Bridging Boundaries through Regional Marine Research

Committee on the Assessment of Regional Marine Research Programs, National Research Council

ISBN: 0-309-51569-6, 128 pages, 6 x 9, (2000)

Bridging Boundaries Through Regional Marine Research

Committee on the Assessment of Regional Marine Research Programs

Ocean Studies Board
Commission on Geosciences, Environment, and Resources
National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C.

NATIONAL ACADEMY PRESS • 2101 Constitution Avenue, NW • Washington, DC 20418

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competencies and with regard for appropriate balance.

This report and the committee were supported by a grant from the National Oceanic and Atmospheric Administration and the Sea Grant College of Maine. The views expressed herein are those of the authors and do not necessarily reflect the views of the sponsors.

International Standard Book Number 0-309-06832-0

Additional copies are available from the National Academy Press, 2101 Constitution Ave., NW, Lockbox 285, Washington, DC 20055: (800) 624-6242 or (202) 334-3313 (in the Washington metropolitan area); Internet <http://www.nap.edu>.

Printed in the United States of America

THE NATIONAL ACADEMIES

National Academy of Sciences
National Academy of Engineering
Institute of Medicine
National Research Council

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. William A. Wulf are chairman and vice chairman, respectively, of the National Research Council.

COMMITTEE ON THE ASSESSMENT OF REGIONAL MARINE RESEARCH PROGRAMS

THOMAS MALONE, *Chair,* University of Maryland Center for Environmental Sciences, Cambridge
BRIAN BAIRD, California Resources Agency, Sacramento
MARGARET MARY BRADY, Massachusetts Department of Environmental Protection, Boston
ROBERT DEAN, University of Florida, Gainesville
D. JAY GRIMES, The University of Southern Mississippi, Ocean Springs
SUSAN HENRICHS, University of Alaska, Fairbanks
JOHN KNAUSS, University of Rhode Island, Narragansett
JOHN BRADFORD MOONEY, JR., J. Brad Mooney Associates, Ltd., Arlington, Virginia
MICHAEL MULLIN, University of California, San Diego
ROBERT O'BOYLE, Bedford Institute of Oceanography, Nova Scotia, Canada
ROBERT PAINE, University of Washington, Seattle
LESLIE ROSENFELD, Naval Postgraduate School, Monterey, California

Staff

SUSAN ROBERTS, Study Director
SHARI MAGUIRE, Research Assistant

OCEAN STUDIES BOARD

KENNETH BRINK, *Chair,* Woods Hole Oceanographic Institution, Massachusetts
ALICE ALLDREDGE, University of California, Santa Barbara
DAVID BRADLEY, Pennsylvania State University, State College
DAN BROMLEY, University of Wisconsin, Madison
OTIS BROWN, University of Miami, Florida
JAMES COLEMAN, Louisiana State University, Baton Rouge
CORT COOPER, Chevron Petroleum Technology, San Ramon, California
CARL FRIEHE, University of California, Irvine
RAY HILBORN, University of Washington, Seattle
EDWARD HOUDE, University of Maryland, Solomons
JOHN KNAUSS, University of California, San Diego
ROBERT KNOX, University of California, San Diego
RAY KRONE, University of California, Davis
CINDY LEE, State University of New York, Stony Brook
ROGER LUKAS, University of Hawaii, Manoa
NANCY MARCUS, Florida State University, Tallahassee
NEIL OPDYKE, University of Florida, Gainesville
MICHAEL ORBACH, Duke University Marine Laboratory, Beaufort, North Carolina
WALTER SCHMIDT, Florida Geological Survey, Tallahassee
GEORGE SOMERO, Stanford University, Pacific Grove, California
KARL TUREKIAN, Yale University, New Haven, Connecticut

Staff

MORGAN GOPNIK, Director
EDWARD R. URBAN, JR., Senior Program Officer
DAN WALKER, Senior Program Officer
ALEXANDRA ISERN, Program Officer
SUSAN ROBERTS, Program Officer
ROBIN MORRIS, Financial Associate
LORA TAYLOR, Office Manager
SHARI MAGUIRE, Research Assistant
ANN CARLISLE, Senior Project Assistant
JODI BACHIM, Project Assistant
MEGAN KELLY, Project Assistant

COMMISSION ON GEOSCIENCES, ENVIRONMENT, AND RESOURCES

GEORGE M. HORNBERGER, *Chair,* University of Virginia, Charlottesville
RICHARD A. CONWAY, Union Carbide Corporation (Retired), S. Charleston, West Virginia
THOMAS E. GRAEDEL, Yale University, New Haven, Connecticut
THOMAS J. GRAFF, Environmental Defense Fund, Oakland, California
EUGENIA KALNAY, University of Oklahoma, Norman
DEBRA KNOPMAN, Progressive Policy Institute, Washington, DC
KAI N. LEE, Williams College, Williamstown, Massachusetts
JOHN B. MOONEY, JR., J. Brad Mooney Associates, Ltd., Arlington, Virginia
HUGH C. MORRIS, El Dorado Gold Corporation, Vancouver, British Columbia
H. RONALD PULLIAM, University of Georgia, Athens
MILTON RUSSELL, Joint Institute for Energy and Environment and University of Tennessee (Emeritus), Knoxville
THOMAS C. SCHELLING, University of Maryland, College Park
ANDREW R. SOLOW, Woods Hole Oceanographic Institution, Massachusetts
VICTORIA J. TSCHINKEL, Landers and Parsons, Tallahassee, Florida
E-AN ZEN, University of Maryland, College Park
MARY LOU ZOBACK, U.S. Geological Survey, Menlo Park, California

Staff

ROBERT M. HAMILTON, Executive Director
GREGORY H. SYMMES, Associate Executive Director
JEANETTE SPOON, Administrative and Financial Officer
DAVID FEARY, Scientific Reports Officer
SANDI FITZPATRICK, Administrative Associate
MARQUITA SMITH, Administrative Assistant/Technology Analyst

Acknowledgments

The Committee for the Assessment of Regional Marine Research Programs is very grateful to the many individuals who played a significant role in the completion of this study. The committee met three times, and extends its gratitude to the following individuals who appeared before the full committee or otherwise provided background information and discussed pertinent issues: Donald Anderson, Ronald Baird, Wendell Brown, George Crozier, Michael Dagg, Gregory Ducote, Paul Howard, Terry Howey, Lewis Incze, David Johnson, Matt Liebman, Alexis Lugo-Fernandez, Gene Meier, Judy Pederson, Donald Scavia, Peter Shelley, David Townsend, Robert Wall, Gordon Wallace, and Dolores Wesson.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review of this report: Robert Bailey (Oregon Department of Land Conservation and Development), Donald F. Boesch (University of Maryland System), B.J. Copeland (North Carolina State University), Robert Dalrymple (University of Delaware), Barbara Hickey (University of Washington), Richard Jahnke (Skidaway Institution of Oceanography), and Andrew R. Solow (Woods Hole

Oceanographic Institution). While the individuals listed above provided constructive comments and suggestions, it must be emphasized that responsibility for the final content of this report rests entirely with the authoring committee and the institution.

The committee gratefully acknowledges the efforts of the Ocean Studies Board (OSB) staff who helped produce this report, particularly the study director, Susan Roberts, and the research assistant, Shari Maguire. For their advice and efforts in bringing this activity to fruition the committee wishes to thank Morgan Gopnik, OSB Director and Ed Urban, OSB Senior Program Officer.

The committee is also grateful for the assistance provided by the following individuals who provided additional background material, data, publication lists, and figures for consideration and use by the committee: William Balch, Eugenia Braasch, Leon Cammen, Philip Gschwend, Lewis Incze, Maureen Keller, Joseph Kelley, Dennis Leigh, S. Bradley Moran, Vijay Panchang, Neal Pettigrew, Cynthia Pilskaln, Nancy Rabalais, Sandra Shumway, Robert Talbot, and Huijie Xue.

For her assistance in data gathering, preparation, and consultation the committee extends its thanks to Constance Carter (Library of Congress).

Contents

Executive Summary

> These conditions involve biological, oceanographic, political, commercial, diplomatic, technological, marketing, academic, economic, and personal relations factors, many of which I do not understand. I've come to the conclusion that nobody else understands all these factors and the interrelations either. Therefore, at every opportunity I seek to thrust together people who have specialized knowledge of one or more of these factors, to the end that they, jointly can produce decisions and conclusions bearing on this objective that are more sound and practical than those produced by any one individual.
>
> —Wilbert McLeod Chapman, 1949[1]

Coastal regions provide the country with valuable natural resources, recreational areas, and prime property for commercial, industrial, and residential development. Over half of the nation's population lives in coastal counties comprising less than one-fifth of the total land area; and growth in these communities is projected to continue at a rapid pace. Nearly 14,000 new housing units are built in coastal counties every week (NOAA, 1998). Coastal counties account for at least 30% of the gross national product for the United States (Culliton et al., 1990), with the cumulative impact from commercial fisheries alone accounting for over $50 billion (U.S. Department of Commerce, 1992). Population pressures have led to the drainage of wetlands and loss of habitat, increased the levels and transport

[1]Wilbert McLeod Chapman, California's top fishery officer in 1949, in reference to the initiation of the California Cooperative Oceanic Fisheries Investigations, a regional fisheries research initiative (Scheiber, 1990).

of nutrients and toxic chemicals into the marine environment, increased shoreline erosion, facilitated the introduction of destructive non-native species, and depleted natural resources. Policymakers are challenged with the competing demands for economic development, mitigation of natural hazards, protection of public health and safety, environmental protection, habitat restoration, and the sustainable use of fisheries and other living resources. The declining health of marine and estuarine ecosystems and the subsequent loss of their economic benefits due to human alterations of the coastal environment has made meeting these challenges more urgent. The protection and restoration of these ecosystems will require research to support ecosystem-based management and sustained monitoring of environmental indices to evaluate the impacts of human activities and understand natural variability.

