocean Margins Program of the Department of Energy]. NECOP also has documented the intensity and areal extent of hypoxia in the northern Gulf of Mexico. This has been particularly relevant for studies of the effects of the record floods of 1993 in the upper Mississippi watershed. Particularly noteworthy are the NECOP-hosted workshops for all researchers active in the area of the Gulf of Mexico impacted by the Mississippi and Atchafalaya rivers. This resulted in a comprehensive workshop report (NECOP/MAR Review Panel, 1991). NECOP will shortly be submitting manuscripts for a dedicated volume of *Estuaries.*

NECOP has made useful contributions to our understanding of the relationship between enhanced primary productivity and water quality in the Gulf of Mexico. The understanding of basic processes gained through NECOP will benefit scientists and managers in all coastal areas, not just the Gulf of Mexico. The limited modeling done under NECOP is the first step towards developing the capability of predicting the impact that nutrient control strategies may have on the productivity of the shelf and to determine the probability of coastal hypoxia. However, the modeling effort to date is insufficient to address the needs of environmental managers, except in a preliminary fashion (MACII, 1993). The utility of this work should be enhanced as the regional physical oceanography becomes better known. Coordination and collaboration with other federal programs, especially the CoOP study on buoyant plumes and the MMS

[6]COP review comments related to 1991 PoCO review report, accompanying a March 18, 1992 letter from NOAA Under Secretary John Knauss to OSB Chairman Carl Wunsch.

Louisiana-Texas Physical Oceanography Study is essential for NECOP to achieve its objectives.

NECOP has a successful history of planning and development. The NECOP-MAR project has produced some excellent scientific results. COP planned to provide NECOP-MAR with 2 additional years of funding at the time of the review. The panel supports this plan and urges that this time and funding be used for analysis and synthesis of results. The NECOP review team has recommended that NECOP-MAR be followed up with further monitoring (Calder, 1992). Although the panel believes this effort would be worthwhile, COP's mission does not include long-term monitoring. **COP should continue to fund state-of-the-art, innovative science in the area of environmental quality and should not commit itself indefinitely to a single program or geographic area.**

Atmospheric Nutrient Inputs to Coastal Areas (ANICA)—The general goal of ANICA is to quantify the fraction of the nutrient loads that enter U.S. estuaries and coastal areas via the atmosphere, particularly nitrogen. The specific objective of ANICA is to assess the existing and continuing nitrogen deposition data around the Great Waters to determine the dry fraction of nitrate deposition.

This is an important goal from both scientific and management perspectives. The 1988 Environmental Defense Fund (EDF) report (Fisher et al., 1988; Fisher and Oppenheimer, 1991) on the importance of atmospheric nitrogen deposition to Chesapeake Bay stimulated intense interest in the role of atmospherically-derived nutrients to coastal waters. However, there is a need to put the data from ANICA in perspective with all other nitrogen inputs to a Great Water such as Chesapeake Bay, including the nitrogen input in a watershed or from ground water that comes from atmospheric deposition. Presently, the project is not examining the fate of atmospherically deposited nitrogen within the watershed. There are large uncertainties in calculating how much of the nitrogen from precipitation falling on a watershed enters coastal and estuarine waters (Hinga et al., 1991). If the removal of nitrogen in terrestrial systems before entry of freshwater into the estuary is very high, as some studies have suggested (Jaworski et al., 1992), than the emphasis on atmospheric deposition may be less relevant to COP.

The progress and quality of ANICA research have been very good, given its severe funding limitations. In fact, it has leveraged some existing programs to achieve remarkable progress. Examples include some of the first direct measurements of atmospheric nitrate dry deposition to a calibrated agricultural watershed. ANICA has also completed a critical evaluation of atmospheric nitrogen deposition to the Chesapeake Bay watershed with proper quality control and assessment. It has set up

some additional deposition monitoring sites in the lower Chesapeake Bay where the data set is limited. It has used data from meteorological buoys in Chesapeake Bay to calculate the dry deposition of atmospheric nitrogen. Finally, it has initiated dry deposition investigations of other airborne chemicals and nitrogen species via eddy correlation measurements.

ANICA has been particularly good in providing essential information to other programs engaged in atmospheric input to coastal waters. For example, the EPA Great Waters program will need atmospheric nitrogen input data, and under ANICA, this has occurred in the Chesapeake Bay Atmospheric Deposition Study. However, ANICA is not as strongly linked with other COP projects as it might be. The COP effort in ANICA needs to link the atmospheric deposition measurements into a regional nitrogen budget. The ANICA program should begin studying factors within the watershed that control nitrogen retention to play a more important role in CEH and COP.

The ANICA program has had good planning, but it has developed slowly due to limited resources. It is now well poised to start undertaking a major field effort in conjunction with the EPA Great Waters program. The timing of EPA Great Waters research is right for COP to start ANICA field research now.

Toxic Chemical Contaminants

The goal of the Toxic Chemical Contaminants (TCC) program is "to assess the levels and effects of toxic contamination in U.S. marine and Great Lakes environments and to develop the capability to predict the effects of those toxins on marine resources and human use" (NOAA, 1991). TCC has four major objectives:

1. Bioeffects surveys—assessment of the extent and magnitude of environmental degradation related to contamination by toxic chemicals;
2. Bioavailability and Bioaccumulation—evaluation of factors and relationships that control uptake and bioaccumulation of toxic chemicals;
3. Bioindicator Development—development of new and improved methodology for quantifying bioeffects of toxins; and
4. Bioeffects Research—bioeffects research to establish links between contaminant exposure and significant effects.

To date, most of the emphasis of has been directed at objectives 1 and 3 with some extramural projects funded under objective 4 to identify biological damage at the immunological and cellular levels. Due to limited funds, no efforts have been directed toward objective 2. The ultimate goal of bioeffects research is to be able to predict consequences of contaminant exposure to populations and communities of marine animals, although present research efforts are directed at understanding effects at the level of the individual organism.

The TCC program has contributed to a broader understanding of the biological effects of contaminants in coastal habitats by adding information to the NOAA NS&T data base. The objectives of the program are similar to those of EPA E-MAP, but the focus of TCC has been on understanding cellular processes as bioindicators of damage, whereas E-MAP has taken a broader ecosystem approach. There is a need for both programs but the COP focus should be on integrating studies of both fate and effects of toxic materials. This will require more research on the factors and relationships that control uptake and bioaccumulation and on the linkages between bioindicators and effects at the species and population level. The panel believes that TCC needs to move in this direction, and in particular, TCC should take the lead in expanding our understanding of the relationship between bioindicators and population effects.

At the last meeting of TCC's TAC (October 1993), the interaction between investigators involved in objectives 1 and 3 was encouraged, to enhance the utility and field deployment of bioindicators developed under objective 3 (TCC TAC, 1993). The TAC also encouraged TCC to synthesize existing information relevant to objective 2. Studies funded under objective 4 will be completed this year and a new round of extramural proposals was to be solicited. With the FY 1994 budget cuts, the extramural research was largely eliminated. **The panel recommends that TCC increase the percentage of its funds that are awarded to extramural grants, achieving the COP-wide level of 40% external funding, and to promote the type of beneficial NOAA-academic interactions that have occurred in other COP programs.**

If TCC is to be integrated into CEH, two shortcomings of the present program need to be addressed: (1) studies on the physical and chemical behavior of contaminants in coastal environments; and (2) linkages between bioindicators and population and community responses. The behavior of contaminants has important bearing on the distribution (and redistribution) of contaminants in coastal environments and the availability of contaminants to marine organisms. A balanced TCC needs to include an assessment of both the fate and effects of contaminants, and it is essential to include a commitment to these studies in future funding.

With regard to population and community level effects, although the program includes bioindicators of important population parameters (e.g., reproduction, development, and growth), these studies are conducted largely in the absence of an understanding of the regulatory processes controlling populations of marine organisms. **Funding in subsequent years should be allocated to study linkages between organismal and population responses.** This is one area where there is a real gap in our understanding. This gap needs to be filled if the program is to make the link between the effects of toxins at the level of an individual to the effects of multiple stressors at an ecosystem level.

The TAC has provided good support for the program and has played a major role in the direction and evaluation of program goals. The program has made good progress over the past few years. TCC results were presented at a symposium held at the Annual Meeting of the Society for Experimental Toxicology and Chemistry in November 1993.

The program has contributed to a broader understanding of the biological effects of contaminants in coastal habitats than would have been available from NS&T and E-MAP alone. Much of the program's past focus has been on developing bioindicators. One measure of success of this effort will be how well new bioindicator assays become incorporated into monitoring programs like NS&T and E-MAP.

Estuarine Habitat Program

The goal of the Estuarine Habitat Program (EHP) is "to provide managers at both the state and local levels with more quantitative information on the rates of habitat degradation and loss, the functional value of specific habitats, the cumulative effects of environmental stress, and how to restore and create estuarine habitats more effectively." (NOAA, 1991)

EHP has three objectives: (1) to determine the location and extent of critical habitats and the rate at which these habitats are being changed or lost; (2) to determine how estuarine habitats function to support living resources and to develop methods for habitat restoration; and (3) to incorporate this information into synthesis documents and computerized data bases useful to habitat managers. The first objective is being addressed with the CoastWatch-Change Analysis Program (C-CAP), and the second is being addressed under the Estuarine Habitat Studies project. Elements of objective three are included in both projects. C-CAP is using geographical information systems (GISs) to organize and analyze information on habitat change and habitat area. EHP is also funding a modeling and synthesis effort on sea grass habitats which is linking a process-based model of eel grass beds into a GIS. The goal

is to develop a spatial habitat model that can be compared to C-CAP's data on habitat change.

Review of EHP Projects

CoastWatch Change Analysis Program (C-CAP) (recently renamed Coastal Change Analysis Program—The objective of C-CAP is to determine the location and extent of coastal habitats and the rate at which these habitats are being altered or lost. C-CAP uses satellite, aerial photographic, and surface-level surveys to map habitat location, extent, and quality, and to determine change through time. The rationale for this effort is that changes due to human population growth and the subsequent impacts on the natural environment occurs faster than anticipated, and no programs have existed to monitor those changes on national and regional levels on appropriate time scales. The C-CAP project has been addressing that objective through three components: (1) land cover change analysis protocol development, (2) regional change analysis and, (3) remote sensing of wetland health (COP, 1993).

Wetland Change Analysis Development —The component focused on the development of wetland change analysis protocols appears to be substantially completed, and has resulted in a guidance document for regional implementation (Dodson et al., 1993). The protocol document provides solid guidelines for developing and implementing a national coastal change analysis program. The protocols have been tested and implemented (on a trial basis) successfully in Chesapeake Bay and North Carolina regions. **Focus on protocol development should be significantly reduced and the use of prototypes completed. The program leader should initiate the in-house development of a procedure to comment on and refine the protocols in the future to take advantage of feedback from users and from research advancements.** There does not appear to be a long-term plan for maintaining and updating protocols and distributing the guidance document. **COP leadership should consider the document operational and seriously evaluate the efficacy of transferring responsibility for protocol maintenance to a NOAA line office in conjunction with the transfer of regional analysis. There may be inherent problems with this type of transfer, and these potential problems should be studied and identified by COP in 1994.**

Research should continue relative to refining change detection algorithms and techniques. The present research efforts appear well defined, competitive, and peer reviewed. The development and use of a Technical Advisory Committee to recommend research topics and to review and select research proposals is commendable. **As existing multi-year research efforts end, the**

percentage of funds allocated to protocol research should be reduced, with an increase in the allocation of funds to research linking C-CAP information with process-oriented modeling at the system level.

Based on recommendation by the COP Director and several workshop reports, there will be much less emphasis placed on accuracy assessment. Although the results of the latest effort to evaluate accuracy are not yet available, it has been observed that this is an extraordinarily complex issue relative to change detection. Although accuracy assessment may not be technically approachable at this time, once initial regional data coverage has been accomplished, it will likely become a significant issue. This will be particularly true for scientific users of the change analysis information. **We recommend not abandoning this portion of research, but it can be kept at a low priority or should obtain non-COP funds; it may require a significant effort to determine change detection accuracy in a manner that is statistically rigorous.**

Regional Change Analysis—The measurement of the extent and type of habitat change provides the first level of measurement in planned landscape-level modeling efforts. Two major prototype projects have been completed and comprise the significant geographic extent of regional application. It does not appear that any large geographic areas will be the subject of any studies in FY1994. The COP Director has indicated that a national one-time coverage is important for continuing change detection. **We agree with that conclusion and recommend that a substantial effort be made to develop additional andlong-term regional programs during 1994 and 1995. To meet its objectives in a cost effective way, the C-CAP project should solidify the criteria for regional participation and actively solicit partnerships (through a request for proposals), that are based on continuing programs, not demonstrations or prototypes.**

It is recognized by the panel that this regional analysis component is not a research effort. To that end, regional analysis must eventually be transferred to some other NOAA program. **COP should begin the identification of NOAA programs that could house the regional analysis on an operational basis. We recommend a late 1996 target for partial or full transfer of regional analysis. COP support to the regional analysis should take the form of research efforts to improve protocol techniques and to utilize the information being generated.** A static protocol without the dynamics of continuing research will eventually be detrimental to the long-term regional implementation.

Remote Sensing of Wetlands Health—Remote sensing of wetlands health appears to be the weakest component of C-CAP. A synthesis document has been produced (Patience and Klemas, 1993) but a minimal research effort has been allotted to this component. **We recommend that the wetland health component of the program be eliminated or delayed in favor of systems modeling and integration of C-CAP data into other COP programs.**

The goals of C-CAP are good and are being accomplished. Through research and planning, a regional implementation document has been produced that will provide national guidelines for change analysis. Although C-CAP has initiated interaction with and responded to other national mapping programs, no linkages that integrate the complementary aspects of the programs are apparent. Change detection and mapping require joint ventures with other agencies. **COP should initiate joint requests for proposals to obtain nationalcoverage.** The 1991 panel review recognized the product orientation of the program and recommended that operational considerations for C-CAP be investigated. It does not appear that COP has effectively investigated the long-term future of the operational components.

Estuarine Habitat Studies Project —The Estuarine Habitat Studies project developed a well defined set of goals and objectives. The goals reflected both basic scientific research and analysis to understand restoration processes and methods to improve them, as well as means to relate these findings to methodologies that could be implemented by coastal managers. Project planners solicited the opinions of academic and agency scientists in formulating these goals and in establishing priorities for the program itself. Although NOAA staff were already involved in restoration activities, the program was not directed solely toward support of existing programs, but allowed flexibility for new approaches being developed in the academic community.

The Estuarine Habitat Studies project, like most of the initial COP efforts, was planned to grow rapidly. As a result, it was anticipated that a large number of activities would be completed early in the project and that funding for coordination, modeling, and synthesis would be available concurrently or at least follow closely. However, funding was lower than expected, available funds had to be distributed over a longer period of time, and coordination activities were not funded immediately. Therefore, the program has fallen behind its initial schedule in terms of meeting the synthesis and modeling objectives. In FY 1993, a new solicitation was generated, resulting in over 140 preproposals. Funding limitations reduced the number of awards to approximately 10 new activities (four of which were holdovers from the previous solicitation).