One obstacle to satisfying this need for research and monitoring is that the boundaries of ecosystems do not conform to political divisions at the local, state, or national level. In contrast, regional features of ecosystems, such as coastal ocean currents, estuarine habitats, and drainage basins, do affect management decisions at a local level. Hence, what at first appears to be a local problem frequently cannot be resolved without the benefit of a regional perspective. For example, the mitigation of the effects of oxygen depletion in bottom waters on the Louisiana shelf may require the development of a nutrient management strategy for the entire Mississippi River watershed. Resolution of these types of problems requires regional approaches to provide coordination across jurisdictional boundaries to address the larger scale scientific concerns of interest to government agencies, academia, public interests, and industry.

Recognition of the regional nature of marine and coastal ecosystem processes has increased the focus on the need for regionally organized research programs. The mismatches between the functional size and complexity of marine ecosystems and the fragmented authority for coastal research and resource management among state and federal agencies have resulted in largely uncoordinated, sector-by-sector management (e.g., fisheries vs. coastal zone management), multiple levels of governance, and geographically and topically constrained research. An additional impediment has been the tradition in scientific research that rewards narrowly focused and discipline-driven research, an approach that is incompatible with the scale and interdisciplinary nature of coastal environmental issues. Because most coastal states have jurisdiction over ocean areas smaller than the regional scales of the environmental issues they must address, regional marine research programs are needed to bridge the gap between state and federal activities and to support the development of ecosystem-based approaches to managing coastal resources.

Historically, most regional-scale programs have been instituted in response to specific environmental or resource issues. For example, the California Cooperative Fisheries Investigation (CalCOFI) program was initiated in 1949 in response to the collapse of the sardine fishery. As appreciation of the interdisciplinary and multidimensional character of environmental issues has increased, there have been attempts to address regional needs more directly. One of these, the Regional Marine Research Program (RMRP), was established by Congress in 1990 to provide a mechanism to fund coastal marine research based on regionally-defined priorities. The RMRP legislation established a system of nine regional marine research boards around the United States. Each board was responsible for planning marine research to address issues of water quality and ecosystem health on a regional scale. Although all nine regions received funding for planning activities and development of a research plan, only the Gulf of Maine RMRP received funding for program implementation. The completion of the Gulf of Maine program, in 1997, presents an opportunity to evaluate whether the process for planning and managing the Gulf of Maine research was adequate, whether the research fulfilled the goals of the program, and whether this experience should serve as a model for similar regional programs elsewhere.

The sponsors of this report included the National Sea Grant Program, the Gulf of Maine RMRP, and the Coastal Ocean Program (COP) of the National Oceanic and Atmospheric Administration (NOAA). Ronald Baird, director of the NOAA National Sea Grant College Program, requested that the Ocean Studies Board of the National Research Council undertake a study of the RMRP, with a specific review of the Gulf of Maine program. At the request of the COP, the scope of the study was increased to include other models for regional marine research, including regional programs developed by the COP. The committee assembled by the National Research Council was specifically tasked to:

1. assess the need for regional marine research,
2. review processes by which regional marine research needs can be defined, and
3. discuss existing programs for regional marine research in the United States.

The study committee was asked to identify short- and long-term approaches that might be taken by NOAA (alone or in cooperation with other agencies) to conduct regional marine research. The Gulf of Maine RMRP and one or more similar programs at NOAA, EPA, and NSF were identified as case studies in the examination of the three issues described above.

EVALUATION OF REGIONAL MARINE RESEARCH PROGRAMS

The committee examined several models for regional marine research and evaluated their performance to identify effective components of past or existing programs that should be integrated into future regional programs. The scope of this study was insufficient to examine all regional marine programs; but at the request of the sponsors, the committee used two NOAA programs as case studies:

- the Gulf of Maine RMRP (GOM-RMRP), established in 1990 and terminated in 1997, and
- the Nutrient Enhanced Coastal Ocean Productivity (NECOP) program in the Northern Gulf of Mexico Program, established in 1989 and terminated in 1996.

The GOM-RMRP and NECOP programs provide contrasts in the identification, planning, and funding of regional research. The GOM-RMRP is an example of a nationally mandated, regionally organized, and regionally implemented research program run through the state Sea Grant offices, whereas NECOP is an example of a regionally implemented program organized at the national level through the COP of NOAA.

Gulf of Maine Regional Marine Research Program

The RMRP legislation emphasized the involvement of scientists and resource managers in setting research priorities and in coordinating regional monitoring and research. In the Gulf of Maine, researchers and managers formed associations that expedited the efforts of the regional marine research (RMR) board in developing the research plan. Research priorities were identified through a series of workshops held under the auspices of the Regional Association for Research on the Gulf of Maine (RARGOM), a regional association of researchers, and the Gulf of Maine Council, a regional association of coastal zone managers.

The Gulf of Maine research plan was funded directly through federal legislation and implemented through the Sea Grant College Program. The plan identified contaminant transport and causes of noxious algal blooms as the top research priorities. Although significant progress was made toward developing circulation models for the Gulf of Maine and understanding the processes that result in algal blooms, the lack of funding for the last half of the 10-year program decreased the scope of the research and limited the opportunities for synthesis and analysis. **The history of the GOM-RMRP highlights the need for a long-term commitment to regional marine research planning and implementation by federal and state agencies.**

Nutrient Enhanced Coastal Ocean Productivity Program

The COP of NOAA conducted NECOP as an initiative under the theme of Coastal Ecosystem Health. The goal of NECOP was to "improve the environmental quality of coastal waters by predicting the harmful effects of nutrient over-enrichment" (NOAA, 1991). The program was originally envisioned to examine nutrient-enhanced productivity in several coastal regions, but funding was only available for the first site selected, the northern Gulf of Mexico (NRC, 1994a). NECOP played a major role in bringing the problem of bottom water hypoxia on the Mississippi shelf to the attention of resource managers and the public. However, the program suffered from several initial design problems. These included the failure to address regional processes adequately, such as the effects of winds and coastal currents on the river plume, and the poor coordination of the program with the Louisiana-Texas Shelf Physical Oceanography Program (LaTex), a study of circulation in the northern Gulf of Mexico that was sponsored by the U.S. Minerals Management Service (MMS; NRC, 1994b). **These problems illustrate the need for regional cooperation and coordination in planning research activities and demonstrate the value of thorough scientific planning and review.**

The committee discussed several other programs with a regional focus that provided useful comparisons with the two case studies described above. One of these, the Long Term Management Strategy (LTMS) for San Francisco Bay, was organized to address the problem of dredged material disposal. The program created a new administrative structure to ensure the involvement of numerous government agencies and interested parties. Because no such structure existed prior to the initiation of this effort, substantial time and financial investments were needed to develop a consensus plan that resolved conflicts over this commercially vital, but environmentally threatening activity. **The history of the LTMS demonstrates the value of having regional associations in place to facilitate resolution of controversial and complex environmental problems.**

In Chesapeake Bay, the Land Margin Ecosystem Research (LMER) program demonstrated the benefits of sustained environmental monitoring. Before the LMER was initiated, a monitoring program had been established by the multiagency, multi-state Chesapeake Bay Program (CBP). The LMER program, sponsored by the National Science Foundation (NSF), had goals similar to NECOP, in that it addressed the role of ecosystems in modulating the fluxes of materials between terrestrial and oceanic systems. However, the LMER benefited from the monitoring program of the CBP. **This monitoring program provided the larger-scale observational framework needed to discern the influence of human activities from interannual environmental variability.**

KEY ELEMENTS OF REGIONAL MARINE RESEARCH

This report describes the key elements of an effective program for regional marine research based on the committee's review of several regional programs. These elements form the foundation for designing a coherent and comprehensive strategy of research and monitoring that addresses environmental issues at the local, state, and regional levels, with oversight and coordination at the national level.

Addressing Societal Needs

Regional marine research requires integrated programs of research and sustained observations to provide results that are responsive to the needs of both scientists and managers. Regional research should improve predictive capability through generalizations obtained by comparative analysis of coastal ecosystems. It should also enable timely assessment and mitigation of local problems that reflect change or variability occurring over long periods of time and large geographic areas. These goals may be accomplished through:

1. *Community Involvement.* Scientists, resource managers, policymakers, and other stakeholders should be engaged in setting research priorities, planning, implementation, program evaluation, dissemination of research results, and public education. Effective means for ensuring the exchange of information among scientists, managers, and the public should be established.

2. *Data Collection and Management.* Procedures need to be established for quality assurance, timely dissemination, and archiving of data. Observing systems should be linked to hypothesis-driven research to improve monitoring and to develop a predictive understanding of environmental phenomena. Potential products might include: circulation models to help predict the dispersion of pollutants or the transport of fish larvae; ecosystem models to help assess the impacts of nutrient run-off and predict episodes of anoxia; and establishment of environmental baselines to allow early detection of a disturbance, such as a toxic algal bloom or the collapse of a fish or marine mammal population. Information gathered from these studies should be communicated through workshops with researchers, managers, policymakers, and other interested members of the community, websites containing accessible databases, and peer-reviewed journal publications.

3. *Effective Use of Expertise.* It is important to ensure that policymakers and managers are informed of the current state of knowledge, the limits of the research, and the risks and uncertainties of management actions. Regional programs should enhance resource managers' capacity to assess ecosystem health using scientifically-sound research and monitoring strategies. Sustained research and monitoring will provide the context and organizational structure for a rapid and coordinated response to unanticipated events and will support adaptive management strategies through assessment of the effectiveness of environmental policies and development of alternative approaches.

Developing Programs for Regional Research

Regional marine research initiatives are most successful when they combine bottom-up and top-down approaches to program development and implementation.[2] Bottom-up identification of research needs ensures relevance and gathers the support of the user communities, while top-down coordination ensures the sharing of information and technologies among different regions and facilitates the establishment of common standards for data collection and management. Three elements for enabling regional marine research were identified:

1. *Develop public and political awareness of the need for regional scale programs.* Regional programs fill a niche between state and federal programs and their success depends on the long-term commitment and cooperation of agencies at both levels of government. Consequently, proponents of regional marine research need to articulate the benefits of regional approaches and develop sustained public and political support. Regional research typically requires substantial effort to coordinate programs and funds to support long-term projects across large areas. Therefore, advocates should explain the need for a regional approach to understand and manage challenges such as fisheries declines, habitat degradation, shoreline erosion, and water pollution.

2. *Coordinate efforts between government agencies at the local, state, and federal level.* Regional research addresses the intersecting needs of state and federal agencies, but there is no governance structure that facilitates bottom-up planning and top-down coordination of research at this scale. NOAA and the other federal agencies that support research in coastal and marine areas currently do not have the programmatic commitment to perform this role. Hence, a mechanism is needed for coordination of research between the various state and federal agencies to ensure that their various scientific priorities and management missions are melded into a cooperative, integrated program. To be effective, the administration of this effort will require leadership to ensure the quality of the research and the productive coordination of regional and national programs.

3. *Develop a strategy for assuring support that is predictable and commensurate with the scale of the program.* Funding must be sustained and predictable for the potential benefits of a regional-scale research program to be realized. However, responsibility for research and monitoring in coastal ecosystems is divided among multiple agencies and levels of government making it difficult to support integrated regional-scale programs. The committee identified three alternative mechanisms to help overcome this barrier:

- Dedicated funding coordinated through a lead agency responsible for leadership, budgeting, and allocation of funds. Oversight would be provided by

[2] "Bottom up" refers to the broad spectrum of users in the target region and "top-down" refers to the program offices in the relevant federal agencies.

an interagency committee and, possibly, a federal advisory committee to provide advice from non-federal user groups. The RMRP, where NOAA was the lead federal agency, provides one possible model for this approach.

- Multiagency funding committed through an interagency Memorandum of Agreement (MOA) and coordinated by an interagency committee. In this model, funds would be allocated by the individual agency based on programmatic relevance.
- Establishment of a pool of funds provided by participating agencies to be distributed by an interagency program. The interagency office would operate through a host agency under guidelines and procedures for allocation of funds determined by a steering committee.

Implementation of these last two funding options requires an interagency program. A partnership of federal government agencies has recently been established, the National Ocean Partnership Program (NOPP), which provides one potential model for this type of interagency program. NOPP is a new program whose role is to integrate national efforts and coordinate national investments in ocean research and education. Although it has potential, NOPP is too recent an initiative to know whether the multiple agencies will succeed in coordinating their efforts and developing sufficient resources to address the organizational needs of regional marine research programs.

Implementation of any of the funding mechanisms described above will require coordination through one agency at the national level. The federal agency with the broadest mandate for marine environmental research is NOAA; hence NOAA should provide the leadership necessary to develop regional marine research efforts of the type recommended in this report. Although many NOAA programs currently have a coastal component, no one office is an obvious choice for implementing a plan for regional research. Therefore, the committee recommends that senior management at NOAA designate an office to assume this responsibility. Leadership through one office is needed to meet the challenges in planning and implementing regional programs and to provide direction, coordination, and oversight of regional marine research.

Finally, programs for regional marine research should ensure that research support is allocated based upon peer review by impartial and unconflicted experts; and that the process is open to public scrutiny. Also, research should be supported through federal-state partnerships, requiring matching funds from states within the region of concern. Regional marine research programs must be designed to serve the multiple needs of science education, basic research, and the application of scientific information to the solution of environmental management challenges in our coastal ecosystems.

1

Introduction

> Region, n. A part of the earth's surface (land or sea) of considerable and usually indefinite extent.
>
> —Random House Dictionary of the English Language (unabridged)

> . . . A region is the next larger-scale system with influence on our own local field of study.
>
> —Scott W. Nixon, 1996

The combined effects of global climate change and human alterations of the environment are expected to be especially pronounced in the coastal zone where human population density is increasing most rapidly. Detecting, assessing, predicting, and mitigating these effects require interdisciplinary and multidimensional approaches to environmental research and management. This type of research and management is also needed for understanding and dealing with natural processes that affect coastal communities, such as storm surges; beach migration; and fluctuations in the salinity and oxygenation of estuarine waters. However, programs that have been established to enable environmental research and apply new scientific knowledge are too often uncoordinated at all levels of government, sometimes even within agencies (Carnegie Commission on Science, Technology, and Government, 1992). Consequently, the potential for unnecessary duplication exists; programs are too limited in scope; gaps and a lack of synthesis between studies occur; and funding levels are insufficient to achieve the goals of the respective programs (NRC, 1990a; Malone and Nemazie, 1996). The mismatch between the problems in coastal ecosystems and the government bureaucracies concerned with environmental research and stewardship of natural resources is exacerbated by the overlapping missions of local, state, and federal agencies and the complexity of this transition region where the land meets the sea (Carnegie Commission on Science, Technology, and Government, 1992). These realities confound the already difficult tasks of defining priorities for environmental research and stewardship, and developing public and political support for these priorities.

Regionally-organized programs of research and management, which are not compromised by artificial political or disciplinary boundaries, show promise in helping to address this problem. Recently, there have been a number of attempts to establish such programs as a means of meeting societal needs more effectively. The National Sea Grant and the Coastal Ocean Program (COP) offices in the National Oceanic and Atmospheric Association (NOAA) asked the Ocean Studies Board (OSB) of the National Research Council (NRC) to assemble a committee to review regional marine research programs in general, and two programs in particular: (1) the Gulf of Maine Regional Marine Research Program (GOM-RMRP), established in 1990 and terminated in 1997, and (2) the Nutrient Enhanced Coastal Ocean Productivity (NECOP) program in the Northern Gulf of Mexico, established in 1989 and terminated in 1996. The committee was charged to assess the need for regional marine research, review processes by which regional marine research needs can be defined, and discuss existing programs for regional marine research in the United States. The GOM-RMRP and other similar programs at NOAA (specifically NECOP), EPA, and NSF were identified as case studies for the examination of these issues. The committee was also asked to identify short- and long-term approaches that might be taken by NOAA (alone or in cooperation with other agencies) to conduct regional marine research.

In addition to the two case studies, GOM-RMRP and NECOP, many other marine research programs with a regional scope have been launched in recent years. This study was initiated to focus on these two NOAA programs, but other regional programs that have addressed similar issues relating to water quality and ecosystem health are briefly examined to provide a broader context. The committee's review includes less detailed examinations of: (1) National Estuary Program (NEP), (2) the Coastal Ocean Processes program (CoOP), (3) the National Sea Grant Program, (4) the Pacific Northwest Coastal Ecosystems Regional Study (PNCERS), (5) the Land-Margin Ecosystem Research (LMER) Program, (6) Long-Term Management Strategy (LTMS) for San Francisco Bay, and (7) the Global Ocean Ecosystem Dynamics (GLOBEC) program.

The committee, a multidisciplinary mix of environmental scientists and managers, with expertise in oceanography, biology, engineering, and resource and coastal zone management (Appendix A) prepared this report over a period of six months. During this time, the committee made two site visits to meet with researchers and managers involved in regional programs. The first meeting was held in New Orleans to examine NECOP and other Gulf of Mexico programs, and the second was held in Boston to consider the GOM-RMRP and related activities (Appendix B).

The report is organized to address the issues outlined in the charge to the committee described above. This introductory chapter concludes with a description of the coastal environment and related issues of environmental stewardship that are intended to provide a perspective for a regional approach to coastal marine research. Chapter 2 explores the rationale for regional marine research programs by defining the environmental problems and identifying the value of a regional approach to these problems. Chapter 3 describes the various processes used to define regional needs and to set priorities for regional-scale research programs. Chapter 4 reviews existing and past regional marine research, including detailed case studies of NECOP and the GOM-RMRP. Barriers and constraints on regional research programs are presented in Chapter 5. Finally, Chapter 6 contains the committee's conclusions and recommendations for approaches that may be taken to address regional marine research needs.

THE NATURE OF ENVIRONMENTAL PROBLEMS IN COASTAL ECOSYSTEMS

The coastal marine environment is a mosaic of complex interacting ecosystems that include rocky intertidal shores, tidal wetlands, estuaries, bays and sounds, and the open waters of the continental shelf. In addition to their heterogeneity, coastal ecosystems differ from terrestrial and oceanic systems in at least four important respects (Chelton et al., 1982; Steele, 1985; Powell, 1989; NRC, 1994b; Cloern, 1996):

- They are typically constrained by irregular coastlines and a shallow, highly variable bathymetry. Proximity to land and the interaction between benthic and pelagic communities promotes cycling of nutrients and enhances the capacity of coastal ecosystems to support living resources.
- They are subject to convergent inputs of materials and energy from terrestrial, atmospheric, oceanic, and anthropogenic sources that vary over a broad range of time-space scales. In addition to the combined inputs of natural processes (e.g., solar radiation, tides, winds, atmospheric deposition, freshwater flows from land, and ocean currents), a wide range of human activities also impact the coastal ecosystem.
- Populations of organisms and processes in coastal ecosystems are more variable on smaller space- and shorter-time scales than is typical of either the open ocean or terrestrial ecosystems.
- Coastal areas support a disproportionate fraction of the human population. It is projected that by the year 2025, 75% of the world's population will live within 120 miles of the coast (Hinrichsen, 1998). This population density reflects

TABLE 1-1 Prominent Natural Perturbations and Anthropogenic Stresses and Associated Indicators of Change in Coastal Aquatic Ecosystems

Perturbation or Stress

- Storms and other extreme weather: variations in wind and precipitation, freshwater runoff and groundwater discharge, waves and storm surge.
- Climate change: long-term trends in temperature, sea level, and regional weather patterns.
- Physical restructuring of the environment: e.g., land-use, alteration of freshwater flow patterns, dredging, port construction.
- Nutrient mobilization and nutrient enrichment of coastal waters.
- Chemical contamination of soil, air, and water.
- Exploitation of living resources.
- Introductions of non-indigenous (exotic) species.