Findings Regarding EHP Projects

Progress in EHP has been slowed by funding constraints. The primary focus of the program has been on the ecology of coastal habitats, primarily seagrass beds, and in evaluating coastal salt marsh restoration methodologies. Additional studies have been funded in the genetics of coastal plant species. These two areas of emphasis address fundamental missions of NOAA and represent basic research necessary to support the management of coastal resources and fisheries. With few exceptions, the panel believes that the research supported by this program reflects the best possible research given the funding and goals of the program.

Because this program has used peer-review of proposals, the quality of the funded research is extremely high. The solicitations attracted a large number of proposals, inundating COP staff with many good ideas that merited funding. Because only the best 5-10% of the proposals are funded and the evaluation is based on a peer-review process, the projects and scientists funded are the best in the nation in the areas of interest. Conversely, the low success rate of proposals has been a problem. Although some effort was made to reduce the number of proposals through the pre-proposal process, too many full proposals were requested relative to the realities of funding. This created considerable frustration among proposers, too much work for the review panel, and diminished credibility of the program. **The panel suggests that the pre-proposal stage be continued, and that a smaller percentage of full proposals be requested, reflecting realistic budget levels.**

EHP has provided a stimulus for interaction of funded researchers through various meetings and presentations. As a result, the principal investigators have been able to integrate their research efforts to some degree. The principal investigators funded by EHP have met several times, sharing results, and encouraging interaction. With some exceptions, this type of integration is critical to the success of the next stage of the program: synthesis and modeling. The panel encourages the integration of the research efforts to demonstrate that the various projects will have some management utility in the future. Several publications were in the process of being completed at the time EHP was initiated and the program was able to fund crucial elements so that early publication resulted. In addition, the scientific personnel funded by the program have very good track records in presentations and publication and the output to the scientific community has been excellent.

During the last fiscal year, EHP solicited proposals to model and integrate findings from the initial research effort. While funding limitations reduced the number of potential studies, EHP has funded significant projects to study integration over watersheds, ecosystems, and habitats. These efforts should begin to link information

about basic ecology developed from the early phases of the program to support the management goals of coastal planners.

The panel cautions EHP not to devote all of its resources to modeling and synthesis and abandon its efforts in process studies. There are real gaps in our understanding of some of the factors which regulate the distribution and loss of eelgrass beds which need to be filled. Another concern is that the seagrass model is being parameterized using data from a single region. This parameterization needs to be tested using data from other regions if the model is to be validated. The present model will also need to be linked to a spatially explicit water quality model in order to address issues of coastal zone management fully. Finally, the panel notes that the lack of a macroalgae category in C-CAP could prove to be an impediment in linking the sea grass model with data on the rate of habitat change, as is proposed. However, the panel recognizes that EHP is making a good start on synthesis and modeling in a difficult area. **To continue to make progress the panel recommends that the modeling and synthesis effort receive regular review and advice from scientists with expertise in both process modeling and GIS. The project should explore closer links with C-CAP, which should become easier as CEH programs and projects are integrated.**

COP has funded several synthesis documents on various aspects of estuarine and marsh research. **Given the limited funding, the panel recommends that COP not fund synthesis documents in the future unless they represent significant efforts to bring together new information.**

The panel continues to be concerned that emphasis on "horticultural" techniques to raise plant strains suitable for certain conditions (poor soils, high salinity, high productivity) may be counterproductive to restoring natural ecosystems. Genetic studies on coastal plant communities are certainly helpful in understanding genetic diversity, but attempts to isolate and create "super plants" may be not be appropriate.

EHP has utilized outside academic experts in formulating the overall program and to assist in program planning. The program has an active TAC and is to be commended for enlisting a variety of people to review the project at various stages. Workshops, panel meetings, and dissemination of planning documents has been very useful in establishing the status of the program and setting the course for new modeling and synthesis efforts. Unfortunately, limited funding has prevented the TAC from meeting regularly.

Future plans are based on the realization that this program may not grow substantially. EHP represents the ideal combination of academia and NOAA scientists striving to provide the best research possible. **Peer review, competitive proposal review, and scientific interaction should be continued (and if possible emulated by**

other programs). To deal with funding limitations, the program should examine some of the projects presently funded or planned to be funded to assure that they focus on restoration and coastal habitat ecology. Casting too broad a net will dilute the ability of the basic research to support the modeling and eventual management tool development envisioned when EHP was initiated.

Gaps in knowledge of coastal habitats and restoration need to be filled. More attention needs to be focused in this area. The project has been responsive to previous recommendations of the panel, in terms of holding workshops for the program scientists, initiating the modeling effort, and supporting expanded geographic scope of the projects.

Resource Information Delivery

Resource Information Delivery (RID) is a cross-cutting program whose goal is to "refine our knowledge of users, define and react to users information needs, and provide access to and interpretation of existing scientific data and information" (NOAA, 1991). **The panel believes that the overall goal of RID is essential for a mission-orientated agency such as NOAA and is an area where COP should play a strong role.**

In 1992, COP conducted a review of its progress in RID (COPR, 1992). **The review team recommended that meaningful statements about the utility of the research should be incorporated into all projects and that an evaluation of how effective COP's previous projects have been in transferring information into the hands of decisionmakers should be conducted.** COP was able to demonstrate that many COP projects have management applications.[7] It was noted that C-CAP, in particular, interacted well with state agencies throughout the development of the program.

The panel recommends the incorporation of RID into the other themes and programs, rather than maintaining it as a separate activity, to help COP better meet its objectives in this area. However, the panel found no planning for implementation of the RID goals and objectives within many of the programs. The panel is concerned that RID goals and objectives may actually be abandoned rather than incorporated into the themes. We believe there may be some merit in investigating the potential for RID to facilitate research within the themes by focusing on improved ways to disseminate information.

[7]Selected Management Applications From Funded Projects, a document created for the panel by the National Coastal Ocean Program Office.

Coastal Ocean Management, Planning and Assessment System (COMPAS)—A major COP effort under the RID program has been the development of the Coastal Ocean Management, Planning, and Assessment System (COMPAS). COMPAS is an automated desktop information system that allows managers to obtain and manipulate data. The goal is to provide federal, state, and local decisionmakers with the information they need to manage resources in estuarine and coastal areas. COMPAS is being funded through a number of state and federal partnerships. The goal of COMPAS is to provide states with the many different types of information needed for decisionmaking in the coastal zone. Previous reviews (COMPAS Review Committee, 1992) have fully supported this goal in the broad sense but have questioned whether NOAA should be heavily involved in the development of the computer interface. COP has responded to this recommendation and is making COMPAS more generic and implementing it in the DOS (disk operating system) environment.

COMPAS is being phased out of COP because it is an operational system, demonstrating its successful development. However, the panel was not presented evidence that NOS, now responsible for COMPAS, will continue the operational expansion of the program. Success of COP research and development is predicated on the operational application and implementation of the results in other parts of NOAA or outside NOAA. **It is recommended that the operational success of COMPAS, as implemented in NOS, be reviewed after the COP effort is completed.**

Economic Valuation —A method for valuing non-market coastal resources, such as beaches, has been developed through RID. Panel members found the goal to be a useful and important endeavor. The project is now focusing on workshops to teach the technique to managers and on training material.[8] The training material has been examined by economists outside NOAA and has received very favorable reviews.[9] It appears that the program is now in an educational rather than a research mode and ready to move out of COP. **We recommend winding this project down or moving it to the National Sea Grant College Program, which has capabilities in training and education (NRC, 1994).**

[8]Northwest Pacific Environmental Valuation Workshop, February 16-17, 1994, NOAA, Seattle, Washington.

[9]March 17, 1994 letter from Hauke L. Kite-Powell (Marine Policy Center, Woods Hole Oceanographic Institution) to Stan Wilson (NOAA/NOS).

Mandated Programs

Three programs were begun in response to specific directives from Congress. In FY 1990, money from the COP budget was earmarked by Congress for a program on the Urbanization and Southeastern Estuarine Systems (USES) in South Carolina. In FY 1993, additional funding was appropriated for COP to study an algal bloom problem in Maui, Hawaii. In FY 1994, Congress earmarked COP's budget to include a new program at the Institute for Environmental Renewal (IER), located in Pennsylvania.

Maui algal blooms-It is too early to evaluate the science of this project, but COP's planning and process for distributing the funds for this study should assure that the study is of high quality and addresses its objectives. The program contains a substantial effort in physical oceanography combined with an ecosystem-level evaluation of the problem. The panel was pleased to learn that much of the program funding was awarded through a competitive process. The proposed effort to use SeaWiFS ocean color data to monitor bloom behavior could provide insight useful in other areas, and helps integrate this work into the overall CEH theme.

The Urbanization and Southeastern Estuarine Systems (USES) Program and the Institute for Environmental Renewal (IER) Program —The panel did not evaluate the science of either the Urbanization and Southeastern Estuarine Systems (USES) program or the Institute for Environmental Renewal (IER) program. The IER program is new and no information was available at the time of the review, even to COP management. The panel is concerned that the goals of this program may be totally unrelated to COP goals.

The USES program is in its fourth year. The panel was disturbed about the lack of integration of this work with other programs within COP, and that the funds have not been awarded on a competitive basis. It is not clear how either of these two programs fit into the new broader CEH theme. These problems are not the responsibility of COP management, rather, they are due to the restrictions placed on COP oversight by the appropriation language and oversight by congressional staff.

A strong and effective COP requires planning, integration, and some predictability in funding. Nearly 20% of the CEH budget is now taken up by congressional earmarks which cannot be strongly integrated within COP. Earmarks erode the ability of COP to accomplish its goals.

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CHAPTER 4

COASTAL HAZARDS

INTRODUCTION

The original CoastWatch and Coastal Hazards themes and the more recent Coastal Forecast System (CFS) program are becoming a single COP theme called "Coastal Forecast System."[10] The new theme includes CoastWatch, Ocean Color, Tsunami, Sea Level Rise, Hurricane Winds, Coastal Winds, Great Lakes Forecasting System (GLFS), and East Coast Forecast System Feasibility Experiment (ECFSFE) programs. Taken together, these programs constitute the precursor elements of a unified coastal forecast and analysis system designed to acquire, analyze, and disseminate information on the present and future physical state of the coastal environment.

Written reports and plans were made available to panel members prior to the formal review held in Washington, D.C. on November 1-2, 1993. This documentation included the FY 1993 Implementation Plans for CoastWatch (COP, 1993a) and the other Coastal Hazards programs, the published Strategic Plan for the Coastal Forecast System (NOAA, 1993), and the report resulting from the 1991 review of COP by the Panel on the NOAA Coastal Ocean Program (PoCO) (NRC, 1991). Much additional information on technical progress and status was contained in the presentations made by each program at the November 1993 review meeting. In addition to presentation

[10]The new theme was referred to as Coastal Hazards at the time of the review and will be referred to as such throughout this report.

material, several groups distributed reprints of papers. Some written responses to specific questions were obtained from presenters following the meeting.

The panel's evaluations and recommendations are organized here according to the panel's charge. Overall assessments and recommendations are presented first, followed by more detailed technical summaries and recommendations for individual programs.

GOALS AND OBJECTIVES

The Coastal Hazards theme is evolving into a Coastal Forecast System. The panel endorses the development of a scientifically valid, operationally useful, and programmatically relevant Coastal Forecast and Analysis System (CFAS) to characterize and predict the physical state of the coastal environment. The present set of programs reviewed within this theme addresses many of the research and development needs required for a CFAS, but the theme management team has not yet linked the theme's programs into a coherent system.

The basic elements of a CFAS are shown in Figure 4.1: environmental data are acquired, processed, and combined with models to produce nowcasts and forecasts of selected environmental variables. Basic CFAS scientific and engineering research and development includes:

(1) improvements in, or additions to, existing data acquisition;
(2) development of accurate nowcast/forecast models (including the associated infrastructure for input and output of data) incorporating an improved understanding of the dominant physical processes; and
(3) development of scientifically valid, policy-relevant data products and their timely dissemination to users.

An approximate mapping of the present Coastal Hazards programs into a CFAS is shown in Figure 4.1 to illustrate how these programs contribute to the central goal of the theme.

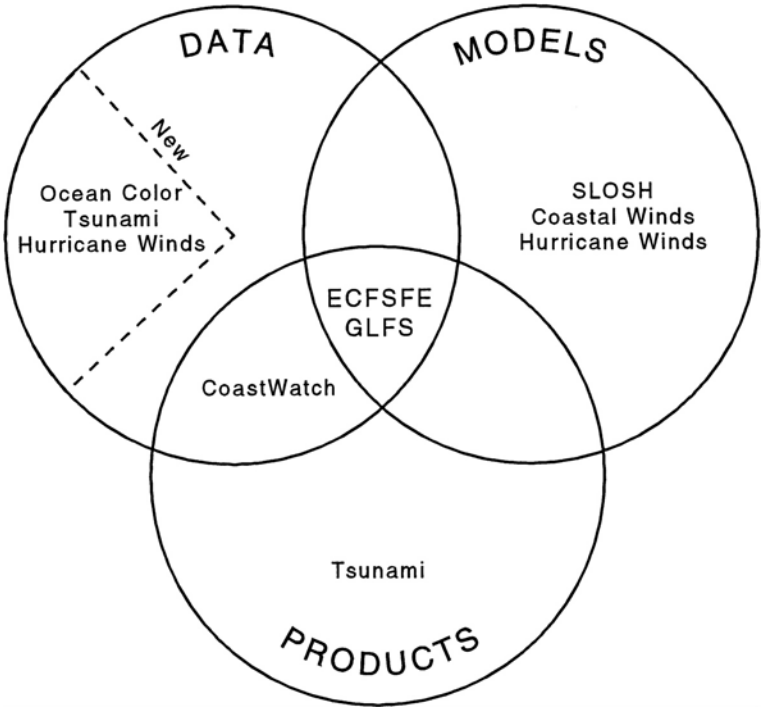

Figure 4.1 Incorporation of Coastal Hazards elements into a Coastal Forecast and Analysis System. SLOSH is the Sea, Lake and Overland Surges from Hurricanes; GLFS is the Great Lakes Forecasting System; and ECFSFE is the East Coast Forecast System Feasibility Experiment.

PROGRESS AND QUALITY

Significant scientific and technical progress has been achieved in most program areas since the 1991 panel review. Highlights include:

(1) development of an operational data acquisition and distribution system in the CoastWatch program;
(2) derivation and testing, as part of the Coastal Winds program, of refinements that will improve the accuracy of coastal winds significantly;
(3) acquisition by the Tsunami program of bottom pressure data in key regions needed to improve physical understanding of tsunami processes; and

(4) the first successful demonstration of a regional Great Lakes Forecast System (GLFS) utilizing inputs from CoastWatch, the NOAA National Ocean Service (NOS), and National Weather Service (NWS) operational models and providing products to a wide variety of users.

Although COP support for these programs has been quite small in monetary terms (13% of the total FY 1993 COP budget for CoastWatch and Ocean Color, 3% for the former Coastal Hazards theme and CFS planning), the investigators associated with the various programs have been resourceful in leveraging COP support. This has led to increased emphasis and focus, and in some cases redirection, of ongoing coastal research and development activities funded by the NOAA line offices.

All activities have reported technical progress to colleagues through presentations at scientific meetings, technical reports, and open literature publications. The panel noted that those programs engaged in vigorous collaboration with outside (academic) scientists also had many publications in the refereed literature and demonstrated the most scientific progress. The infusion of new ideas and energy into Coastal Hazards programs by both outside scientists and new COP-funded post-doctoral investigators represents one major benefit of the agency-academic partnership approach adopted by COP.