Indicators of Change

- Accumulations of algal biomass and harmful algal blooms.
- Oxygen depletion.
- Fish kills, mass mortalities of birds and mammals.
- Temperature increase and sea level rise.
- Saltwater intrusion into rivers and groundwater.
- Flooding and coastal erosion.
- Increased susceptibility to natural hazards, loss of property and human life, and higher insurance rates.
- Habitat loss: e.g., losses of wetlands, sea grass beds, coral reefs.
- Diseases and accumulations of chemical contaminants in marine organisms.
- Growth of non-indigenous species.
- Loss of biodiversity.
- Decline and loss of living resources.
- Socioeconomic instability and public health hazards.

the rich natural resources, transportation hubs, jobs, and desirable living conditions found in these areas.

Although many of the changes that are occurring in coastal ecosystems (Table 1-1) appear to be directly or indirectly related to human activities, the rates and magnitudes of such changes reflect the combined effects of natural perturbations and anthropogenic stresses (NRC, 1994b). In its review of the status and future of oceanography, the NRC concluded that two high priorities for the ocean sciences are studying the roles of the ocean in climate change and the dynamics of coastal ecosystems (NRC, 1992). More recently, the NRC identified improving the health and productivity of coastal oceans, sustaining ocean ecosystems for future generations, and predicting climate variations over a human lifetime as the three broad areas of research that “present great opportunities for advances in the ocean sciences and will lead to concrete improvements for human life on this planet” (NRC, 1998). In summary, both of these reports emphasize that:

> The challenges of sustaining living marine resources, protecting and restoring ecosystem health, mitigating natural disasters, and safeguarding public health require substantial advances in our basic understanding of how such perturbations are expressed within and propagated among coastal ecosystems.

Substantial advances cannot be achieved in the absence of a regional perspective. The effects of natural perturbations and anthropogenic activities occurring in local ecosystems must be considered in the context of larger-scale changes in ocean circulation, climate, and land-use practices to develop a predictive understanding of the causes and consequences of environmental variability and change.

The perturbations, stresses, and indicators of change listed in Table 1-1 are occurring on local to regional scales in coastal waters worldwide. They are globally ubiquitous, indicating profound changes in the capacity of coastal ecosystems to support living resources. They reduce the value of the coastal zone to the national economy by reducing fishery yields, increasing living expenses, and escalating susceptibility to natural hazards. In the absence of scientific understanding of coastal ecosystems and how they are affected by both anthropogenic and natural forcings, it will become more difficult to solve or avoid environmental problems.

Without the ability to distinguish natural variation from human impacts, the formulation and implementation of environmental policies becomes increasingly controversial. Hence, the nation's highest research priorities must include documentation and prediction of the effects of natural processes and human activities on coastal ecosystems.

RESOURCE AND ENVIRONMENTAL MANAGEMENT IN THE COASTAL ZONE

As human populations and activities increase in the coastal zone, the combined effects of global climate change and human alterations of the environment are expected to be especially pronounced in coastal areas, in part as a consequence of the convergent effects of inputs from land, sea, air, and people discussed above. It is here that the problems of sustaining living resources, protecting and restoring ecosystem health, mitigating natural disasters, and protecting public health will become most pronounced over the next several decades.

In the 1970s, the enactment of federal environmental laws (e.g., Clean Water Act and its amendments; the Marine Protection, Research, and Sanctuaries Act; Fishery Conservation and Management Act; Coastal Zone Management Act; the Endangered Species Act; and the Marine Mammal Protection Act) launched a more national approach to the protection and restoration of living marine resources and habitats. These legislative mandates typically employed a command-and-control approach, with oversight and enforcement by federal agencies and implementation by state agencies. Reduction in point-source pollution, creation of marine resource inventories, recognition of estuaries of national significance, and development of coastal management plans represent some of the milestones of these programs.

Despite the efforts and progress by federal, state, and local government agencies, the degradation of coastal waters and resources continues. There are indications that the incidences of harmful algal blooms, zones of hypoxia, contaminated shellfish, and population declines of fish species may be increasing (Table 1-1), with significant consequences to public health, regional economies, and the capacity of coastal ecosystems to support living resources and many human activities. Polluted runoff, municipal and industrial pollution, contaminated sediments, and habitat fragmentation and degradation continue to pose management challenges. Today, resource managers struggle to identify and acquire the scientific information needed to improve the decisionmaking process in order to protect and restore affected marine ecosystems. Currently, coastal and ocean programs at all levels of government vary in their capacity to acquire, synthesize, use, disseminate, and maintain technical and scientific information.

Resource management programs are now shifting from a command-and-control approach to a community-based decisionmaking model that requires greater public understanding of ecosystems and their processes (Kazancigil, 1998). In 1998, the federal government launched the Clean Water Action Plan (CWAP; DOA et al., 1999) intended to comprehensively protect and restore valuable water resources and aquatic habitats into the 21st century. The CWAP is based on the watershed approach and is intended to respond to specific resource management problems within individual watersheds (DOA et al., 1999). For managers to make decisions based on this approach, a greater understanding of coastal ecosystems will be required. An integrated, regionally relevant marine research program may be one vehicle for providing the necessary framework of creditable scientific and technical support for management. The regional approach not only provides a more effective means to observe, analyze, and predict environmental change in local ecosystems, but also provides an opportunity for community involvement, which is needed to build the support and capacity for a sustained, successful program.

2

Regional Marine Research, Why Do It?

The United States contains thousands of regions, from area codes to climate zones, that have been defined for various purposes by many groups. For the purposes of this report, region is defined as the next larger scale of organization in time and space required to understand the local scale of interest (Powell, 1989; Lee, 1993; Nixon, 1996). It must be emphasized that regional research is not simply large-scale research, and that the argument for doing regional research does not imply that smaller systems are so well understood that it is time to move on to larger systems. As concisely expressed by Nixon (1996):

> The concept of 'region' implies an awareness of, and an interest in, functional linkages among systems . . . once we have quantified the influence of larger scale processes and events, we will be in a better position to make useful predictions about the future state of our local ecosystem of primary concern.

Assessing and understanding the effects of natural perturbations and anthropogenic stresses on coastal ecosystems requires a regional perspective that links larger-scale changes in ocean circulation, climate, and land-use practices to local changes in coastal marine ecosystems. Although some programs are regional, as defined by the size of the area that is under investigation, a special feature of many regional programs is the ability to fill the gap between local and global scale studies. In this context, a major purpose of regional marine research is to determine how events are propagated from one scale to another and then to predict the consequences of these events.

LINKING LOCAL AND GLOBAL SCALES

Multidisciplinary research on ecosystem processes (e.g., biogeochemical fluxes, nutrient cycling, and trophic dynamics) is typically limited in duration and spatial coverage. Although satellites have provided observations of oceanic variables (e.g., sea surface temperature, surface waves and currents, and ocean color) at a global scale, the properties that can be measured are typically limited to the ocean surface and the resolution is generally not sufficient for local studies in near-shore regions. Rarely do we ask the question: what are the largest and smallest scales that must be observed to capture most of the variance of the properties of interest (Powell, 1989)? Regional marine research and monitoring provide the means to bridge the gap between local process studies and global-scale observations.

Large spatial scales tend to be associated with long time scales and greater ecological complexity, and small scales tend to be associated with short time scales and less ecological complexity (Malone and Botsford, 1998). Even when events or processes must be studied at one spatial scale, their effects propagate to influence outcomes of societal importance on smaller and larger scales. For example, the process by which a larval fish finds its first meal occurs within a volume encompassing cubic millimeters to centimeters, requiring the analysis of small-scale distributions of larvae and potential food. Yet, such studies of the interactions of small-scale physical and biological processes and their effects on the feeding success of larval fish are important in understanding and predicting the success or failure of a year-class of fish, the large-scale result of utmost importance to society. Conversely, El Niño is a basin to global-scale event. Although monthly water temperatures measured at a single Pacific coastal station may yield a good temporal record of local trends, understanding the El Niño phenomenon requires large-scale observations of water temperatures and ocean-atmospheric interactions in the tropical Pacific Ocean. Small-scale, process-oriented experiments and observations need to be embedded in, and integrated with, large-scale monitoring. The value of many studies has been limited by the lack of integration between small- and large-scale processes.

Although prediction is fundamental to understanding interactions and exchanges within and among coastal ecosystems, little progress has been made in predicting change and variability across scales of time, space, or ecological complexity (Nixon, 1996). Linking local events to global-scale environmental changes will provide a powerful tool for resource managers, policymakers, and the public in preparing for future management challenges. Examples include the prediction and mitigation of natural hazards, and the contribution of longer time-scale climate variability such as the ocean-atmospheric event, El Niño-Southern Oscillation (ENSO). The scientific and management communities have long recognized the dominant forcings of coastal ecosystems and the general nature of coastal ecosystem dynamics that define indicators of change (Table 1-1).

However, a major barrier to the goals of predicting environmental changes and assessing consequences of these changes is the scarcity of observations of coastal ecosystems of sufficient duration, spatial extent, and resolution. Knowledge, both theoretical and empirical, concerning the propagation of variability across scales, through and between coastal ecosystems, is also lacking. Realistically, there are too many coastal ecosystems, too few resources, and too little time to evaluate the causes and consequences of environmental change in each system. Hence, prediction will be an important tool for extrapolating results, for testing hypotheses, and for developing theories that can be applied to a broad range of systems with sufficient certainty to be credible. Regional marine research and the comparative analysis of selected ecosystems in a regional context will be critical to the development of a predictive understanding of environmental variability in the coastal zone.

RESEARCH IN THE CONTEXT OF SUSTAINED OBSERVATIONS

Hypothesis-driven, or question-oriented, studies designed to reveal the mechanisms underlying environmental processes are especially valuable when done in the context of sustained, long-term observations. Monitoring provides the information needed to develop, test, and refine environmental models and therefore is an integral component of regional research programs. Comparative studies are important in the development of useful empirical theories, but unless they explicitly include the influences of larger-scale processes and events on the ecosystems being compared, such comparisons will be of limited value.