UTILITY OF THE RESEARCH

All programs have identified specific customers for their environmental products. This was especially evident with the GLFS, CoastWatch, and Tsunami programs. Users of products span the range from academic researchers to policymakers, operational agencies, businesses, and secondary schools, underscoring the broad utility and potential impact of these COP-supported activities. For example, the CoastWatch system has formal agreements with 85 regular users of its system. Many external users obtain sea surface temperature data from the CoastWatch systems; other Coastal Hazards programs (e.g., GLFS) use CoastWatch products as inputs for their predictions. Another example of the utility of products of the Coastal Hazards theme is the series of maps prepared by the Tsunami program to predict the extent of tsunami inundation at several vulnerable U.S. Pacific Coast and island sites.

THEME MANAGEMENT

There was a disparity in the level of formal technical review instituted by the various programs. CoastWatch has an active Technical Advisory Committee (TAC), representing the interests and viewpoints of the relevant external communities. The

discipline provided by the reviews clearly helped to focus program objectives and approaches. Unfortunately, no other programs in the present Coastal Hazards theme have successfully established a similar review process, despite attempts to do so.

In addition to providing input to COP management, formal reviews provide a forum for technical exchange between programmatically distinct, but scientifically related, program activities. Several NOAA participants in the November 1-2 panel meeting commented favorably on the technical benefits they derived from listening to the presentations of their colleagues. These contacts should lead to an increased awareness of relevant work within NOAA and to future cooperation.

RESPONSIVENESS TO PAST REVIEWS

The programs in the present Coastal Hazards theme were not organized into a single theme at the time of the 1991 panel review (NRC, 1991). Responsiveness to specific programmatic suggestions are thus examined below in the individual program reviews. However, the 1991 review did recommend that the programs identify more specifically their objectives, intended products, and potential customers. In addition, the 1991 review also stressed the benefits that could result from increased collaboration with academic scientists and infusion of recent graduates and/or postdoctoral investigators into COP programs. The panel is pleased to note that although there have been significant budget shortfalls, programmatic reorganizations, and redirections of focus in the last two years, the individual programs generally have followed the 1991 recommendations.

FUTURE PLANS AND THEME RECOMMENDATIONS

Most of the panel's recommendations regarding future plans are best presented in the context of the individual program reviews. However, four areas of concern are identified here because of their overall importance to COP and/or their cross-cutting nature, impacting not only other Coastal Hazards programs but also programs in the other two COP themes:

(1) COP must organize the transition of mature products, algorithms, and systems from research-oriented development to operations managed by the NOAA line offices. In particular, CoastWatch has developed, tested, marketed, and established a reliable distribution system for a suite of important sea-surface temperature and reflectance products based on satellite measurements. Routine operation of the system requires significant resources. While most of the support for these activities is already

provided by line offices, COP must take care to avoid becoming burdened by essentially operational responsibilities to the detriment of its mission for research and development.

(2) COP managers must continue to stress the benefits of outside collaboration in all aspects of COP research and development and timely publication of results in the open literature. Peer review of research is essential.

(3) COP must support acquisition of SeaWiFS ocean color data for the Alaska coastal region. Although this was part of the original FY 1993 plan for the Ocean Color program, an Alaska site was not chosen in FY 1993, and funding constraints in FY 1994 have caused COP to delay for yet another year. **The panel recommends that the implications of this gap in the national coastal ocean color data base be analyzed carefully to ensure that it does not devalue the investment being made in the other coastal ocean color sites.** In addition, attention must be paid to the implications of this gap on the ongoing Bering Sea FOCI studies being conducted by the Coastal Fisheries Ecosystems (CFE) theme.

(4) COP must continue to foster improvements in the accuracies of coastal wind analyses and forecasts produced by operational models such as the ETA model. Given COP's severely limited resources, research on improving model predictions of coastal winds is anticipated to have greater short-term reward than investments in large-scale data acquisition systems for coastal winds.

The Coastal Hazards theme should adopt as its overall goal the development of a scientifically valid, operationally useful coastal forecast and analysis system. COP has a clear and unique role within NOAA in identifying and supporting scientific research and development needed to develop such a system, and the adoption of a clear mission statement by the Coastal Hazards theme should help ensure that the different programs within the theme contribute to the overall goal. A coastal forecast and analysis system could provide ocean color and coastal winds data of great utility for coastal fisheries research (including CFE) and management.

Formal technical review and advisory procedures should be incorporated as soon as possible at the theme planning level and when appropriate within individual programs. The theme TAC is necessary to help management evaluate the quality and appropriateness of individual programs, and to foster increased communication between theme programs. Some of the programs may be too small to support their own TACs.

The panel further recommends that the Coastal Forecasting System program, having been successful in developing a conceptual design for a coastal forecast and analysis system (CFAS), now be charged with the evaluation and assessment of the other programs within the Coastal Hazards theme as well as continued planning for the CFAS. The new role of the CFS program would thus focus on identification and initiation of new scientific and engineering research and development programs needed to build a scientifically and technically sound CFAS. This would complement the developing NOAA-wide effort in this area.

INDIVIDUAL PROGRAMS—ASSESSMENTS AND RECOMMENDATIONS

CoastWatch Program

The overall objective of the CoastWatch program is to support federal, state, and local decisionmakers and researchers by providing timely access to coastal data and products. Since 1989, CoastWatch activities have focused on supporting clients with near-real-time coastal and Great Lakes imagery products from (primarily NOAA) polar orbiting satellites. This task has involved developing an initial set of surface temperature and radiance products, establishing reliable communication networks both to acquire satellite data and to distribute the products to clients, and identifying and interacting with users/clients to insure that the products are scientifically and operationally useful.

The CoastWatch program has been successful in establishing an operational demonstration system for data processing and distribution, involving a central operations support group and eight distributed nodes hosted at NOAA laboratories. Raw satellite data are received from the NOAA National Environmental, Satellite, Data and Information Service (NESDIS), and 1-km Local Area Coverage (LAC) radiances and multi-channel sea surface temperatures (MCSST) are generated. These data products are then forwarded electronically to the nodes by the Ocean Products Center of NOAA/NOS. Additional tailored products can be generated at the node, and each node also has a “help” desk manned by a trained analyst to provide background information in response to user requests. Nodes distribute products to local users, primarily via the Internet electronic communication network. Eighty-five users have signed formal Memoranda of Agreement and interact with the system on a regular basis. Funding from COP has allowed the development of a cohesive CoastWatch system, with COP providing linkages among several NOAA line offices. It is unlikely that the CoastWatch system would have been as successful, comprehensive, or useful if COP had not contributed its perspective and focused support to encourage the cooperation of several different NOAA groups in CoastWatch research and development.

The CoastWatch goal of developing an operational demonstration data acquisition and distribution system is of crucial importance to the ultimate development of a CFAS. The utility of CoastWatch data products and the reliability of the system become clear when it is recognized that many research users rely upon CoastWatch as the primary means for acquiring coastal LAC and MCSST data for their own archives. In addition, near-real-time coastal forecast efforts such as the Great Lakes Forecast System and the new East Coast Forecast System Feasibility Experiment (both discussed below) rely upon CoastWatch products for portions of their routine input.

The CoastWatch program has remained focused on system development, production, and dissemination of a limited, yet extremely useful, set of data products. This is consistent with relevant recommendations of the previous panel review in 1991.

CoastWatch first convened a TAC in early 1992 to examine the program and to provide recommendations on its future course. The report of the TAC[11] was primarily concerned with procedural and structural recommendations, which was appropriate considering the maturity of the program. Clear progress has been made on several of the TAC's recommendations, chiefly the involvement of the outside user community and the need for clear statements of the program's goals. As with the present review, the TAC identified a need for increased effort related to the development of science products and applications.

The primary recommendation arising from the present review concerns the transition of CoastWatch operational costs from COP to other NOAA line offices. **The panel feels strongly that the burden of continuing operations of CoastWatch should not be borne, even in part, by COP, but rather by the operational line offices (NESDIS and NOS). Having demonstrated the feasibility and utility of CoastWatch, COP support should now be focused on scientific and research issues associated with development and testing of new products.**

Tsunami Program

The overall aims of the Tsunami program remain the mitigation of tsunami damage (economic, physical, and sociological) to Alaska, Hawaii, California, Oregon,

[11]Letter dated July 10, 1993 to Kent Hughes (CoastWatch Program manager) from William Pearcy (Oregon State University), Eileen Hofmann (Old Dominion University), and Ronald Tipper (Joint Oceanographic Institutions, Inc.) and letter dated November 29, 1993 to Kent Hughes from Eileen Hofmann.

and Washington. This work is in direct support of NOAA's responsibility as the primary national source for tsunami warnings and hazard mitigation.

The program is managed by the NOAA Pacific Marine Environmental Laboratory, and has clear objectives in the areas of observations, modeling, and generation of user products, such as inundation maps. They are developing and deploying bottom pressure recorders (BPRs) with the dual aims of (1) acquiring accurate data supporting retrospective modeling of tsunami generation and propagation mechanisms, and (2) establishing the basis for a future system capable of providing real-time warnings, covering tectonically active regions off the coasts of Alaska, Oregon, and Washington. Modeling activities include the evaluation and refinement of sophisticated inundation models developed by Japanese scientists, and used in Japan, including tests based on actual recent tsunamis for which adequate data exist. The program has been especially aggressive in acquiring relevant data both from their BPRs and from post-inundation site visits. Modeling has also been broadened to take into account the relationship between background sea level (established independently of tsunamis) and the extent of inundation. User products are focused on the production of inundation maps for key U.S. coastal sites, including Hilo Bay, Hawaii; Eureka and Crescent City, California; and coastal Oregon.

The program appears to be well managed, and there is significant progress being achieved in all areas. It has so far been successful in synthesizing the needs and approaches required by scientific research with the objectives dictated by the operational roles of NOAA and other federal and state agencies. The program is commended for its decision to base modeling work on the best established models, even though they were developed in Japan (rather than by U.S. researchers), and to fund U.S. academic experts to help evaluate and further refine the models (rather than building a separate capability within NOAA). BPR development and deployment efforts have been linked closely with the accuracy requirements of the modelers as well as the need to acquire measurements in previously data-sparse geographical regions. The new efforts aimed at developing a real-time reporting capability for the open-ocean BPR data directly supports operational needs. Throughout, there has been a strong emphasis on reporting research results in the refereed literature and at both scientific and programmatic conferences.

The program has identified the ultimate federal and state users of its products [e.g., the NOAA National Weather Service (NWS), the Federal Emergency Management Agency (FEMA), and the California Seismic Safety Commission] and seems to have developed a good working relationship with them. The program reports that the new inundation maps being produced are of great utility to the ultimate users.

Hurricane Winds Program

NOAA, through the National Meteorological Center (NMC) and the National Hurricane Center (NHC), has the national responsibility for predicting the time, location, and intensity of landfalling hurricanes. Precise specification of the near-surface hurricane wind field is required to ensure that warnings are accurate. Economic and sociological consequences of overly conservative predictions are nearly as important as the consequences of underpredicting the magnitudes or extent of hurricane conditions. The Hurricane Winds program is aimed at developing techniques for accurately modeling surface wind fields in hurricanes through real-time data assimilation and analysis. Retrospective analyses are performed in support of these modeling activities, yielding wind fields that are useful for developing and testing storm surge and wave models used in other products of the Coastal Hazards theme.

The landfalls in the United States of several large tropical storms and hurricanes in the past three years have provided an extensive data set illustrative of measurement and modeling capabilities. Program personnel have been analyzing these recent events intensively, and there is evidence that their surface wind field models and assimilation techniques are becoming more accurate. Some scientific results have been reported in the refereed literature and at various conferences.

The Hurricane Winds program has been particularly aggressive in acquiring data from diverse sources and using all available data in their analyses. These activities have highlighted an institutional problem within NOAA/NMC/NHC; only small subsets of available measurements and model outputs are used operationally to generate forecasts. Program personnel credit the availability of COP support with allowing them to develop mechanisms for real-time data acquisition and products, as well as the communication links to the traditional operational organizations; previously, attention had been focused almost exclusively on retrospective analyses. Nonetheless, there was frustration expressed by the scientists that the operational organizations were not making effective (or, at times, any) use of the products.

The scientific work being conducted appears to be valid and useful. COP can be credited with the change in emphasis from purely retrospective analyses to development of a system for real-time data acquisition and analysis. In addition to further scientific and engineering refinements, however, the theme management must ensure that the program is generating products that will be used by the clients. In this case, the problem appears to be on the clients' side, but strong support for continued COP funding will probably require agreement by the clients that the program's results are useful.

Coastal Winds Program

Accurate knowledge of near-surface winds over the coastal oceans is critical for modeling the coastal zone and predicting coastal hazards. Measurement and prediction of coastal surface winds, however, is extremely difficult. Operational atmospheric models typically have insufficient spatial resolution to allow accurate modeling of the wind field in coastal regions. Small-scale features of the coastal wind field are of relatively greater importance than similar-scale variations in the wind field over the open ocean. The nearby presence of land strongly influences the wind field, and the simplified topography used in many large-scale numerical weather prediction models is insufficient in coastal areas; in some instances, spectral truncation of land topography leads to coastal ocean areas being treated as land in the models! Despite the economic, sociological, and scientific importance of the near-surface coastal wind field, numerical weather prediction has not placed special emphasis on the accurate prediction of coastal winds.

Several activities at NMC, supported in part by COP, have been initiated to improve the accuracy of coastal surface wind predictions and modeling. These include:

1. The use and enhancement of a high resolution (40- and 80-km) regional model (ETA) for prediction of coastal atmospheric circulation;
2. Verification of both global and regional models for numerical weather prediction in coastal as well as open-ocean regions;
3. Operational daily verification using buoy (both coastal and open ocean) data in collaboration with the Marine Forecast Branch of NOAA/NMC;
4. Production of SST fields for the ETA model (1/8 degree resolution) from analyses of satellite high-resolution (8-km) SST measurements;
5. Validation and assimilation of low-resolution surface wind speed data derived from the operational measurements from Defense Meteorological Satellite Program (DMSP) satellites and an evaluation of ERS-1 scatterometer vector winds.

The “ETA” model, covering the continental United States and adjacent coastal areas, is the highest resolution (yet spatially extensive) regional model in the NMC suite. Initial indications of the accuracy of the ETA model were not encouraging, and the near-surface winds predicted by the model did not appear to be sufficiently accurate to allow use in coastal sea level and hazard prediction systems. With COP

support, a postdoctoral scientist has been added to the NMC team refining the ETA model, focusing specifically on refining the model's surface flux calculation and turbulence parameterization scheme. A new, more accurate, computationally-efficient scheme for turbulence parameterization has been developed and implemented, along with an increase in near-surface vertical resolution and a vertical nesting scheme for calculating fluxes over steps in the model topography (important near the coast). The work has been published extensively in the refereed literature, as well as in a variety of conference proceedings and World Meteorological Organization reports.