It has become increasingly clear that interannual and interdecadal variability in coastal ecosystems, associated with ocean basin or global atmosphere-land-ocean interactions, is part of the natural, variable baseline for short-term field studies and predictive models. Whether this variability is viewed as consisting of events, cycles, regime shifts, or a long-term trend, it must be taken into account, particularly if the effects of natural perturbations and anthropogenic stress are to be resolved (for the purpose of mitigation, litigation, or costly remediation and restoration). Similarly, the results of a regional program of finite length may be used to make managerial decisions, policies, or regulations of greater lifetime. The assurance with which this should be done depends not only on the quality and completeness of the research in the program itself, but also on understanding of the larger-scale climatic state within which the program was conducted.

The importance of research in the context of sustained observations (i.e., long-term monitoring) is illustrated by three examples, one concerning the regional effects of large-scale meteorological events on Chesapeake Bay and two concerning fisheries management on the west coast. The Chesapeake Bay case illustrates the impacts of unpredictable events. The fisheries examples illustrate the importance of the interplay between observations and the development of theory. All three are cases of ongoing studies in which coupled biological-physical models play an increasingly important role in supplementing incomplete observations.

Case 1—A major event occurred in June 1972 that had a delayed, but dramatic impact on nutrient research and management throughout the Chesapeake Bay region (Malone et al., 1993). Tropical Storm Agnes dropped more than 5 inches of rain over the entire watershed in 2 days; 30% of the region received over 12 inches of rain. The major rivers discharging in Chesapeake Bay crested with record highs and extensive flooding. The resulting input of nutrients from diffuse sources into the watershed caused multi-year increases in phytoplankton productivity, a massive decline in submerged attached vegetation (e.g., *Zostera marina*), and mass mortalities of oysters and soft shelled clams (Boynton et al., 1982; Orth and Moore, 1983). The storm highlighted the system-wide susceptibility of the Bay to nutrient enrichment from land-based sources (e.g., fertilizers and animal wastes) and demonstrated that short-term, high-energy events can have long-term consequences. These changes provided the motivation for the establishment of the Chesapeake Bay Program (CBP), a sustained and integrated program of monitoring and modeling, designed to answer questions concerning the effects of human activities on water quality and living resources and to assess the efficacy of management decisions intended to protect the environment and sustain living resources.

Case 2—The coastal Pacific sardine fishery, in the late 1940s the world's second largest fishery in tonnage, collapsed in 1948-1950. Controversy between state and federal fisheries agencies as to the role of overfishing in the collapse was resolved in part, by establishing the California Cooperative Oceanic Fisheries Investigations (CalCOFI), a monitoring program with a regional, ecosystem (rather than singlespecies or local) perspective (Scheiber, 1990, 1995; NRC, 1990a). Prior to the collapse of the fishery, tagging studies had shown that the range of the sardines extended from British Columbia to Baja California. This made it clear that a regional initiative was needed because "the sardine respects neither state lines nor national boundaries" (CalCOFI, 1950). In 1948, the California Cooperative Sardine Research Program was established to study the biological, physical, and chemical oceanographic processes that affected the sardine populations in the waters off California (NRC, 1990b). In 1953, the program was renamed the California Cooperative Oceanic Fisheries Investigation and expanded to include other pelagic marine fishes.

A particularly important discovery for the CalCOFI investigations were anoxic sediments containing fish scales that could be counted to determine the prefishing levels of both the sardine and its putative competitor, the northern anchovy (Soutar and Isaacs, 1974; Baumgartner et al., 1992). This showed that fishing probably exacerbated a natural decline and spatial contraction of the sardine stock and that the decline was not simply a case of over-fishing an otherwise stable population (see Wolf, 1992, and Smith, 1995, concerning the sardine's recent recovery). In this instance, although variation in the populations' sizes and coastal ranges are well established, causal connections with physical forcing are still uncertain (Box 2-1).

Case 3—In the salmon case, the shift in the success of populations at different degrees of latitude has been related, through correlation, to the North Pacific or Aleutian Low oscillation (a "regime shift," reflecting ocean-atmosphere warming and cooling) which was observed during the 1970s (Francis and Hare, 1994). Several plausible theories as to mechanistic causes have been advanced (Polovina et al., 1995; Brodeur et al., 1996; Gargett, 1997); and there is an indication that the salmon's first year of life in the ocean is a critical one. However, time-series measurements of ecological parameters, other than those that can be derived from the salmon themselves, are sparse. Several programs (e.g., West Coast Global Ocean Ecosystems Dynamics [GLOBEC], Pacific Northwest Coastal Ecosystem Study [PNCERS]) have been established in an attempt to address this deficiency.

STATE AND FEDERAL COLLABORATION IN RESPONSE TO ENVIRONMENTAL CRISES AND EVENTS

The examples above illustrate the importance of research in the context of sustained observations. The emphasis of this section is on the challenge of responding quickly to an event or crisis, both to mitigate impacts and to improve predictive understanding. Examples of relevant observing systems include the tsunami warning system, the Tropical Atmosphere-Ocean (TAO) array for detection and prediction of El Niño events, and the current effort to design and implement the U.S. coastal component of the ocean observing system. Prediction of the 1997 El Niño gave the CalCOFI program an opportunity to proactively document the ecological impact of a climatic event; this case illustrates the value of a working partnership between state and federal agencies (Box 2-1). Important and underdeveloped tools include assimilation techniques and numerical models for timely analysis and predictions of extreme events and their consequences. Current programs to address this need are being funded by the National Ocean Partnership Program, with the goal of integrating local and regional measurement systems and numerical models through data assimilation schemes. The hope is to develop generic datamodel systems that will be useful for a broad range of applications.

Responses to environmental crises are typically based on past experiences with phenomena such El Niño, tsunamis, oil spills, and harmful algal blooms. Such events cover a range of magnitudes and frequencies. Other events are surprises and often cause dramatic system-wide changes. A clear example is provided by the introduction of an Asian clam, *Potamocorbula amurensis*, to San Francisco Bay (probably via ballast water). The clams' subsequent establishment and growth has radically altered phytoplankton biomass and the abundance of

Box 2-1
California Cooperative Oceanic Fisheries Investigations (CalCOFI) in 1998

Two major environmental changes, which led toward different designs of sampling, provide a case history illustrating the importance of pre-emergency cooperation between agencies. CalCOFI is a collaboration among the Scripps Institution of Oceanography of the University of California, San Diego; the Southwest Fisheries Science Center of the U.S. National Marine Fisheries Service (NMFS), the National Oceanic and Atmospheric Administration (NOAA); and the California Department of Fish and Game, and has emphasized careful, long-term (nearly 50 years) monitoring for the purpose of documenting environmental change. A committee with representation from the three agencies meets routinely to establish policies.

Although the program had originally sampled monthly, from northern California to mid-Baja California, in 1984 the sampling program was changed to quarterly cruises, each with 67 stations spaced from San Diego to Port San Luis (San Luis Obispo), and 700 km seaward. In 1997, NOAA scientists predicted a major California El Niño, which led to a plan, supported primarily by University of California researchers, to:

a) Continue sampling far offshore so that the position and flow of the California Current, and the extent of oligotrophic regions west of the Current, would be monitored; and
b) Obtain additional resources to intensify temporal coverage so that the waxing and waning of the El Niño could be described.

The fisheries agencies were more interested in the increase in the population of the California sardine, whose decline 50 years earlier had led to the establishment of CalCOFI. The increase was accompanied by the expansion of the spawning area north of the area sampled by CalCOFI. Hence, to obtain both fundamental understanding (in relation to environmental processes) and data on spawning biomass (from sampled eggs and larvae), these agencies urged expansion of the survey north and along the coast, even at the cost of abandoning the farthest offshore sampling.

Within a few months, the University of California and NOAA each agreed to provide the resources (about $300K each, from a base of $750K) to accomplish the goals of all three agencies. Without the pre-existing collaboration in the management of CalCOFI, it is doubtful that this could have been accomplished in time. However, such resolutions can be short lived. The mutually supportive responses of the agencies to ecological changes in 1998 frayed badly in 1999, due to budgetary problems within NMFS. This imperiled the documentation of the return to “normalcy” after El Niño, which was even predicted to overshoot to “anti-El Niño”, or La Niña, conditions by NOAA physical scientists.

native zooplankton populations (Cloern, 1996). Such introductions of non-indigenous species can lead directly to the loss of living marine resources (including commercial species of fish) and result in a decrease in species diversity. Invasive species require a rapid response to study and mitigate the problem, underscoring the importance of flexible and adaptive programs for research and monitoring.

PROBLEMS TRANSCEND GEOPOLITICAL BOUNDARIES, AGENCIES, AND DISCIPLINES

A comparative study of the scientific basis of policy and management decisions in four coastal seas (Baltic Sea, Chesapeake Bay, North Sea, Seto Inland Sea) resulted in two important conclusions relevant to this analysis (Morris and Bell, 1988). First, research activity independent of mission (operational) agencies and the availability of objective scientific advice from the scientists who conduct this research enhance the quality of management decisions. This occurs despite the reality that economic, political, and social forces often overwhelm the technical links between scientific information and management decisions. Second, sound and effective environmental and resource management depends on recognizing and understanding "the system as a whole" in a regional context. When the decisionmaking process does not consider the largest scale required to capture the variance of factors relevant to the local scale of interest (natural and anthropogenic), it is likely that the unsustainable use of resources will persist until the full scale of the problem is appreciated (Lee, 1993). For example, spatial scale mismatches occur when the consequences of change are far removed from the source of change (e.g., mass mortalities of sea lions along the southern California coast and El Niño, depletion of oxygen in bottom water of the northern Gulf of Mexico and fertilizer use in the watershed of the Mississippi River, declines in fish stocks in a coastal ecosystem and upstream diversions of freshwater). Likewise, temporal-scale mismatches occur when long-term ramifications are not considered (e.g., the unsustainability of wild fish stocks in the long term when fishing pressure is too high in the short term, the gradual loss of wetlands in river deltas due to dams, channel formation, levees, and other diversions of freshwater) (Boesch, 1996).