The accuracies of model-produced surface winds must be quantified before the model outputs can be used as inputs to coastal hazard forecast, warning, and scientific analysis systems. The presentations indicated that, with COP support, such an operational validation program has been started. Unfortunately, the levels of analyses that were presented seemed insufficient to answer the scientific questions. Mere tabulation of differences in low order statistics (such as mean biases and root mean squares) between buoy measurements and interpolated model predictions) are insufficient. The scientific rigor and insight so clearly present in the previously discussed refinement of the ETA model is not evident here.

Additional activities have involved analysis of remotely-sensed SST and near-surface wind data and their assimilation in regional and global atmospheric circulation models. The NMC standard blended product is a 15-day composite of all available in situ and satellite data, analyzed on a 1 × 1 degree grid and filtered and smoothed to an effective 3 × 3 degree resolution. With COP support, work has proceeded with developing high resolution SST products (1/8 degree resolution) for the ETA model domain, interpolating the 0.5 degree NESDIS products and merging the 1/8 degree coastal products where available. Beginning in May 1993, NESDIS produced a Great Lakes SST product with 1/8 degree resolution (compatible with the GLFS system) which included flagging of pixels contaminated by ice. These ETA SST products are presently being validated with buoy and ship data and are used to set surface boundary conditions in the regional ETA 40-km model (started in May 1993).

Near-surface wind speed estimates with broad spatial coverage are available from the DMSP Sea Surface Microwave Imager (SSM/I) microwave radiometer instruments; more recently, wind velocity estimates (both speed and direction) have become available in near-real-time from the scatterometer flown on the European Space Agency's (ESA's) ERS-1 mission. After extensive analyses and conventional validation studies, SSM/I data began to be used operationally in the NMC Global Data Assimilation System in March 1993; ongoing studies are aimed at developing procedures to use full-resolution data to generate high-resolution surface wind and pressure fields. Data presented at the review suggest that inclusion of the SSM/I data significantly improved the quality of analyses and forecasts over the ocean (open

ocean buoys are used as comparisons). It is less clear whether the coastal forecasts and analyses were influenced to the same extent.

Significant errors associated with vector wind data from the ERS-1 scatterometer instrument (mainly at low wind speeds and directional errors associated with ambiguity removal) have hindered the utility of these data. The validation process continues, although it appears that the most recent fast-delivery data produced by ESA are of high quality. No information was presented about ongoing activities related to assimilation procedures for these scatterometer data; previous studies both in the United States and abroad indicate that near-surface wind data must be assimilated in a very sophisticated manner in order for additional data to make a marked positive impact on the forecast.

Results pertaining to operational model validation, SST, and wind speed/velocity products have been reported extensively at professional conferences. However, no open-literature papers have apparently been submitted. The scientific community would benefit from knowledge of the ongoing work through the open literature, and significant scientific input may be obtained from associated reviews. **In the long term, both the Coastal Winds program and the Hurricane Winds program should communicate extensively, and strive for a common model of the coastal environment.**

Ocean Color Program

The Ocean Color program was started in FY 1993, with the aims of acquiring, processing, and promoting the scientific use of SeaWiFS data from U.S. coastal waters. At the time the program was initiated, SeaWiFS was scheduled to be launched in late 1993 and the primary objective was to assure that a complete set of SeaWiFS coastal data was acquired off the U.S. Gulf, West, Alaskan, and Hawaiian coasts and adjacent waters the U.S. East coast and the Great Lakes were to be covered by NASA-funded facilities). In addition to acquiring the data, processing it to Level 1 (radiances), archiving it locally, and transmitting it to a NASA-funded archive at Goddard Spaceflight Center, each NOAA station funded by the Ocean Color program was asked to propose science-related activities involving higher-level processing, algorithm development, and/or application demonstrations. Proposals were solicited from four existing NOAA facilities, close to or co-located with CoastWatch nodes (to take advantage of existing data acquisition, processing, and communications facilities). The science-related and algorithm development portions of the proposed work were to be done in collaboration with non-NOAA investigators.

Three of the four desired sites were chosen in FY 1993 (Hawaii, West Coast, and Gulf Coast); in each case, approximately half the funding was allocated to the

science portion of the investigation. No site was chosen covering the Alaskan region. Due to technical problems, including the ability of the SeaWiFS color sensor to sample near shore, the SeaWiFS mission launch was delayed by NASA until mid-1994.

The Ocean Color program correctly recognizes that a prominent scientific use of ocean color data involves retrospective analysis, and that such processing and analysis is possible (and will be pursued aggressively by the scientific community) only if a comprehensive data set is available. As no other agency has taken responsibility for coastal data (NASA and the U.S. Navy are concentrating on global, open-ocean data sets), COP and the Ocean Color program are commended for moving actively to assure that, initially, all available data are collected and archived. The emphasis on linking the acquisition and low-level processing activities to local academic research, that applies the ocean color data, is admirable.

It is difficult to assess progress, given the relatively recent inception of this activity and the delay in the SeaWiFS launch. In particular, the presentations to the panel did not address details of the various algorithm development activities.

As noted above, acquisition and archiving of the data will at least preserve it for retrospective analysis by the scientific community. At present, neither the accuracies of the coastal algorithms under development, nor the capabilities of the SeaWiFS instrument in coastal regions, is known.

The extent to which the Ocean Color program has identified and is interacting with user groups beyond the research community is not clear. An early June 1992 review of the embryonic Ocean Color program by the Nutrient Enhanced Productivity advisory committee raised issues regarding the availability of near-real-time Ocean Color products via CoastWatch and emphasized that a broad class of users require such rapid delivery. The presentation to PoCO (this review) also suggested that there was little formal interchange between NASA and the Ocean Color program. This is especially critical, as the whole East Coast and Great Lakes portion of the SeaWiFS data set will be acquired by NASA's Wallops Flight Facility, and incompatibilities between the NOAA and NASA portions of the data would degrade its scientific utility. On the other hand, the January 11-12, 1994 Interagency Coastal Water Color Workshop, co-sponsored by NOAA, NASA, and the Office of Naval Research in Silver Spring, Maryland, is a very positive step in the right direction.

The present fiscal climate will not allow the planned Alaska site to be established in FY 1994. Although this will surely diminish the value of the Ocean Color data set, its impacts on researchers and other COP activities that represent potential users of the Ocean Color products have not been quantified.

Coastal Storm Surge Modeling Program

The prediction and understanding of inundation of low-lying coastal areas due to hurricane and extratropical storm surges continues to be a pressing societal concern. For example, barring only the recent California earthquake, Hurricane Andrew was the costliest natural disaster in U.S. history, accounting for $30 billion in damage. The extratropical ("Halloween") storm of 1991 was also costly, causing an estimated $ 168 million in damage to property and loss of life along the northeast U.S. coast.

The overall goal of this program is to develop operational storm surge models capable of delivering accurate storm surge estimates in both real-time and hindcast situations. The existing model for tropical storms, the Sea, Lake and Overland Surges from Hurricanes (SLOSH) model, has been in existence for some time, and (though the available literature is scant) appears generally to be capable of producing useful estimates of storm surge if provided with accurate predictions of hurricane strength, trajectory, and size. The systematic improvement of hurricane wind field predictions anticipated from the COP Hurricane Winds program should therefore materially improve SLOSH performance. **These impacts should be documented in the refereed literature.**

Unlike fast-moving tropical storms, which cause rapid rise and fall of sea level in the immediate vicinity of landfall, extratropical storms are of significantly longer duration and larger spatial scale. As a consequence, the simple linear wave dynamics built into the SLOSH model may not be entirely satisfactory for the case of extratropical storms, and the issue of lateral boundary condition specification becomes especially problematic. Nonetheless, because present NOAA forecasting practices depend on statistical methods for issuing coastal flood warnings for extratropical storms, more reliable dynamical models of extratropical storm surges clearly are required.

The FY 1993 Implementation Plan for Coastal Hazards (COP, 1993b), the most recent plan available to the panel, calls for the development of an extratropical storm surge model capable of real-time application in an operational NOAA setting. The development of an extratropical storm surge modeling capability seems well justified. As planned, development of the new extratropical storm surge model will proceed in several stages. First, a baseline model, based on SLOSH, will be implemented for the purposes of parameter and boundary condition exploration, and for eventual comparison with other candidate models. Second, complete sets of data will be developed, based on two storms that struck the U.S. east coast (the Halloween storm of 1991 and the January storm of 1992), for systematic testing of extratropical storm surge models. Third, the performance of the baseline model on these test problems will be

published, and comparisons undertaken with comparable models from academia and industry. Second- and future-generation extratropical surge models will be chosen based on such systematic testing. The success of a surge model is intimately tied to good surface wind analyses and predictions. Therefore, this program has links to the Coastal Winds and Hurricane Winds programs. In the long term, the improved coastal winds should improve the surge model. **The panel urges that COP avoid developing a surge model that is adjusted to a different wind data set.**

These specific plans and objectives seem quite sensible. The panel is particularly pleased to see in the plan an increased role for collaboration with academia and industry and for communication through peer-reviewed channels. Both are in conformity with the recommendations made in our previous review (NRC, 1991). The panel also encourages NOAA to keep abreast of the excellent research on storm surge modeling ongoing in Europe.

In the future, some thought must be devoted to the approach for merging NOAA's storm surge modeling capabilities within the Coastal Forecast System. However, the immediate needs and modeling concerns of the storm surge and CFS programs are rather different, so that independent pursuit of these two projects is desirable at this early stage. **Nonetheless, technical and informational exchange between the two programs should be instituted and strengthened.**

Great Lakes Forecasting System (GLFS)

The Great Lakes Forecasting System (GLFS) is a coastal prediction system designed to analyze the present state of each of the Great Lakes and to provide up to 2-day forecasts of their physical states. A variety of input meteorological observations, remotely-sensed radiance and SST data, and meteorological forecasts are used as input, and predictions and analyses (nowcasts) of the 3-dimensional (3-D) circulation and thermal structure are planned. In its present implementation, the system produces nowcasts for Lake Erie only, assimilating wind stress and thermal forcing fields into the Blumberg-Mellor 3-D circulation model (Blumberg and Mellor, 1987) (the model can also be used presently to generate up to 1-day forecasts with 2-km horizontal resolution when run on a CRAY-YMP computer and 5-km resolution when run on a workstation). A shallow water wave prediction model is also used to predict the lake-wide wave field. Output products are transmitted as images upon request from users; transmissions to underway boats can be accommodated via portable telephone. Selected input data are obtained from, and all products are made available to, the local CoastWatch node.

GLFS is a cooperative effort between the NOAA Great Lakes Environmental Research Laboratory (GLERL) and the Department of Civil Engineering at Ohio State University (OSU). GLERL is responsible primarily for overall system design, analysis and assimilation of meteorological data and NWP products, and calibration of GLFS model output. Operational GLFS model runs are conducted at OSU, which also has responsibility for development of visualization and user interface tools, and selected enhancements of the overall model (such as the addition of tributary flows). Support comes primarily from the NOAA Environmental Research Laboratories, COP, and the Sea Grant program, although a host of other agencies and private concerns provide funding or in-kind support.

The GLFS effort represents an important scientific and programmatic accomplishment for NOAA, and for COP in particular. As it utilizes routinely many of the components of a future coastal forecasting system (such as the NMC ETA model for near-surface winds, CoastWatch for thermal data input and product distribution, and the Blumberg-Mellor circulation model), it provides an excellent proof-of-concept and testbed for future coastal ocean prediction systems. At the same time, the careful attention paid to product development and system (including model) verification has made the actual products themselves useful to researchers and federal, state, and local resource users and policymakers.

COP support has had a direct influence on the present form of GLFS. Before COP involvement and the existence of a COP-supported, functioning CoastWatch system, GLFS was an ad hoc collection of independent process models and data acquisition systems, with products generated only on a sporadic and “as-needed” basis. Funding support from COP provided stability for planning and operations, and CoastWatch provided a stable source of data as well as an operational distribution system for products.

East Coast Forecast System Feasibility Experiment (ECFSFE)

The objective of this activity is to determine the feasibility of an operational East Coast coastal nowcast/forecast system, providing information on temperatures, salinities, currents, and waves/sea-level in response to astronomical and atmospheric forcing. The activity is a joint effort involving the Princeton University Geophysical Fluid Dynamics Laboratory (GFDL), NMC, and NOS. The core of the system is the Blumberg-Mellor ocean model, with atmospheric forcing provided by the NMC ETA model. The system is being developed at NMC, where it will also reside.

Since the project was initiated in late April 1993, the Blumberg-Mellor model has been transferred successfully to NMC, and ETA model and astronomical (tidal)

input has been used for experiments. Skill assessments are still being developed, centered initially around system predictions of sea level and SST. Initial experiments have shown that the ETA model winds associated with hurricane-strength events are inaccurate, and thus lead to significant underpredictions of sea level excursions. Although not presently operational, it is expected that near-real-time altimeter sea level data from the ERS-1 satellite will be assimilated into the model in the near future. Additional near-term enhancements include upgraded skill assessment (comparisons with NOS Next Generation Water Level data and Ocean Products Center-analyzed SST data), completion of the tidal capability, sensitivity studies with respect to surface and lateral boundary conditions, coupling the present model to an estuary model, and completion of predictability studies.

ECFSFE is a follow-on to GLFS, which will require dealing with an open oceanic boundary, a complication not encountered in the Great Lakes study, and will provide an opportunity to utilize remotely-sensed ocean surface height information. ECFSFE has been identified by CFS as the second major prototype forecast system that should be examined prior to establishment of a national system. Not only will ECFSFE products be useful, but the "lessons learned" in its development at an operational site (NWS) will prove valuable in future development efforts. Although the program has only recently been initiated, significant progress has already been achieved.

From the start, a Steering Committee composed of four members (two from NOS, and one each from Princeton/GFDL and NMC) was established to oversee and help plan the project, and to assure coordination among the various organizational elements. The plan for expanding the scope of the activity appears reasonable and achievable. At present, the activity does not include facilities for outside groups to contribute modules or process models. **The panel recommends that the program examine whether such a facility must be "built-in" from the start in order to ensure efficiency and accuracy.** It is noted that NMC is adding a similar "model testbed" facility for use by the outside community.

Coastal Forecast System (CFS)

As noted above, the ultimate goal of CFS is the development of a modern, flexible, end-to-end system that provides data and forecasts to a wide range of coastal users. The CFS program is uniquely suited for developing the requirements for a full, national coastal forecast system and justifies both the scientific and operational requirements and the associated costs. The broad perspective of the CFS activity allows it to identify key short- and long-term gaps in ongoing work; in addition, this perspective allows evaluation of the results of other projects in the context of a future forecast system.

CFS has documented the philosophy of a future observing system (NOAA, 1993), and developed its structure sufficiently to allow realistic planning budgets to be presented. They sponsored a workshop at the Woods Hole Oceanographic Institution in June 1993, at which an economic cost-benefit analysis of a future CFS was conducted (Marine Policy Center, 1993). Both of these activities are vital for the successful initiation of a full-scale CFS program within NOAA. The CFS activity has not actively evaluated the products of the other Coastal Hazards programs, nor have they to date addressed issues such as the overlap in approaches for calculating storm-induced sea level rise.

The panel was informed that negotiations are underway with other NOAA line offices, including NWS and NOS, for a NOAA-wide CFS activity. In this expanded activity, the role of COP will be to identify and conduct research and development activities required to refine models. System and forecast validation will be conducted by NOS prior to transition of CFS to full operations at NWS. Aggressive evaluation of ongoing Coastal Hazards programs and analyses of the needs to develop new data sources, or expand present ones, will increasingly become a part of the COP-CFS role.

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CHAPTER 5

SUMMARY AND RECOMMENDATIONS

SUMMARY

The panel found that the Coastal Ocean Program (COP) has successfully fostered innovative science in important applied areas. This success has resulted from a mixture of new programs and incremental additions to existing programs. In most cases, COP-funded research has succeeded because of its partnership approach of combining the human, fiscal, and facilities resources of NOAA with resources from outside the agency. Research funded by COP would have been, in many cases, impossible without the partnership approach. In view of the NOAA strategic plan, COP has much to offer in providing the scientific foundation for a large part of NOAA's mission in the coastal ocean area. COP has improved the coordination and interaction among NOAA line offices by providing financial resources and a planning structure for joint programs.

The panel endorses the three COP themes and recommends that the program should maintain a multi-theme approach. The panel also endorses the decisions to consolidate the former seven themes into the three present themes; it is likely that increased coordination of programs within the new themes will promote new approaches and insight into coastal hazards, coastal fisheries ecosystems, and coastal environmental quality. Achievement of COP goals (see Introduction and Background) could be enhanced by substantial coordination of COP with other parts of NOAA and with other agencies, such as the Environmental Protection Agency, the National

Science Foundation, the U.S. Army Corps of Engineers, the Department of Energy, and the U.S. Geological Survey.

The panel identified several COP deficiencies that should be addressed to help the program reach its full potential and recommended actions (discussed below) to help COP overcome these deficiencies. Many of COP's problems relate to its unfulfilled expectation of steadily increasing funding. In fact, the program has received level-funding for several years. COP invested its resources in initiating programs that were planned to provide a comprehensive coastal research program when full funding was finally achieved. As funding plateaued at a lower than anticipated level, the result has been a program that is spread too thin at the theme and program levels, with resulting disappointment in the marine science communities within and outside NOAA. In response to the reality of level funding and previous advice from the panel, COP has begun the process of consolidating and integrating related themes. The panel supports this direction and provides advice in this report to help COP accomplish this goal. Another challenge facing COP is to develop mechanisms for the transfer of research and development activities into operational status when the time is appropriate.

At present, there is a lack of long-range planning and detailed technical review at the theme level. This is a primary function of the Program Management Committees (PMCs) and Technical Advisory Committees (TACs) set up at theme levels. Some of these advisory groups have ceased to function, rarely meet or have never met, and need to be revived. **The panel recommends that COP also should improve long-range planning at the COP-level, especially its strategies for funding and sequencing major field programs.** One factor that has complicated long-range planning of COP is the encumbrance of COP with congressional earmarks and add-ons.

RECOMMENDATIONS

1. **Effective Technical Advisory Committees should be formed for each of the three themes.**

   For COP to be successful, it is essential that its various programs remain focused on the larger goals of the themes. It is also important that the planning process for individual programs be evaluated and integrated at the theme level. This will identify critical gaps in knowledge and research activity where new efforts are needed and highlight approaches that are successful. A new focus on theme-wide goals is increasingly important as some programs within the themes are ending and new ones are being initiated. The present structure of the TACs has been effective in providing guidance and technical review at the program level. However, these

TACs alone cannot assure that the theme as a whole will continue to meet its goals or provide the perspective necessary to help design new programs. In the past NOAA has relied upon "theme teams" to assist in long-range planning. The "theme teams" were largely composed of NOAA scientists and scientific managers from the individual programs. These individuals have an important role to play in COP operation and management, but we believe that COP would benefit from the insights of independent committees composed of individuals not directly involved in the programs. We recommend that each theme form its own TAC. The purpose of the theme-level TAC should be to assist COP management in integration of programs, development of new programs within a theme, elimination of programs, and long range planning for the evolution of the themes. A parallel review structure should be set up for each theme so that review mechanisms operate more consistently across themes.

2. **COP should streamline its advisory structures at the program and project levels.**

A comprehensive advisory structure was developed by COP in anticipation of large budget increases, and in part because of panel advice in 1991. The panel recommends that COP, while strengthening its TAC advisory structure, examine the program and project advisory structures to streamline them and to decrease overhead. It should be possible to set up theme TACs of reasonable size that can advise all programs within a theme, thus allowing the elimination of some PMCs. TACs may not be necessary for each program; only large programs should have separate TACs. To provide theme TACs an opportunity to guide the mix and content of programs, TAC members should be involved in program-level reviews.

3. **Given uncertainties in funding, themes should develop flexible plans with prioritized goals and alternatives.**

The initial plans and expectations of the COP themes were optimistic about budgets, which resulted in solicitation and implementation of programs at levels that proved to be unrealistic. In the future, prioritization in program planning should be requested in solicited proposals, with alternative plans presented to propose research that could be carried out at lower than anticipated funding levels. Alternative or contingency plans should be reviewed and considered at the outset to insure that scientifically defensible programs are funded under good or bad budget situations. This is particularly true for multiyear field programs, and for programs that depend on the results of activities funded outside COP.

4. **Planning for the next 5 years, of COP and its themes, should be initiated now.**

   It is not too early to begin planning for COP's second 5 years now. A strategic plan for overall directions is needed to guide COP and to inform the scientific community about future prospects, both with respect to theme areas to be supported and realistic estimates of dollar amounts that will be available. To form the best NOAA-academic partnerships, it is critical to begin planning well ahead of anticipated program implementations. If COP or its themes will change substantially during the next 5 years, it is even more important to develop the plan, have it reviewed, and inform the research community about it as soon as possible.

5. **Procedures for solicitation and review should be standardized among themes and programs.**

   Review of present programs within COP themes has revealed a nonuniform solicitation and review process for research proposals. The panel strongly recommends that the process be standardized to the extent possible among themes, and especially that it be standardized for programs within each of the themes. All proposals (both NOAA and academic) should be treated identically in a process that is objective and which has effective, rigorous peer review. Standardization of the review process will insure that high-quality science is supported and it will build a reputation of excellence for COP. Developing and documenting a standardized procedure also would help combat the perception (sometimes warranted) that external proposals are subjected to more rigorous review than are proposals submitted by NOAA scientists.

OTHER ISSUES

Transition

Several activities supported by the Coastal Ocean Program (COP) have accomplished their initial stated objectives, and others will do so over the next few years. Some of these programs, such as CoastWatch, have developed prototype operational products and have established operational demonstration systems. Other programs, such as the Nutrient Enhanced Coastal Ocean Productivity project, have made comprehensive progress on the basic scientific issues that they set out to study.

Support from COP for routine operations drains funds that should be applied to unique COP research and development activities. Likewise, in a period of level budgets, indefinite continuation of work on some topics, while scientifically valid, may preclude initiation of other more timely studies. As noted in the COP response to the

1991 review by the Panel on the NOAA Coastal Ocean Program, " ` COP [is] a science program which develops new information and techniques for decision-makers, [and it] should not invest in long-term, operational efforts to collect and/or distribute ` data [or products]."

COP management has begun negotiations to transfer operational responsibility for several CoastWatch products from COP to line offices of the National Oceanic and Atmospheric Administration (NOAA). Successful transition would be a significant accomplishment for COP because COP's objective is to conduct research and development needed to provide users with accurate scientific products for coastal science, management, and policymaking. Transition would make these products and systems available to their ultimate users to operate, and would free COP to pursue further scientific studies.

The panel recommends that COP:

1. **continue to negotiate with NOAA line offices to assure that operations associated with presently mature COP-developed products and systems are transferred rapidly and efficiently;**
2. **communicate regularly with the line offices on the status of other, ongoing COP activities that are nearing completion or significant achievement;**
3. **ensure that future COP programs have clear statements of measurable goals and objectives, to allow both internal evaluation and early coordination with the line offices to which operational responsibility will eventually be transferred; and**
4. **encourage involvement of appropriate users of COP-derived products and information throughout planning and research phases of COP activities to ensure the utility of COP results.**

The panel also recommends that NOAA (specifically the Office of the Chief Scientist) document the fate of programs that have been transferred to determine if the transfer has been successful and to evaluate COP's performance in initiating useful programs. The panel recommends that the first analysis be completed by NOAA by FY 1996, to help COP plan more effectively for subsequent fiscal years.

Earmarks and Add-ons

Congress has frequently required COP to spend a portion of its appropriation on congressionally-mandated projects. COP now includes three programs added by Congress, in South Carolina ($700,000), Hawaii ($400,000), and Pennsylvania ($800,000). Two of these programs did not include additional congressional appropriations. Consequently, COP has had to reallocate funding from existing programs elsewhere within its budget. One program (the Maui project in Hawaii) does include the necessary appropriations to avoid sacrificing other parts of COP.

Recognized strengths of COP lie in its reliance upon careful planning, its development and implementation of priority research, and its insistence upon peerreview processes to select the best research proposals submitted by the scientific community. The panel notes that congressional add-ons and earmarks now total at least $ 1.9 million, representing over 16% of the COP budget. This trend is alarming. Although the panel is aware of the political reasons for add-ons and earmarks, it is very concerned about their impacts on COP funds. Earmarks and add-ons seriously diminish the ability to implement COP priority programs fully, and can diminish the scientific quality of its research because decisions are removed from the peer-review process. Program funds are being diverted from planned and peer-reviewed scientific programs to those that have little accountability and tenuous connections to COP goals and objectives. The panel commends COP for attempting to bring some program integration to the add-ons and earmarks, and for achieving some level of accountability in these programs. **COP should continue to articulate the negative consequences of earmarking, and at the same time make a greater effort to communicate COP successes.**

Communication of COP Contributions

COP provides unusual opportunities for collaborative research between NOAA and academic scientists and it funds a broad range of research activities, yet there is little recognition of “COP Science” as a distinct entity in the same way that research funded through Sea Grant, NSF, ONR, and other extramural sources have clear ties to the funding source. This occurs because COP uses the NOAA line offices to channel its funds. Although this may seem to be a superficial problem, it results in the virtual invisibility of COP and the failure to develop a constituency to argue for its support. **The panel recommends that COP develop more effective mechanisms to promote its unique philosophy and research program to the public, NOAA, the Department of Commerce, and Congress.**

APPENDIXES

Appendix 1

Bering Sea FOCI Site Review Report

INTRODUCTION

The Bering Sea Fisheries Oceanography Coordinated Investigations (FOCI) received its first funding from the Coastal Ocean Program (COP) in FY 1991. This report fulfills a requirement of the Coastal Fisheries Ecosystems (CFE) theme, that a thorough review of a program be conducted after three years of support. The review was conducted by the Coastal Fisheries Ecosystems subgroup of the panel on 13-14 January 1994 at NOAA's Pacific Marine Environmental Laboratory (PMEL) in Seattle, Washington.

The concept and scientific justification for Bering Sea FOCI had their origins in the International Scientific Symposium on Bering Sea Fisheries (the Sitka Conference, 1988 (COP, 1991), which identified the major research needs for management of walleye pollock in the Bering Sea. Bering Sea FOCI has two major research objectives, both intended to provide information useful for management of Bering Sea pollock stocks: 1) determine stock structure and 2) gain an understanding of mechanisms and processes leading to recruitment. These objectives have been approached through a coordinated program of physics, biology, and modeling. Significant progress has been achieved (COP, 1993a).

Substantial efforts to assess pollock stocks and to provide logistical support by the NMFS and PMEL laboratories have significantly supplemented Bering Sea FOCI studies. Because the pollock resource is important both ecologically and economically, the NMFS Alaska Fisheries Science Center has invested substantial base

resources to assess the stocks of pollock for management purposes. The Bering Sea FOCI program interacts with the Pollock Research Program of the NMFS Alaska Fisheries Science Center, particularly on stock structure research.

Bering Sea FOCI has forged partnerships between NOAA and academic scientists to complement NOAA expertise in areas of physics, biology, and modeling. The research being carried out in the Bering Sea FOCI program is consistent with the NOAA Strategic Plan (NOAA, 1993) element "Build Sustainable U.S. Fisheries" because results could lead toward predictive capabilities for managing marine fishery resources.

Bering Sea FOCI draws heavily upon talent and experience from the Shelikof FOCI project. The emphasis on patches of pollock eggs and larvae, the role of eddies, and the directed transport of patches that have been the major research efforts in Shelikof FOCI have been carried over, in part, to Bering Sea FOCI. Initial observations with respect to both physics and biology have indicated that the environment and processes in the Bering Sea are more complex than in the Shelikof Strait, however, and that results of Shelikof FOCI may not be directly applicable to the ecology and behavior of pollock in the Bering Sea.

Results to date from Bering Sea FOCI indicate that a major spawning aggregation of pollock utilizes the southeastern Bering Sea, and investigations by Bering Sea FOCI are now focused on that area. There is evidence of a cross-slope flow toward the shelf in the southeastern Bering Sea that could advect larvae spawned offshore to this area. There also is evidence that eddies may form in the Aleutian Basin and slope waters, which potentially could entrain pollock larvae. Preliminary studies of zooplankton and larval nutritional condition suggest that prey are less abundant in the Bering Sea than in the Shelikof Strait and that pollock larvae may be more likely to starve in the Bering Sea. A food-chain model supports the observations that food may be limiting to pollock larvae in the Bering Sea.

Initial observations, analyses, and syntheses have demonstrated significant progress in understanding basinwide circulation processes and the probable importance of a link between physical oceanography and larval pollock biology. Studies of the dynamics of larval pollock populations and their food resources, which are crucial to Bering Sea FOCI, will be linked closely to the studies of Bering Sea physical oceanography proposed for 1994. Sophisticated molecular biological approaches suggest that several different genetic stocks of pollock may exist in the Bering Sea.

The program is making significant progress in four areas: (1) stock structure determination, (2) circulation and physics, (3) recruitment mechanisms, and (4) food chain relationships. For the site review, the Bering Sea FOCI program provided the

subgroup with presentations, documents, and notes regarding each project, in addition to an overall summary document (COP, 1993b). The site review report comments on each research area, in addition to making specific recommendations and observations about present and future Bering Sea FOCI activities.

STOCK STRUCTURE

The subgroup was provided with information on stock structure, including knowledge derived from stock assessment research by NMFS scientists on Bering Sea walleye pollock and recent results of Bering Sea FOCI-funded research on (1) genetic discrimination of stocks and (2) circulation patterns in the Bering Sea. Significant emphasis is being focused on the pollock resource apart from research in the Bering Sea FOCI program, through NMFS annual and triennial surveys. Within the framework of traditional fisheries assessment (based upon the assumption of a unit stock in the eastern Bering Sea shelf), stock structure is acknowledged to be an important source of uncertainty in assessments. Estimates of pollock recruitment show significant variability that is not easily explained by stock size and environmental variability. In species with multiple stocks, recruitment may vary among stocks and may respond differently to environmental variability. Consequently, if recruitment variability in Bering Sea pollock is to be understood, stock structure must be defined.

The site review presentations gave evidence of distinct spawning aggregations of pollock in the Bering Sea and also variability in the biological characteristics of pollock in different areas. Successful identification of stocks often requires diverse approaches to the problem. In the Bering Sea, suggested research on stock structure includes biological studies of stock separation, circulation and larval drift research, a large-scale tagging study, and assessment models that include between-area migration. Past research on stock structure of Bering Sea pollock included measurements of chemical and isotopic composition of otoliths and limited electrophoretic studies; neither conclusively demonstrated separate stocks. A stock assessment of eastern Bering Sea pollock, now underway at the University of Alaska (funded by NMFS), will incorporate information presently known about stock structure and inferred movement patterns.