The Gulf of Maine Council on the Marine Environment, a governmental organization established in 1989, serves as a successful example of an approach to addressing problems transcending geopolitical boundaries. The five jurisdictions bordering the Gulf of Maine (Massachusetts, New Hampshire, Maine, New Brunswick, and Nova Scotia) organized themselves to serve the role of facilitator and convenor on key gulfwide issues affecting each of the jurisdictions. The council includes representatives of government jurisdictions, and the business sector. One valuable example of a measure implemented by the council was the creation of an action plan that is interwoven into each jurisdiction's annual work plans. As a result, there was a concerted effort to jointly support Gulfwatch, a gulfwide toxics monitoring program. The combined investments lead to greater long-term support, understanding, and awareness of the issue within the Gulf of Maine.

A second example is the CBP. The CBP began with the first Chesapeake Bay Agreement in 1983, in which the U.S. Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Administration (NOAA), the states of Maryland, Pennsylvania, Virginia, and the District of Columbia agreed to work together to protect and restore Chesapeake Bay and its resources. This led to the initiation of the National Estuary Program (NEP). A second Chesapeake Bay Agreement was signed in 1987, which expanded the scope of the 1983 Agreement with 29 commitments for action in six areas: living resources, water quality, population growth and development, public information, education, and public access and governance. Perhaps the most important aspect of the Agreement was the scientific consensus that provided the rationale and will to commit to a 40% reduction of controllable sources of nitrogen- and phosphorus-loading by the year 2000. This commitment was reaffirmed by the Chesapeake Bay Agreement's 1992 Amendments that identified specific indicators to be used to measure the effectiveness of the nutrient management strategy.

The success of the CBP lies, in part, with the interaction between monitoring and research and with its effectiveness in promoting continued public support (Malone et al., 1993). From the beginning, the CBP established linkages between decisionmakers, management agencies, the scientific community, and the public through a governance structure built around the Chesapeake Bay Executive Council and its three advisory committees: the Citizens Advisory Committee, the Science and Technology Committee, and the Implementation Committee. An important result was the development of a process for producing data products useful to scientists, managers, and policymakers through a three-tiered reporting strategy that was endorsed by the National Research Council (NRC, 1990a):

- Level I, semi-annual data reports for technical audiences summarize the status of data collection and tabulates data;
- Level II, bi-annual reports, also for technical audiences, provide some analysis that describes relationships among variables and places data into an ecological and regional perspective;
- Level III reports, produced periodically for politicians, management agencies, and the public, provide an overall assessment of the status of the Bay and of potential management actions that might follow from scientific findings.

Recently, this three-tiered reporting strategy has been replaced with "state of the bay" reports, through publications in the *Bay Journal*, and via the Internet site for the Chesapeake Information Management System (CBP, 1999). The governance structure of the CBP and the reporting strategies described above, resulted in the most comprehensive and sustained observing system in the nation. Hennessey (1994) reviewed the CBP and concluded that the evolution and refinement of its management objectives based on monitoring data, research results, and scientific information represent a model for the effective application of adaptive environmental management.

Coastal ecosystems generally encompass multiple jurisdictions and cultures. This adds to the complexity of managing the already complex coastal environment with its contrasting scales of variability and mix of terrestrial, freshwater, and oceanic inputs. Hence, the challenges of coastal zone management are exceptionally difficult and underscore the importance of implementing proactive, adaptive approaches to environmental and resource management. In many cases, comprehensive regional research programs that are based on an extensive communication network will be needed to effectively link political, social, cultural, commercial, and environmental interests.

DATA MANAGEMENT

Integrated data management is of central importance to the success of regional marine research. For the most part, data management has been handled by each program individually to meet needs specific to that program. However, data management should also enable constructive and timely interactions for monitoring, research, modeling, and user groups. This goal requires more integrated approaches that are designed to meet the needs of both user groups and data providers and ensure that the legacy of regional marine research programs—the data—is available for future generations of scientists and managers.

Coastal data and information systems are needed that use and enhance existing national and regional data center capabilities. Initial efforts should focus on regional approaches to data management and synthesis that can be networked to achieve national scale assessments, such as the development of accepted protocols, intercalibration procedures, quality control, timely data dissemination and analysis, and archives. Currently, the effort to develop a report card for environmental health, "Designing a Report on the State of the Nation's Ecosystems," includes provisions for assuring consistent, nationwide standards for data quality, distribution, and linkages to the data sources (H. John Heinz Center for Science, Economics, and the Environment, 1999). However, it is important that the data products address regional needs and are provided in a format that is both accessible and interpretable by the local, state, and regional management agencies. Data management must be flexible in order to accommodate disparate data types and scales of sampling, including emerging and new technologies; data must be in a format that is suitable for a broad audience, including multi-user capabilities and real-time data dissemination. The goal should be integrated data systems designed to allow users to exploit multiple datasets and to ensure the flow of data to national archives.

The National Oceanographic Data Center (NODC) has begun to work with external data centers and is active in planning for the regional development of the

U.S. Coastal Global Ocean Observing System (GOOS). This effort should be coordinated with other regional efforts such as LabNet, a regionally organized project of the National Association of Marine Laboratories (NAML). NAML is in the process of designing and testing LabNet as a means of networking laboratories for more timely access to data and information and cost-effective monitoring of coastal waters. The purpose of LabNet is to provide the infrastructure required to exchange and integrate data collected at different locations, on different time and space scales, and using different methodologies for a nearly seamless analysis and visualization of patterns.

3

Processes By Which Regional Marine Research Needs and Priorities Are Defined

It is instructive to consider how regional marine research needs have been identified and research priorities set when formulating the plans for new research programs. This review provides a framework for considering the strengths and weaknesses of the planning approaches used and identifies common elements in the planning of successful programs. Approaches to research planning can be categorized as follows:

1. *Community Plans*—A process with substantial, direct input from stakeholders, including broad participation from the regional scientific and management communities;
2. *Scientists' Plans*—A process that has broad national participation by the scientific community but little direct involvement of managers and other stakeholders outside the scientific community;
3. *Agency Plans*—Prioritization and planning by agencies with the advice of a select group of scientists and, sometimes, managers;
4. *Legislative Mandates*—Research mandated by legislation, which may bring into play any of the above.

Most research planning includes some combination of these categories, however, one of these planning approaches is usually characteristic of the process for defining goals and setting priorities.

COMMUNITY PLANS

This process typically incorporates inputs from some combination of resource managers, local and state regulatory agencies, government, non-government organizations (NGOs), individuals or collectives of stakeholders not represented by the NGOs, science funding agencies, and scientists. Such a process generally yields the broadest possible range of proposals, discussion, and information. In addition to the identified product of a research plan, the communication and mutual education that can occur among these groups can have many benefits. For example, scientists can learn the specific needs and concerns of the other groups, and groups outside the scientific community can learn the capabilities and limitations of environmental research. Even if many of these concerns cannot be addressed immediately by research, the discussions can help to establish longer-range goals. Stakeholders and managers can learn that certain types of research, while not offering immediate solutions to their problems, lay an essential foundation for addressing their concerns. A disadvantage is that it can be expensive, in both time and money, to obtain direct input from all concerned individuals and groups. Further, it is sometimes a daunting task to assemble a coherent research plan from the disparate views presented from many different perspectives. However, once a process for obtaining, assimilating, and using community input is established, most of these difficulties are greatly reduced. Two examples of programs planned with different types of broad community participation will be discussed: the Regional Marine Research Program (RMRP) and the National Estuary Program (NEP).

Despite the challenges of community-based planning, these two examples illustrate the value of this approach. The design and implementation of future regional marine research programs can benefit from the experiences, and perhaps specific organizations and procedures, employed by the RMRP and NEP.

Regional Marine Research Programs

The 1990 amendment to the Marine Protection, Research and Sanctuaries Act created the Regional Marine Research Program (Public Law 101-593) in the form of nine geographic areas with specified boundaries: Gulf of Maine, Mid-Atlantic, South Atlantic and Caribbean, Gulf of Mexico, Southwest, Pacific Northwest, Alaska, and the Insular Pacific (Figure 3-1). The legislative mandate was to:

1. set priorities for regional marine and coastal research in support of efforts to safeguard the water quality and ecosystem health of each region; and
2. carry out such research through grants and improved coordination.

The Act prescribed that a Regional Marine Research (RMR) Board, consisting of 11 members and chaired by a Sea Grant Program Director, be established for