Genetics studies by Bering Sea FOCI investigators have identified differences between western and eastern Bering Sea populations of pollock, but the relationship of genetic differences to spatial and temporal distribution patterns remains unclear. Studies funded by Bering Sea FOCI to develop genetic tools to assess stock structure apparently are of high quality. The program is to be commended for attracting a talented researcher to address the stock structure questions. **Although the preliminary results are encouraging, continued sampling should address both spatial and temporal**

variability; i.e., migratory patterns of pollock dictate that time (season) as well as geographic location need to be considered in designing a sampling strategy. Information from the assessment model being developed at the University of Alaska would be useful in this effort. The genetic studies of Bering Sea FOCI seem to be carried out in isolation from other program elements. **To remedy this problem, the program's molecular biologist should increase interactions with the NMFS stock assessment scientists as well as with other Bering Sea FOCI researchers to ensure that genetic stock structure research is integrated with more traditional physical and fisheries oceanography research to benefit the program fully.**

The immediate need from genetic studies is to identify separate spawning stocks, should they exist, to facilitate planning for long term recruitment and stock assessment research. This is particularly important now that the scope of the research has narrowed to concentrate on the eastern Bering Sea. While it remains a worthy goal, efforts to develop a “magic bullet” to identify the source stock of an individual larva or juvenile may be premature until the source stocks or populations are defined genetically. The apparent lack of integration of genetics with other techniques may stem from the geographic separation of the investigators involved. **Special effort should be made by the Bering Sea FOCI Executive Council to ensure inclusion of all program scientists in planning efforts so that research is coordinated to promote efficiency and to increase the relevance of results to overall program goals.**

CIRCULATION AND PHYSICS

The subgroup was impressed with results of the initial research and syntheses of existing data on the physical environment of the Bering Sea. The decision to shift the investigation from the larger-scale environment of the Aleutian Basin to more process-oriented studies in support of biology in the southeastern Bering Sea is timely. As Bering Sea FOCI progresses, field programs must include integrated physical oceanography and biology observations. **When integrated data sets are obtained, they should be made available to all participants as quickly as possible.** The initial efforts suggest that timely distribution of data will be accomplished and that truly biophysical descriptions of the Bering Sea ecosystem, and the role of pollock in it, will result.

The subgroup noted one important facet of Bering Sea physical oceanography and associated biology that is neglected in Bering Sea FOCI. Sea ice has not been considered, but it probably plays a major role in controlling the spring bloom and secondary production. The impact of sea ice on the Bering Sea shelf ecosystem and its interannual variability are potentially important factors affecting pollock recruitment, as well as broader aspects of shelf ecology.

Much of Bering Sea FOCI research revolves around the question of exchange between the deep basin and the shelf. Quantification of this flux is described as a program goal. With the available funding and vessel time, it is uncertain how well this goal can be met. Initial computations of cross-shelf exchange using drifters seem promising, but a complete characterization is still lacking. Bering Sea FOCI has developed and deployed the "Peggy" mooring that includes a sophisticated instrument array, but it is not placed in a location where it can address the issue of cross-shelf exchange adequately. There is a need to link Lagrangian determinations of circulation with the population biology of pollock larvae, which presumably is to be carried out in planned 1994 cruises. **If the physical oceanographers in Bering Sea FOCI do not believe that they can obtain good cross-shelf flux estimates, their efforts should be redirected toward more achievable goals in support of the recruitment variability objective.**

The dynamics of eddies (which proved to be of critical importance in Shelikof FOCI) also are addressed in various contexts in Bering Sea FOCI. The role of eddies in the transport of larvae across the shelf break and in biological enhancement will require carefully planned mesoscale measurements. A plan and sampling design are needed that will allow food chain processes to be studied in relation to the eddy field and which will allow the transport processes for key organisms to be elucidated.

RECRUITMENT MECHANISMS

The subgroup views larval pollock sampling as the cornerstone of future Bering Sea FOCI efforts. Previous and preliminary surveys have set the stage for intensive, synoptic sampling in the 1994 field season. We encourage the investigators to utilize early results of the larval sampling and models of larval dynamics to guide them in developing a rigorous and extensive sampling program. In addition, simultaneous measures of zooplankton abundance and conductivity-temperature-density (CTD) data must be obtained during the larval surveys to help focus and calibrate the food-chain modeling effort.

Given the complexity of the recruitment problem and the risks associated with choosing a single, synthetic approach, we encourage the investigators to focus their effort by recognizing three distinct sets of questions and scales, which are nested in a hierarchy of factors that regulate recruitment success. Bering Sea FOCI investigators should recognize that recruitment may be defined at each of three levels: the cohort, the year class, and the population. Those distinctions help define specific goals and can provide the basis for formation of small working groups with a common interest. **Three general goals should be:**

1. **Couple physical dynamics to larval survival.** This issue focuses on larval mortality by considering small-scale patch effects and the short time scales of early larval life history. Components would include research efforts on nutritional status, egg and larval transport, larval survival, and larval feeding ecology. A component that considers predation on eggs or larvae is also desirable. Results will yield information about the factors that govern the success of larval cohorts. Short-term, food-chain dynamics modeling is an appropriate general tool.
2. **Evaluate the success of juvenile cohorts. This effort should focus on the issue of mortality on intermediate time and space scales and incorporate research on cannibalism and the effect of non-pollock predators. Its goal should be to provide a basis to estimate survival of pollock to one year of age.** The results can be linked to population models based on results of assessment surveys and could provide the basis for forecasting strengths of year classes. Age-structured pollock population models would serve as the analytical tool. Those models might be modified to allow monthly or shorter time steps important to growth-rate dynamics and changing rates of predation. A working group session might quickly define what is needed to proceed.

   The proposed field studies near the Pribilof Islands in 1994 will provide an excellent opportunity to develop and test mechanistic hypotheses. **The design of this research should utilize results of laboratory studies of juvenile pollock behavior.** Structuring field studies around the questions of interactive effects of food, predators, and temperature will help maximize knowledge gained from the limited ship time available in 1994. Results also may prove to be important for marine mammal conservation because of the role pollock plays in the ecology of some marine mammals in the Bering Sea. This element of research also might become the cornerstone of future and more extensive work on the juvenile life stage.
3. **Develop understanding of pollock interactions in the context of community and ecosystem dynamics.** This effort would emphasize the role of large-scale, long-term effects such as those resulting from interannual variation in climate, fishery exploitation rates, and changes in the intensity of species interactions involving pollock as prey, competitors, and/or predators. Research would emphasize feedbacks that result from variable recruitment. It would develop hypotheses concerning the nature of compensatory changes in the structures of pollock populations and food webs. Models of food web dynamics will need to be developed.

Small working groups could develop the most appropriate (i.e., parsimonious) models in the coming months. Large and complex ecosystem models seem unwarranted at this stage of planning and research.

For each of these goals, the formation of small working groups is desirable. **They should meet or communicate frequently as they develop the conceptual framework, information sources, sampling protocols, and modeling tools required to evaluate key questions.** By focusing on the scales most pertinent to those goals, their results will promote more rapid and complete understanding. Syntheses of those results could help to prepare Bering Sea FOCI for the next larger level of effort.

FOOD CHAIN RELATIONSHIPS

Knowledge of food chain dynamics of larval fish plays an important role in developing a working hypothesis on recruitment variability, and in designing field and laboratory research. The subgroup saw little evidence of a collective working hypothesis on this topic, and is concerned about a lack of coordination among research projects in this area. To date, the zooplankton and larval feeding studies are based on only a few samples at a few stations, and the larval fish surveys were not coupled with the basic studies on physical circulation and hydrographic studies. Little attention has been devoted to phytoplankton production and its relationship to larval dynamics.

Bering Sea FOCI investigators believe that larval patches may be associated with mesoscale eddies. They suggested that larvae are in better environments when entrained in eddies, or when transported onto the southeast Bering Sea shelf. However, the role of eddies and/or transport onto the shelf is not well defined in the context of what nutritional benefits may be derived, including possible ice-edge effects. Bering Sea FOCI investigators are encouraged to develop a working hypothesis that is mechanistic, not merely correlative. It is not sufficient to suggest that larvae survive and grow better inside eddies or on the shelf. It is important to understand why this might be the case. Also, it is important to consider how high-density patches of larvae of small spatial extent contribute to recruitment compared with potential contributions from lower densities of larvae dispersed over the broad extent of the Bering Sea. The results of such calculations might guide development of sampling plans and allocation of sampling effort.

A new project will soon be initiated in Bering Sea FOCI to gain a greater understanding of the functional aspects of planktonic food production and its relationship to larval survival. A major component of this project will be a new mooring. But, a

single chlorophyll-measuring mooring may not be sufficient to test ideas about food chain dynamics in eddies, slope waters, or shelf waters. **If logistically possible, field studies should be expanded to include measures of nutrients and phytoplankton (cell counts and at a bare minimum, chlorophyll concentrations) in conjunction with the CTD grids and sample transects conducted on larval survey cruises.**

Survey grids should be designed to test ideas about larval survival and larval food production in eddies and on the shelf. Because survey cruises cannot always set out to sample an eddy (eddies are discovered only after the fact), investigators need to collect comprehensive information at each station during surveys. The surveys conducted to date have lacked coordination in obtaining data on variables of interest, but improvements were evident in planning for the 1994 season. It is important that samples be collected to test hypotheses about probable benefits to larvae in eddies or on the shelf versus larvae swept off the shelf into the slope and basin areas. The possibility of detecting and tracking eddies in real time from sea surface temperature and/or ocean color measurements from satellites should be explored.

Apparently, after survey samples are analyzed and interpreted, the food-chain model will be employed to draw conclusions. This leads to a number of issues that must be addressed and which must be considered by Bering Sea FOCI investigators. (1) What questions do the program scientists want the model to answer? (2) Will the model need to be reparameterized and refocused to answer those questions? (3) Will there be a need for additional measurements, for example profiles of photosynthetically active radiation and diffuse extinction coefficients? And, (4) are the investigators who are providing input data for the model expecting too much from it? **A working group should address these issues.**

FINDINGS AND RECOMMENDATIONS

The subgroup developed a number of specific recommendations:

1. **Lagrangian studies on cross-slope and cross-shelf transport must be coordinated with coincident biological studies on pollock larvae and plankton.** It appears that the developing 1994 sampling plan will incorporate this approach.
2. **Small working groups of Bering Sea FOCI investigators should be organized, and should meet frequently to develop hypotheses, plan research, evaluate progress, and assess the need to change directions in each of the research areas.** Working in groups will have a focusing effect and will improve collaborations, and leadership will emerge.

3. **Significant progress is being made in the food-chain modeling of pelagic ecosystem processes but care should be taken to ensure that data collection does not become an effort solely to satisfy needs of the model. The model itself should be expanded to estimate more than growth potential of pollock larvae. Survival rates of larvae are one obvious extension that should be pursued.**
4. The molecular biological approaches to determine stock structure show promise. **However, the research (to an extent) is being carried out in isolation. The investigators conducting genetics studies should interact with NMFS stock assessment scientists and Bering Sea FOCI investigators.** All would benefit from increased interactions and faster progress will be made toward answering stock-related questions of recruitment variability in pollock.
5. **It is critical to understand the flux of water from the deep basin to the shelf in the southeastern Bering Sea to determine how larvae might be transported from offshore to inshore areas where feeding conditions may be better.** If the planned efforts by program scientists are not sufficient to address this issue, new plans or redirected efforts may be required.
6. **There is a need for mechanistic studies of eddies and their dynamics, particularly of the mechanisms that can advect eddies in slope waters onto the shelf. These studies must be linked closely to biological studies of pollock larvae distributions.**
7. **Sea ice, polar water, spring blooms, and possible relationships to pollock recruitment should be considered in Bering Sea FOCI, because of their dominant effects on the Bering Sea shelf system.**
8. Research on pollock larvae abundances and distribution, their relationship to zooplankton prey resources, and to larval condition, survival rate, and dispersal are central issues with respect to recruitment mechanisms. **A major effort should be made in 1994 to address these issues.**
9. **Juvenile pollock research is encouraged, but it should be focused on the most important issues, which may be primarily effects of predation and cannibalism on dynamics in this stage.** The proposed research in 1994 is a preliminary effort to develop this element of Bering Sea FOCI.
10. The larval and juvenile pollock behavior research (which is not funded by Bering Sea FOCI) has produced results that may be highly relevant to ongoing

studies of the vertical distribution of pollock in the Bering Sea. **It is important to consider results of the behavior research in designing Bering Sea FOCI field studies. Collaboration between the behavioral scientist and Bering Sea FOCI investigators should be encouraged.**

11. **The subgroup does not believe that a goal (as presently stated) of Bering Sea FOCI should be to increase the yield of Bering Sea pollock. We think that a more appropriate goal is to increase understanding of production and recruitment processes, so as to insure continuing high yields.** This "risk aversive" goal will mesh nicely with goals of the NOAA strategic plan, which emphasize "sustainability."
12. **In the longer term, Bering Sea FOCI may wish to shift its emphasis toward ecosystem-level processes on the Bering Sea shelf. Pollock should remain a key component of Bering Sea FOCI, but the goals of the research could expand to address the problems of species interactions and their consequences in this coastal fishery ecosystem.**
13. **Successful leadership in a CFE program requires equal and communicative participation by the three partners, i.e., scientists from the NOAA Office of Oceanic and Atmospheric Research, the NOAA National Marine Fisheries Service, and academia.** Without equal participation, maximum contributions and coordination may not be achieved. At present, the Bering Sea FOCI Executive Council does not represent the three partners equally. Its composition could be improved by adding additional academic representation.
14. **The process of project solicitation, selection, and review could be improved in Bering Sea FOCI by making the solicitation more open and treating academic and NOAA partners equally with respect to proposal review.** The Technical Advisory Group of Bering Sea FOCI could be utilized to help develop a standardized and acceptable procedure.

SUMMARY

The subgroup recommends that COP continue to support Bering Sea FOCI for the remainder of its planned 5-year term. In addition, the subgroup summarizes below its findings regarding Bering Sea FOCI's goals and objectives, accomplishments, utility, responsiveness to past review, and future plans.

Goals and Objectives — The Bering Sea FOCI program has made significant progress toward its goals of understanding recruitment processes (oceanographic processes and stock contributions) of walleye pollock in the Bering Sea, now specifically in the southeast Bering Sea. The subgroup endorses the overall approach but recognized a need for greater coordination in planning and observations among biologists, physical oceanographers, and modelers. In the long term, as Bering Sea FOCI progresses to the end of its first 5 years and begins to plan subsequent studies, a more ecosystem-oriented approach, rather than a pollock-specific approach, may be warranted to investigate recruitment processes of Bering Sea fishes.

Accomplishments — NOAA-academic partnerships have been developed. Bering Sea FOCI has made progress in defining circulation, stock structure, and the probable importance of the southeast shelf as a spawning area and probable larval nursery. The program has gathered preliminary evidence that eddies may be important for pollock recruitment in the Bering Sea and that larval food may be limiting in this system. A food-chain model has been developed which, while helpful, needs to be expanded to account for larval pollock mortality in addition to growth. The "Peggy" mooring is useful to obtain physical data in the eastern Bering Sea, although limited because of its location in the deep off-slope water. The program is becoming more coordinated and in the 1994 field season will conduct its first integrated biological and physical measurements.