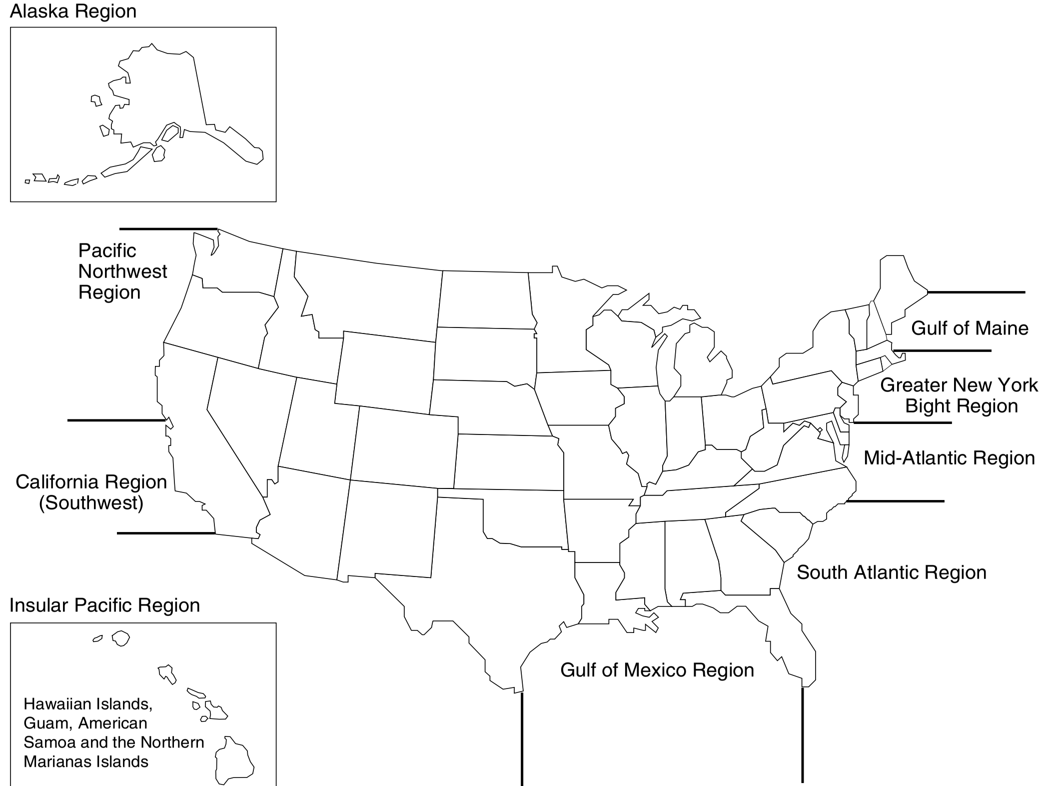

FIGURE 3-1 Regional Marine Research Program (RMRP) areas as defined under the authority of the South Carolina Fish Hatchery Act (P.L. 101-593; Figure from: "The Regional Marine Research Program [RMRP]: A new approach to marine research planning," in *Coastal Management*, 1993, Vol. 21 (4), p. 328. B.C. Bryant, Taylor & Francis, Inc., Philadelphia, PA. Reproduced with Permission. All rights reserved.). Note that this program is referred to throughout the text in capital letters. When reference is made to regional marine research in general, lower case letters are used.

each region to develop a 4-year research plan that included: (1) a summary of environmental status and trends, (2) an inventory and description of research related to water quality and ecosystem health, (3) a statement of research needs and priorities and their justification, (4) a plan for incorporating existing marine, coastal, and estuarine research and management activities into a coordinated regional program, and (5) a description of research objectives and timetables for their achievement through the funding of projects submitted as grant applications to the Administrator of the National Oceanic and Atmospheric Administration (NOAA). Although the authorizing legislation implied that funds would be available to implement the research plans in each region, only the Gulf of Maine plan was actually funded in the congressional appropriation.

Although all nine regions followed these general instructions, their planning processes differed significantly. The following examples are given to illustrate these differences.

1. The Gulf of Maine RMR Board enlisted the help of an existing regional scientific association (the Regional Association for Research on the Gulf of Maine [RARGOM]) to develop its research plan. The Association for Research on the Gulf of Maine (ARGO-Maine), the precursor to RARGOM, had worked with Senator George Mitchell's staff to draft the RMRP legislation, which was passed in 1990. After review and revision by the RMR Board, the plan drafted by RARGOM became the Gulf of Maine Research Plan (Robert Wall, in letter to committee dated August 16, 1999). Three earlier workshops and conferences were important in identifying the research needs of the Gulf of Maine (GOM-RMRP, 1992). The first, "The Gulf of Maine, Sustaining Our Common Heritage" (December 1991), was an international conference (United States and Canada) that concentrated on issues of interest to resource managers and environmental policymakers. The second activity was a scientific workshop on the Gulf of Maine at Woods Hole (January 1991) that summarized the status of research in the Gulf of Maine and identified priorities for future research. The third effort was the "Marine Research and Activity Plan" developed by the Maine Marine Research Board in 1991. This Gulf of Maine Research Plan was the only RMRP funded under the authorizing legislation and hence was the only research plan to be implemented. This program will be discussed in greater detail in Chapter 4.

2. In the Southwest region, the Sea Grant Deputy Director took a strong role in organizing the process. Three invitation-only workshops, including U.S. and Mexican participants from academic institutions, government agencies, and user groups, were focused on natural variability, cumulative impacts and thresholds in biological systems, habitat protection and management, and restoration of coastal marine habitats. Participants in these workshops drafted research needs and priorities that were submitted for outside review and synthesized into the final research plan.

3. The Insular Pacific Region had a very inclusive planning process. A team to develop the plan was formed by the University of Hawaii Sea Grant Program. The team and the RMR Board compiled a list of agencies and organizations interested in marine research in the region. Private consulting firms, public interest groups, and other private organizations were invited to participate. Input was collected through questionnaires and interviews. Research plans, annual reports, and other documents from these organizations and agencies were reviewed. A draft plan was then compiled by the development team and revised in response to the Board's review. Workshops were held in Hawaii, Guam, and American Samoa to allow marine scientists to review and comment on the draft plan. The final draft of the plan was sent out for review and comment to all the contributing organizations and agencies and to public interest and marine resource user groups.

The planning processes of the other regions fell somewhere within this spectrum, ranging from broad community participation to being largely the work of a small group of scientists and managers.

National Estuary Program

The NEP was established in 1987 by amendments to the Clean Water Act, with the mission to identify, restore, and protect nationally significant estuaries of the United States. Unlike traditional regulatory approaches to environmental protection, the NEP targets a broad range of issues and engages local communities and interest groups in the resource management process. The program focuses on maintaining the integrity of the entire ecosystem. NEP activities for designated estuaries are funded jointly by the state and the federal government through the U.S. Environmental Protection Agency (EPA).

The NEP is designed to encourage local communities to take responsibility for managing their own estuaries. Each estuary program (twenty-eight estuary programs are currently in existence, see Box 3-1) is made up of representatives from federal, state and local government agencies responsible for managing the estuary's resources, as well as members of the community—citizens, business leaders, educators, and researchers. These stakeholders work together to identify problems in the estuary, develop specific actions to address those problems, and create and implement a resource management plan to restore and protect the estuary with support from federal, state, and local authorities. Although the NEP is concerned mainly with developing plans for management and monitoring, research is often needed to achieve the goals of these plans, because there is insufficient knowledge to support decisionmaking.

The EPA administers the NEP, but committees of local government officials, private citizens, and representatives from other federal agencies, academic institutions, industry, and estuary user-groups carry out program decisions and activities. Estuaries are selected for inclusion in the NEP through a nomination pro-

Box 3-1
Estuaries in the National Estuary Program

Albemarle-Pamlico Sounds, North Carolina
Barataria-Terrebonne Estuarine Complex, Louisiana
Barnegat Bay, New Jersey
Buzzards Bay, Massachusetts
Casco Bay, Maine
Charlotte Harbor, Florida
(Lower) Columbia River Estuary, Oregon and Washington
Corpus Christi Bay, Texas
Delaware Estuary, Delaware, New Jersey, and Pennsylvania
Delaware Inland Bays, Delaware
Galveston Bay, Texas
Indian River Lagoon, Florida
Long Island Sound, New York and Connecticut
Maryland Coastal Bays, Maryland
Massachusetts Bays, Massachu-setts
Mobile Bay, Alabama
Morro Bay, California
Narragansett Bay, Rhode Island
New Hampshire Estuaries, New Hampshire
New York-New Jersey Harbor (Harbor Estuary Program), New York and New Jersey
Peconic Bay, New York
Puget Sound, Washington
San Francisco Estuary, California
San Juan Bay, Puerto Rico
Santa Monica Bay, California
Sarasota Bay, Florida
Tampa Bay, Florida
Tillamook Bay, Oregon

cess. Nominations must be submitted to the EPA by the Governor(s) of the state(s) where the estuary is located during specific nomination periods.

Once selected, each NEP site creates decisionmaking committees made up of relevant stakeholders, including members of the scientific community, to identify and prioritize the problems in the estuary. Most NEP sites choose a management framework that includes a Management Committee to oversee routine operation of the program; a Policy Committee, made up of high-level representatives from federal, state, and local government agencies; a Technical Advisory Committee (TAC) to guide scientific decisions; and a Citizens Advisory Committee to represent the interests of estuary user-groups and the public. Together, the committees develop a Comprehensive Conservation and Management Plan (CCMP) for protecting the estuary and its resources. The objective of each NEP site is to create and implement a CCMP that addresses the environmental problems facing the estuary and recommends short- and long- term management measures to address these problems. Although federal funding for CCMP development is substantial in some cases, in general, much less federal funding has been available for implementation. A critique of the NEP has been that " it does not provide funds or processes for implementation or accountability" (NRC, 1997).

The Santa Monica Bay Restoration Project (SMBRP) in California serves as an example of how one NEP site determined their regional research needs. Two stakeholders, the Bay Watershed Council (BWC) and the TAC were primarily responsible for identifying and prioritizing research needs. The BWC is the governing body of the SMBRP and is composed of representatives of elected officials, government agencies, dischargers, environmental groups, and the general public. The TAC is composed of technical staff from government agencies, environmental groups, and scientists from local universities and research institutes. SMBRP used a consensus building process to identify four major areas of concern:

1. How safe is it to swim in the Bay?
2. How safe is it to eat Bay seafood?
3. Are fisheries and other living resources in the Bay adequately protected?
4. Is the health of the Bay's ecosystem adequately protected?

Actions to address these issues are summarized in the Bay Restoration Plan published in 1994 (SMBRP, 1994, 1995). As the functions of the SMBRP shifted from development of the action plan to implementation, the focus also shifted, from problem characterization and evaluation of action (technical solution) alternatives, to status and trend analysis and evaluation of action effectiveness.

In both the RMRP and the NEP, the community planning approach was employed successfully, despite the difficulties inherent in developing a consensus from a broad spectrum of stakeholders. In the case of the NEP, stakeholders identify the problems and develop a consensus on the management actions that need to be taken. This is essential to the voluntary implementation of these plans and helps develop community support. Similarly, the RMRP process brings together researchers, managers, and agency representatives to identify and prioritize the research needs in the area. This not only helps match the needs of management with the expertise of the scientists, but also improves communication among the research and management communities throughout the region. The incorporation of community-based planning methods is an important feature in the development of regional marine research programs. Because different regions and issues may require different approaches, future programs could benefit from examining the specific organizations and procedures employed by the RMRP and NEP for including participation by stakeholders to determine how different approaches can be applied to meet the specific issues that arise in different regions.