Utility — Bering Sea FOCI clearly has potential to contribute information important for management of pollock in the Bering Sea. The program promises to yield knowledge about mechanisms of recruitment variability and stock structure. Its research will contribute to the "sustainability" and "predictability" goals of the NOAA strategic plan. In addition to increased knowledge about pollock recruitment variability, better understanding of the Bering Sea ecosystem, with its valuable fish, marine mammal, and seabird resources will be an important product of the research.

Responsiveness to Past Reviews — Bering Sea FOCI has not been reviewed in the past. The program is to be commended for the recent appointment of an excellent Technical Advisory Group, who will advise Bering Sea FOCI and provide independent review on a regular basis.

Program Management — Bering Sea FOCI has formed a six-person Executive Council. To be effective, this council must represent the NOAA and academic partners and must provide strong leadership to coordinate the interdisciplinary research of Bering Sea FOCI. Procedures to solicit, select, and review proposals apparently have differed for NOAA and academic partners. **These procedures must be standardized and should be equally rigorous throughout the program. Working groups should be constituted in specific research areas to promote coordination and planning.**

Future — **Bering Sea FOCI should move gradually toward ecosystem science. Understanding pollock ecology should be an important, but not exclusive, goal of the research. Program plans should insure that physical and biological elements of the program are fully coordinated and synoptic. It is emphasized again that working groups should be formed, not only to plan and coordinate ongoing research, but to develop visions of how elements of Bering Sea FOCI should evolve in the future.**

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Appendix 2

SABRE Site Review Report

BACKGROUND

The South Atlantic Bight Recruitment Experiment (SABRE) was initiated in FY 1991. This site review report fulfills the requirement of the Coastal Fisheries Ecosystem (CFE) theme to conduct such reviews after 3 years of program support. The review was conducted at the Duke University Marine Laboratory, Beaufort, North Carolina, on January 27-28, 1994.

The concept of SABRE had been nurtured during the 1980s by NOAA and academic scientists. The advent of the Coastal Ocean Program (COP) provided support that launched SABRE in 1991 as one of two initial projects within CFE. The goal of SABRE is to understand the relationship between variation in environmental factors and the variable recruitment of "estuarine-dependent" fishes in the South Atlantic Bight (COP, 1993). The program addresses NOAA's need to build sustainable fisheries, a major element of the NOAA Strategic Plan (NOAA, 1993).

SABRE investigations center on Atlantic menhaden, *Brevoortia tyrannus,* an abundant and heavily exploited species that is representative of many coastal fishes that are estuarine-dependent in the juvenile stage. Past research has indicated that several factors, including storms, larval advection, and juvenile survival in estuaries all may have important effects on recruitment and year-class strength. The SABRE program addresses many of these factors and examines characteristics of survivors across life history stages.

SABRE's approach to investigate recruitment is to study survivors at "critical junctures" in their life history (SABRE, 1994). This approach is an alternative to "traditional" approaches based on estimating mortality rates of early life stages. Process-oriented studies are not emphasized in SABRE, although some are included. Traditional recruitment research, which relies on estimating mortality rates and processes correlated with it, is thought by SABRE to be too complex and too expensive. The approach taken by SABRE depends upon establishing birthdate distributions from otolith-aging analyses and comparing those distributions at several stages during the first year of life. Observed shifts in apparent birthdate distributions result from stage-selective mortalities and can be the basis to judge how changes in habitat or environment affected the generation of recruits.

A strength of SABRE is the successful partnership that has been developed between NOAA and academic scientists. The leadership of SABRE is strong and

complementary. In this sense, SABRE is an excellent example of how CFE research was envisioned.

SABRE is entering its third field season in 1994. Lower than expected budgets have limited offshore sampling, and menhaden eggs and larvae have proven to be elusive. Sampling older larvae at inlets has been far more predictable. A shift in emphasis is evolving in SABRE that focuses increasingly on the late postlarval stages at the inlets and juvenile stages within the estuaries.

The panel review team recognized that SABRE was making significant progress in several areas. The following are discussed specifically: (1) offshore processes (eggs and larvae); (2) inshore processes (late-stage larvae and juveniles); (3) physics and physical modeling; (4) biological modeling; and (5) new technologies.

OFFSHORE PROCESSES

Offshore sampling of limited spatial and temporal extent in 1992 and 1993 found few menhaden eggs and indicated that their distributions were extremely patchy in space and time. An optical particle counter (OPC) has been modified by SABRE scientists to sample menhaden eggs. This new sampler potentially is an important innovation for ichthyoplankton surveys. A large patch of menhaden eggs was discovered and sampled by the OPC during January 1994, demonstrating the promise of this instrument to discover patches and delineate their structure quickly and efficiently. The OPC technology would benefit if supplemented by effective net or acoustic sampling to define both the spatial extent and vertical distribution of eggs and young larvae. The panel subgroup believes that it is important for SABRE to know the temporal and spatial distribution of eggs to initialize the birthdate distribution and provide data to model the inshore drift of larvae. The subgroup concedes that this will require more extensive financial resources than are currently available, given the large expanse of potential spawning area.

The subgroup recognized that limited vessel time and scarce funds constrained the offshore sampling effort and that it would be difficult for SABRE to mount an effort greater than that now being undertaken without additional NOAA support. However, use of small nets to survey wide areas (e.g., CalVet nets; Lasker, 1985) may be one means to define and map large areas of menhaden egg occurrence quickly and efficiently. Historical samples of ichthyoplankton [e.g., from the Marine Resources Monitoring, Assessment, and Prediction activity (MARMAP)] may be a source of information on menhaden egg occurrences and distributions which should be explored.

SABRE has not emphasized process-oriented research. But, promising studies on larval nutritional condition (metabolic enzyme analyses and RNA/DNA ratios) indicate that larval condition varies. Understanding larval nutrition and how it affects growth or survival could be a valuable product of SABRE research. The plan to examine otoliths from larvae sampled for condition studies to determine their age and estimate growth rates will provide valuable correlative data. A single predation study by SABRE indicated that chaetognaths probably were not a significant predator of menhaden larvae.

The offshore egg and larval stages of menhaden extends over the first 50 to 90 days of life. A large fraction of the variability in survival and eventual contribution to variability of year classes could occur during the offshore phase. To meet SABRE's long-term goals it is important for the program to evaluate this source of variability and compare it to that generated during the estuarine juvenile phase.

INSHORE PROCESSES

The SABRE inshore program has several components that address the late larval and juvenile stages. Sampling at the inlets for larvae is a cost-effective means to sample and quantify numbers of larvae that enter the estuary. Physical modeling and moorings addressing near-inlet conditions must be closely tied to biological sampling at inlet mouths. These physical studies, if linked to the offshore physical modeling, could provide an effective tool to assess entry to estuaries.

The subgroup believes that inlet sampling should be linked to offshore larval sampling; two approaches to accomplish this could include (1) extensions of presently supported behavioral research on smaller planktonic larvae, to larger larvae which are competent to enter the estuary, and (2) studies of nutritional condition of larvae entering the estuary to relate to condition of larvae offshore. It is possible that changes in behavior of larger larvae may promote retention near shore and prevent offshore, but not alongshore, advection. Behavioral information is important to provide data to help direct physical modeling.

In inlet studies, the best temporal information is provided by NMFS surveys at Beaufort Inlet which have yielded time series data crucial to SABRE. The time series indicates that menhaden larval abundances vary on intra- and inter-annual time scales at Pamlico Sound inlets.

The relationship between patterns of ingress at Beaufort Inlet and subsequent age 0 + abundance derived from virtual population analysis (VPA) suggested that the offshore larval phase may be important (i.e., annual ingress to estuaries may be

related to subsequent catch or year-class strength). As a result, a project to sample larvae at several inlets was developed to quantify ingress to Pamlico Sound. This research component does not appear to be well justified and results may not be critical to SABRE, because the variance of age 0 + abundance estimates will be high and ingress of larvae to a single estuarine system may not be reflected in VPA results that depend upon contributions of age 0 + menhaden from many estuaries. Also, because only one data point per year can be obtained to correlate larval ingress and age 0 + abundance, it will take many years to detect any relationship that might exist.

Studies of otoliths from menhaden larvae and juveniles play a central role in SABRE; extracting information from the chronological record in otoliths is consistent with the SABRE philosophy of examining characteristics of survivors. SABRE research has demonstrated that otolith age estimates up to 200 days after hatching are reliable, which allows estimates of birthdate distributions of survivors to be established at different life stages. Future otolith research will require application of improved and new technology. The review team encourages SABRE scientists to examine emerging otolith technologies (including image analysis and elemental analysis) as possible ways to elucidate events in the early life history of survivors.

The subgroup was concerned that some SABRE investigators may be confusing birthdate distributions of survivors with temporal distribution of spawning. To date, SABRE has been unable to confirm the latter, but it remains an important goal. With continued sampling at spatially separated inlets, determining variations in the birthdate distributions at these inlets in conjunction with a verifiable model of transport toward inlets may provide an indirect approach to identify offshore spawning areas and times.

Studies by SABRE on dispersion of late-stage larval and juvenile menhaden within estuaries are only beginning. Although there was evidence of spatial variability in size and age distributions of estuarine juveniles, the subgroup noted that such results could be a sampling artifact. Improved and more extensive sampling to define the age structure of estuarine juveniles will be required.

Although research to date has concentrated on sampling menhaden at inlets and in the estuaries, other estuarine-dependent fishes are also collected, including several species of commercial importance. These collections are an important source of information for future research. Comparisons of temporal and distributional patterns of occurrence among species may be effective to establish mechanisms of transport and estuarine entry.

SABRE has justified its expansion of research on estuarine juveniles based on a life-stage model which suggests that significant variation in year class strength is contributed during the estuarine juvenile phase. The subgroup endorses the estuarine

emphasis by SABRE in years 4 and 5 but cautions that improved temporal sampling of eggs offshore will be needed if the program continues beyond its fifth year.

PHYSICS AND PHYSICS MODELING

Overall, the efforts by SABRE to quantify the physical mechanisms involved in the life history of menhaden are generally well planned. **However, the program shouldalso question the extent to which physical measurements and models are meeting needs of the program.** For example, what is the reliability of the finite element model? The remote sensing effort has provided useful background information, but must be focused better in both time and method of application if it is to serve SABRE's goals. Finally, the moored instrument effort seems poorly integrated with other elements in SABRE and it is unclear how mooring data will be used.

The reliability of models and the scope of future modeling efforts should be clarified. Can the finite element model reproduce currents observed in the many past mooring programs conducted in the South Atlantic Bight? Does the model produce Lagrangian statistics comparable to those that will be measured in the drifter program? Precision levels are crucial to decide if the model sufficiently addresses questions posed by the program. With de-emphasis of offshore egg and larval research, the model can be used to gain insight into how transport processes may operate. But, back-calculation of larval drift from the model is fundamentally flawed because calculations cannot track non-reversible processes associated with turbulent dispersion and larval mortality (which isn't included in the model). **The modeling, which is promising, should proceed to a verification phase and then to a set of simulations to address, from a conceptual basis, issues that cannot be addressed in the offshore sampling effort because of insufficient funding.** The subgroup does not believe that the model by itself is sufficient to replace offshore sampling.

The nearshore inlet model is both interesting and relevant, but to date has not been developed for the North Carolina inlets and it appears that this modeling effort will be discontinued. A significant point is that Onslow Bay inlets, which are the subject of SABRE investigations, differ from Chesapeake Bay or river-dominated inlets such as Cape Fear and others to the south. **If the goal is to understand physics of inlets, a coupled model including the sounds, inlets, and near-shore shelf in the sampling region should be developed. Such a model also must also be cognizant of and incorporate the known biology of menhaden early life stages to contribute fully to SABRE.**

The remote sensing analysis seems only loosely tied to other SABRE components. How will Coastal Zone Color Scanner (CZCS) data be used? Will a

comparative analysis of sea surface temperature (SST) and biological data be carried out? If so, analytical techniques to compare these data must be developed. Finally, it is not certain that velocity fields can be depicted accurately from the SST data. There are a few successes using this approach to quantify surface circulation, but most attempts have not been tested against sea-truth data.

The near-inlet moored instrument program potentially can provide significant contributions to SABRE. However, velocity vector diagrams for the near-inlet regime do not automatically contribute to a description of inlet larval flux. It was unclear how SABRE will use these data. Will they be used to verify the transport models and if so, are the mooring placements appropriate? **The program should carefully consider its requirements for physical data to address recruitment variations in the context of the SABRE science plan.**

BIOLOGICAL MODELING

The basic biological model employed to date is derived from a life table approach. It has the merits of allowing detailed resolution of mortality patterns for different life stages. It is constrained by certain assumptions —stable age distribution and equilibrium population dynamics—and may require more than five years to produce definitive results because of probable high levels of interannual variability.

This model has indicated that the most sensitive component of the life history is the juvenile stage. That conclusion has led several SABRE investigators to focus new effort on resolving the dynamics of juvenile survivorship by otolith analysis and increased field effort within the estuaries. While that may be wholly justified, caution is required because "sensitivity" evidence is derived in part from the model structure and, therefore, may mislead the research effort. Analysis of life table models often leads to the conclusion that the juvenile stage is where population regulation is most important because numbers are declining exponentially while reproductive value is increasing as its mirror image. Their intersection produces the dynamics perceived as maximum sensitivity at the intermediate (juvenile) life stage. High sensitivity in the juvenile stage may, in fact, be real for menhaden. Alternatively, the apparent sensitivity of juveniles could be a consequence of the model that was applied.

We recommend that the modeling approach be expanded. For example:

1. The menhaden catch record in the fishery offers opportunity to analyze interactions of variability among age groups. A time series analysis of the catch record could be used to generate input for the life stage model

which might represent the stochasticity of recruitment to earlier life stages and could be the basis for a model and analysis.

2. The planned development of the individual-based model (IBM) might allow SABRE investigators to move beyond the constraints of otolith data by using the IBM to generate variability in size (and age) distributions of recruits to the "peanut" fishery.[12] Hindcasting with that model could be the basis for inferring size-dependence of survivorship bottlenecks in the juvenile or larval stages. **Following the philosophy of the project, the models should be used to generate alternative hypotheses, then winnowed by comparisons with the data and/or expertise of investigators.**
3. Predators and predation rates probably will become an object of research as emphasis on the juvenile stage increases. Accordingly, a non-linear approach to modeling the density dependence of recruitment and/or predator functional responses would help represent possible rapid changes in predation effects. Similarly, intra-seasonal variability in predator-prey interactions might be the justification for a field assessment of the frequency of menhaden in predator diets. It might also be a basis for inferences about local and large-scale migration patterns. At the least, investigators need a means to explore the diversity of likely causes of size-specific mortality. Models can help in this task.

Our recommendation is not intended to dissuade SABRE from using the life table approach. It is a valuable tool. However, we are concerned that a single theoretical/analytical focus may lead to a biased and insufficient view of the problem. A broad modeling approach will offer the comfort of confirmation and the prospect of new insights.

NEW TECHNOLOGIES

SABRE has adopted, developed, or applied several new or advanced technologies, including remote sensing, finite element modeling, development of an optical egg counter, otolith applications, and biochemical condition indices. There has been excellent progress in developing some technologies. The rapid metabolic enzyme method to define larval menhaden condition is particularly promising as a means to create an index of the probability of starvation in the SABRE sampling area. It is not

[12]"Peanuts" are age 0 + menhaden newly recruited to the fall fishery.

clear, however, whether enough synoptic biological information will be collected in the offshore area to maximize its potential benefits.

The OPC, modified for use as a menhaden egg sampler, is now developed and operational for 1994 cruises, which is a significant step forward for SABRE. Its present mode of deployment restricts inferences because it only samples a single, near-surface depth. The instrument will be very useful to locate egg patches in SABRE and could serve similar purposes in other programs. Without concomitant net sampling to define the areal and depth-integrated abundances of eggs, the OPC may not achieve its full potential in SABRE. A multifrequency, towed, acoustic particle sensor also is being deployed, which, when used with the OPC, will provide a "smart-sampling" capability that could add unique dimensions to ichthyoplankton and zooplankton sampling. The present limitations of the offshore program in SABRE will limit the usefulness of these technologies.

Otolith aging studies are state of the art and are essential for SABRE to determine birthdate distributions of survivors. Proven methods are being followed in an attempt to extend use of daily increment technology to menhaden juveniles more than 200 days old. Attempts to undertake elemental analyses in otoliths as a means to interpret environmental conditions in early life histories were not successful, but there is potential to explore these emerging technologies further.

Satellite remote sensing, an advanced but not new technology, if used to test the finite element model, might be a useful tool to help interpret larval distributions and transport on the shelf. However, it is not clear that any additional satellite studies are planned in SABRE.

FINDINGS AND RECOMMENDATIONS

1. **The management team and overall management are strong in SABRE and should be maintained.** Addition of a physical oceanographer to the Program Management Committee may be desirable.
2. The added emphasis on estuarine studies of juvenile menhaden is endorsed by the subgroup. A caveat is required because little is known about the importance of offshore processes that affect eggs and larvae. There is little likelihood that the offshore component of SABRE can be expanded given present funding levels and level of logistical support. **A careful use of existing data sets and models to explore offshore dynamics is recommended as a cost-effective but partial alternative.**

3. Juvenile studies are important. The life-table model, although based upon incomplete information about life stages of menhaden, indicates that this stage is sensitive and worthy of critical examination.
4. The subgroup encourages the continued application of the finite element model and the eventual linkage of it to near-inlet transport models, which must be developed. **This modeling should be done in conjunction with behavior studies, particularly those that define the vertical distribution behavior of larval menhaden. Observed egg distributions should be used to generate advection pathways for larval menhaden to predict how larvae reach the inlets.** The model cannot be used to back-calculate egg distributions.
5. **Net collection methods that are rapid and effective should be included in the offshore program as a means to determine the depth-integrated distributions and abundances of menhaden eggs.** The CalVet net used in California Current studies of anchovy eggs may be a suitable gear.
6. **Historical samples of menhaden eggs and larvae, if they exist, should be obtained and examined.** The MARMAP samples that were processed in South Carolina are an example; others may exist. Such samples could help to define spawning areas and the seasonal dynamics of egg production.
7. As juvenile studies are expanded in scope, study of the predation process will become increasingly important. Carefully designed studies of predation on juveniles within the estuaries will be required.
8. Additional biological and biological-physical modeling is encouraged. Individual-based models linked to physical transport models are a promising approach. **Box models in which dynamics of offshore stages (eggs and larvae) and inshore stages (juveniles) are highlighted, should be considered.**
9. Synthesis documents on menhaden biology and shelf physics of the South Atlantic Bight will be useful. **The former should include a critical assessment of estuarine-dependence and the role of nearshore nurseries for menhaden. Such documents apparently were anticipated in SABRE's original plan. They should be produced.**
10. The procedures to request proposals, review them, and select projects for support have followed high standards in SABRE. Nevertheless, the procedures that were followed may not always promote the most innovative science. **Future calls for proposals should encourage a degree of innovation, in addition to filling critical gaps in the program.**

11. Inclusion of other estuarine-dependent species in SABRE, especially if research emphasis moves toward juvenile stages in estuaries, is desirable.

SUMMARY

The subgroup recommends that COP continue its support of SABRE for the remainder of its planned five-year term. In addition, the subgroup summarizes below its findings regarding SABRE's goals and objectives, accomplishments, utility, responsiveness to past review, and future plans.

Goals and Objectives — SABRE's goal is to understand the relationship between variation in environmental factors and the variable recruitment of estuarine-dependent fishes, specifically menhaden, in the South Atlantic Bight. Hypotheses are not explicit in SABRE, but the research embraces a philosophy that advocates an "alternative approach" to recruitment variability research. This approach, which the subgroup supports, relies on detailed investigations of characteristics and birthdate distributions of survivors at several life stages, which will reveal how stage-specific and size-specific processes operated to control the resulting recruitment. In this approach, hypotheses become emergent features of the research. Success will depend on determining birthdate distributions of menhaden at critical egg, larval, and juvenile life stages.

Accomplishments — SABRE has demonstrated progress in several areas. Ingress at inlets and patterns of its variability have been defined. Techniques for aging otoliths of menhaden up to 200 days old have been developed. The optical particle counter has been modified and developed to sample menhaden eggs. The application of metabolic enzyme analyses to determine the nutritional condition of menhaden larvae apparently is successful. The finite element model of circulation and probable transport in the South Atlantic Bight is functional and has potential to provide understanding of advective pathways for eggs and larvae. The formation of an effective partnership between NOAA and academic scientists and of a highly effective management team has contributed strongly to the effectiveness of the program.

Utility — The research carried out and planned should lead toward better understanding of how recruitment variability is generated in menhaden and will define critical life stages or habitats in the recruitment process. Menhaden ecology may be representative of the ecology of many estuarine-dependent species; thus, findings from SABRE may have wide application in understanding the effects of the environment on estuarine-dependent fishes. New sampling technologies developed for SABRE will be transferable to other fishery oceanography programs. The overall result of the research by SABRE will lead fisheries toward becoming a predictive science.

Responsiveness to Earlier Reviews — SABRE apparently uses and is responsive to its Technical Advisory Group. The present review is the program's first formal review; the CFE TAC has not reviewed the program since its initiation.

Planning and Management — Many feel that SABRE is the best of COP programs in the sense that an effective partnership has been formed, much of it before COP formally was established, by combined efforts of NOAA and academic scientists. The partnership and team continue to be strong. Research planning is ongoing and has evolved as logistical support proved to be insufficient for a large offshore effort. Some projects have been terminated in favor of new ones more related to the central goals and shifting emphasis of the program. An objective proposal process has been used to bring new projects into the program. Some criticisms of research project design may be warranted, but overall this is a strong effort in the area of planning and management.

Future — Program focus will shift toward the estuary, at least in the short term, and to juvenile menhaden, as a result of life-table model predictions and the practical reality of logistical and budgetary support. With this emphasis, studies of predation on juveniles must be emphasized. An offshore effort still is needed to develop the best procedure for use of the optical particle counter to characterize temporal and spatial distributions of spawning. **Plans should be developed to accomplish as much as possible, given logistical and budget constraints, to determine the temporal distribution of menhaden spawning. Coupled physical-biological models, including individual-based models, should be developed. Research planning that extends beyond the present five-year life of SABRE should be underway. Effective sampling of all early life stages, perhaps eventually including the three or four major estuarine-dependent species, should be emphasized in future research.** Life-table model predictions, which now guide research planning, should be evaluated and verified.

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Appendix 3

Acronyms and Definitions

ANICA	Atmospheric Nutrient Inputs to Coastal Areas
AOML	Atlantic Oceanographic and Meteorologic Laboratory
BPR	Bottom Pressure Recorder
C-CAP	Coastwatch Change Analysis Program
CEH	Coastal Ecosystem Health
CEHAB	Causes and Effects of Harmful Algal Blooms
CFAS	Coastal Forecast and Analysis System
CFE	Coastal Fisheries Ecosystems
CFS	Coastal Forecasting System
CoOP	Coastal Ocean Processes program (NSF)
COP	Coastal Ocean Policy Roundtable
COPR	Coastal Ocean Program
DMSP	Defense Meteorological Satellite Program
ECFSFE	East Coast Forecast System Feasibility Experiment
EDF	Environmental Defense Fund
EHP	Estuarine Habitat Program
E-MAP	Environmental Monitoring and Assessment Program (EPA)
ERL	Environmental Research Laboratory
ERS-1	Earth Resources Satellite-1
ESA	European Space Agency
FOCI	Fisheries Oceanography Coordinated Investigations
GIS	Geographical Information System
GLERL	Great Lakes Environmental Research Laboratory
GLFS	Great Lake Forecasting System
GLOBEC	Global Oceans Ecosystems Dynamics program
IER	Institute of Environmental Renewal
LAC	Local Area Coverage
MACII	Mississippi-Atchafalaya Coastal Interaction Initiative
MARMAP	Marine Resources Monitoring, Assessment, and Prediction
MCSST	Multi-Channel Sea Surface Temperatures
NANO	National Assessment of Harmful Algal Blooms
NCOPO	National Coastal Ocean Program Office
NECOP-MAR	Nutrient Enhanced Coastal Ocean Productivity-Mississippi Atchafalaya Rivers
NEP	Nutrient Enhanced Productivity
NESDIS	National Environmental Satellite, Data, and Information Service
NHC	National Hurricane Center
NMC	National Meteorological Center

NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NRC	National Research Council
NS&T	National Status and Trends
NWS	National Weather Service
OPC	Optical Particle Counter
OSU	Ohio State University
PI	Principal Investigator
PMC	Program Management Committee
PMEL	Pacific Marine Environmental Laboratory
PoCO	NRC Panel on the NOAA Coastal Ocean Program
SABRE	South Atlantic Bight Recruitment Experiment
SeaWiFS	Sea-viewing Wide Field Sensor
SEFCAR	Southeast Florida and Caribbean Recruitment Experiment
SLOSH	Sea, Lake and Overland Surges from Hurricanes
SSM/I	Sea Surface Microwave Imager
TAC	Technical Advisory Committee
TCC	Toxic Chemical Contaminants
VPA	Virtual Population Analysis

Appendix 4

Panel Biographies

Robert C. Beardsley chaired the panel. He is a senior scientist at the Woods Hole Oceanographic Institution (WHOI). Dr. Beardsley earned his Ph.D. in physical oceanography from the Massachusetts Institution of Technology in 1968. He presently serves as director of the WHOI Coastal Research Center. Dr. Beardsley's research interests are in the physical oceanography of continental shelves and shallow seas, and geophysical fluid dynamics.

Thomas Church is a professor at the University of Delaware, where he has been a faculty member since 1972. He earned his Ph.D. in chemistry from the University of California at San Diego in 1970. Dr. Church's research interests include atmospheric transfer of trace elements to the marine environment; trace metal transport and cycling in salt marshes, estuaries, and coastal waters; and reduction-oxidation processes of metals, sulfur compounds, and nutrients.

Michael H. Freilich chaired the Coastal Hazards subgroup of the panel. He is presently an associate professor at Oregon State University and serves as a Principal Investigator on the ERS-1 and EOS satellite scatterometer projects. Dr. Freilich earned his Ph.D. in Oceanography from the Scripps Institution of Oceanography in 1981. He is a member of the Ocean Studies Board. His research interests focus on the connections of marine winds to physical oceanography and use of satellites to measure marine winds.

Carl Friehe is a professor at the University of California at Irvine. He earned a Ph.D. in chemical engineering from Stanford University in 1968. Dr. Friehe has most recently been involved in the Tropical Oceans and Global Atmosphere program and the Air-Sea Interaction and Marine Boundary Layer Research program. His research interests are in the areas of air-sea interactions, turbulence, and aircraft instrumentation.

Anne Giblin chaired the Coastal Ecosystem Health subgroup of the panel. She has been an Associate Scientist at the Ecosystems Center of the Woods Hole Marine Biological Laboratory since 1990. Dr. Giblin earned her Ph.D. in Ecology from Boston University in 1982. She has served on the Governing Board of the Estuarine Research Federation and as president of the New England Estuarine Research Society. Dr. Giblin's research interests are in nutrient cycling in marine and lake sediments and overlying water columns.

enneth D. Haddad is a research administrator for the Florida Department of Natural Resources. He earned an M.S. from the University of South Florida in 1982.

Mr. Haddad has served on many advisory groups for the National Oceanic and Atmospheric Administration, the Environmental Protection Agency, the Department of Interior, and the state of Florida. His expertise is in the areas of remote sensing and management of environmental data.

Dale B. Haidvogel is a professor at Rutgers University. He earned a Ph.D. in physical oceanography from the Woods Hole Oceanographic Institution-Massachusetts Institute of Technology Joint Program in 1976. Dr. Haidvogel has been a member of the World Ocean Circulation Experiment Working Group on Numerical Modeling and the NSF Scientific Advisory Committee for Ocean Sciences. His research interests focuses on large-scale ocean dynamics, coastal ocean physics, and numerical algorithms for large-scale and regional ocean circulation models.

Edward D. Houde chaired the Coastal Fisheries Ecosystems subgroup of the panel. He has been a professor at the University of Maryland since 1980. Dr. Houde earned a Ph.D. in fishery science from Cornell University in 1968. He has served on many state, national, and international advisory committees. Dr. Houde's research interests focus on fisheries ecology and oceanography, particularly with regard to the larval stages of fishes; fisheries management; recruitment processes, and trophodynamics.

Michael N. Josselyn is a professor at San Francisco State University. He is also president of Wetlands Research Associates, Inc. Dr. Josselyn earned his Ph.D. in marine botany from the University of New Hampshire in 1978. He is a fellow of the Sigma Xi Research Society and the California Academy of Sciences. Dr. Josselyn's research interests include wetland resources, estuarine algal ecology, and tropical seagrass ecology.

James F. Kitchell has been on the faculty of the University of Wisconsin since 1974 and has been a professor there since 1982. He earned his Ph.D. in Biology from the University of Colorado in 1970. Dr. Kitchell has also been the Associate Director of the Center for Limnology at the University of Wisconsin since 1982. He serves as the coordinator of the Living Resources Program of the University of Wisconsin Sea Grant College Program. Dr. Kitchell's research interests are in the areas of carrying capacities for fish species, food web dynamics, and bioenergetics of fish populations.

Judith McDowell is a senior scientist at the Woods Hole Oceanographic Institution. She earned a Ph.D. in zoology from the University of New Hampshire in 1974. Dr. McDowell presently serves as the director of the Sea Grant program at the Woods Hole Oceanographic Institution. Her research interests are in the areas of physiological ecology of marine animals, developmental and energetic strategies of marine animals, physiological effects of pollutants on marine animals, and invertebrate nutrition.

John B. Mooney, Jr. is a private consultant. He earned a B.S. from the U.S. Naval Academy in 1953. After a distinguished career in the U.S. Navy, Admiral Mooney retired and served as director of the Harbor Branch Oceanographic Institution. He was elected to the National Academy of Engineering in 1988. Admiral Mooney's expertise is in the area of ocean engineering, particularly related to submersible vehicles.