SCIENTISTS' PLANS

Research proposals to the National Science Foundation (NSF) are selected for funding based on merit as assessed by peer review. Although NSF Ocean Sciences core programs do not target a specific place or region, some programs are developed that have a specific geographic focus and designated funding. Planning for these programs may be initiated by NSF or by groups of scientists. In either case, this is followed by special sessions at national scientific meetings and workshops to engage the scientific community in a discussion to assess the importance of the issue to be addressed and to define goals. Frequently, selected groups of scientists, such as the Ocean Studies Board (OSB), are asked to comment. When a broad research need is identified and incorporated into NSF's long-range plans, funding for more extensive research design activities can be obtained via a proposal process that includes peer review. Normally, an individual or small group of scientists takes a leading role in requesting funding to support planning workshops. These workshops lead to reports, which the NSF program managers can then use to promote these programs both within NSF and externally. If sound plans with wide community support, consistent with NSF's broader goals, emerge from the workshop process, they have a good chance of being funded through focus programs. The funds are distributed by NSF's normal competitive proposal review process, except that the specific goals and priorities of the focus programs are added to the simple merit criterion for proposal success.

The extensive discussion of these research plans within the research community has the advantage that virtually every scientific nuance of a problem is considered during the process. When the process works well, it promotes scientific consensus building, as the issues are thoroughly aired and the strongest arguments prevail. The disadvantages are that the process is time-consuming and arduous. Sometimes, meaningful consensus on research priorities does not emerge and reports are so broad and inclusive as to be almost useless in allocating limited resources. In other instances, workshop discussions and report writing are dominated by smaller groups with strongly held views, so that the product is not representative of the majority. The latter problem is alleviated if the reports are subjected to substantive peer review. Finally, consistent with NSF's basic science mission, direct input from managers and stakeholders is rarely sought. This results in programs that help fulfill the need for a fundamental understanding of coastal processes; however, these programs do not necessarily provide immediate solutions to contemporary coastal ocean problems. Three examples of programs designed by broad-based groups of scientists are the Land-Margin Ecosystem Research (LMER), Coastal Ocean Processes (CoOP), and the Global Ocean Ecosystem Dynamics (GLOBEC).

Land-Margin Ecosystem Research

The NSF, as part of its Global Geosciences Program initiated LMER in 1988. The broad goals of LMER are to characterize changes in inputs of materials and energy from land, air, and ocean to estuarine and coastal marine ecosystems and to assess the effects of these inputs on populations and processes in an ecosystem context. Projects funded by this program incorporate four key elements:

1. Multidisciplinary teams collaborating on a common problem;
2. Comparative approaches to assess the commonality of processes;
3. Experimental studies that integrate across a range of scales in time and space;
4. Development of models as heuristic, diagnostic, or predictive tools.

As with most NSF programs, goals were established by involving the scientific community in a series of workshops. Using the results of these workshops, an advisory committee was formed to inform NSF on research needs and formulate a plan for implementation. The American Society of Limnology and Oceanography, the Estuarine Research Federation, and the Southern Association of Marine Laboratories endorsed the call for research. A steering committee of scientists from the community at large was formed to oversee the program, and a coordinating office was established. The scientific community was invited to form teams and prepare proposals for five-year projects, and ultimately six such projects were funded based on the results of peer and panel review. Of the original six LMER sites, three are currently funded. The active ones are Chesapeake Bay, Maryland; Columbia River, Washington; and Georgia Rivers, Georgia. The former sites are Waquoit Bay, Massachusetts; Tomales Bay, California, and Plum Island Sound, Massachusetts. LMER will end with the expiration of the current funding for the remaining three sites.

Coastal Ocean Processes

This is an interdisciplinary research program, which seeks to achieve a new level of quantitative understanding of the cross-margin transport of biologically, chemically, and geologically important materials. CoOP grew out of an earlier research planning exercise, Coastal Physical Oceanography (CoPO), which conducted several planning meetings during the late 1980s and identified key physical processes and important questions relative to cross-margin transport. CoOP was initiated when it was recognized that the cross-margin transport of materials could not be understood without knowledge of a wide-range of processes, including biological formation and decomposition of particles, particle sinking and resuspension, and many others. NSF and the Office of Naval Research (ONR) provided funding for CoOP planning activities and an interdisciplinary steering committee, consisting of biological, chemical, geological, and physical oceanographers and meteorologists interested in the coastal ocean, was selected. The steering committee held a community workshop (Brink et al., 1990) and prepared a science prospectus (Brink et al., 1992). In this latter document, they built upon an idea first proposed by CoPO planners, that coastal ocean processes could be best understood by studying regions where cross-margin transport is dominated by one physical forcing mechanism, such as wind or tides. By synthesizing data and models from several such regions, more complex coastal areas could be understood. In 1994, CoOP began a series of scientific community workshops based upon idealized coastal regions described in the science prospectus. The first such workshop dealt with research questions and priorities for cross-margin transport on wind-driven shelves. The workshop was open to anyone who wished to attend. From the input of the working groups and external reviewers of a draft document, the workshop organizing committee prepared a science plan, which was later the basis for an announcement of opportunity (AO). Since the wind-driven shelf workshop, similar workshops dealing with the Great Lakes and with buoyancy processes on shelves have been held. From the beginning, CoOP planning has been conducted and directed by the scientific community. Although societal needs are considered and used as an important justification for coastal ocean research, CoOP does not seek direct input from stakeholders, local or state agencies, NGOs, or other concerned parties, but rather relies on documents prepared by other groups (such as the National Academies) to identify relevant needs.

Global Ocean Ecosystem Dynamics

GLOBEC began with an interest in the causes of fluctuations in abundance of pelagic marine organisms, including fluctuations due to the possible impact of global change (the effect on the environment of increasing atmospheric concentrations of greenhouse gases), as discussed at a meeting sponsored by NSF, NOAA, and ONR in 1988. The long-term goal of the program is to understand how physical processes influence marine ecosystem dynamics in order to predict the response of the ecosystem and the stability of its food web to climate change. U.S. GLOBEC has research efforts in Georges Bank/Northwest Atlantic Region, and the Northeast Pacific, with components in the California Current and the Coast Gulf of Alaska, and it is contributing to the international GLOBEC program in the Southern Ocean. The international GLOBEC is a core program of the International Geosphere Biosphere Program (IGBP).

Research priorities for U.S. GLOBEC are reached by a consensus vote of the Scientific Steering Committee (SSC). The SSC, initially established in 1989, is an elected body drawn from the scientific community to represent a disciplinary, regional, and institutional balance. Nominations for new members each year are solicited from the oceanographic and fisheries communities and a slate of candidates is selected by the Executive Committee and voted on by the full committee. This process is designed to ensure that a broad range of scientific expertise and viewpoints are represented on the SSC and that research priorities reflect a consensus position on the key questions to be addressed.

Selection of study regions for U.S. GLOBEC is based on the following scientific criteria: (1) the ability to establish linkages with climate-scale factors; (2) the choice of general system types and potential for comparative analysis with the same system types in other regions; (3) the availability of an historical series of biological, physical, and chemical observations on the system to permit retrospective analyses and development of hypotheses; (4) the potential for collaborative and complementary work with other groups of investigators; and (5) the identification of ecologically and economically important target species in the region. Like CoOP, this program addresses issues of relevance to the governance of local, state, and regional resources, specifically fisheries, but relies on the scientific community to provide the guidance for the research program.

Although it is too soon to evaluate the success of these ongoing scientist planned programs, some preliminary assessments can be made. LMER has advanced the understanding of nutrient cycling and trophic dynamics in estuarine systems and quantified their roles in modulating the transport of nutrients and carbon from land to the open ocean. CoOP has contributed to a better understanding of cross-shelf transports of major nutrients, carbon, and sediments, and has implemented plans to enhance sustained near-shore observations through the integrated use of shipboard measurements, towed sensor arrays, and moored instrumentation. GLOBEC has advanced the understanding of how physical processes influence juvenile cod and haddock populations on Georges Bank and has played an important role in the development and application of ecosystem models that incorporate realistic trophic dynamics (NRC, 1999). Except for a few of the LMER sites, the achievements of these programs have gone largely unnoticed by the public at large, and applications of their results to problems of environmental protection, resource management, and environmental prediction so far have been limited.

AGENCY PLANS

In contrast to the basic science mission of the NSF and the U.S. National Aeronautics and Space Administration (NASA), other agencies have regulatory or management missions and support research programs that are more applied. These agencies typically use a planning process in which agency program managers take the lead in setting and prioritizing research goals. Usually, substantial input from scientists, resource managers, or other groups is included. However, this input tends to be advisory, rather than directive, and circumscribed to some extent. For example, an agency might select a small group of scientists to serve on an advisory panel and receive a narrower range of viewpoints than would be represented in a planning workshop. An agency might also limit the range of input it receives by asking specific questions of its advisors, as opposed to giving them an open-ended charge to design a research program. A variation of this approach is for an agency to ask a study organization such as the National Research Council (NRC) or the JASON Program (a unit of the Mitre Corporation used by the U.S. Department of Defense [DOD] and the U.S. Department of Energy [DOE] to assess needs) to conduct a study and make recommendations that would lead to a research plan. The obvious disadvantage of the agency approach is that if input from the scientific and management communities is limited, vital information, key questions, and valuable research avenues can be missed. The agency process tends to be more susceptible to political manipulation than community or scientists' plans. On the other hand, this approach can have clear advantages. It often is less time-consuming and less expensive than seeking broader input to the decisionmaking process; and it allows agencies to maintain focus on their specific mission. In addition, thoughtful collaboration among agency personnel, scientists, and resource managers can often yield a sound research plan.

The two programs described below illustrate difficulties that can arise with inadequate interagency coordination. Agency research planning does not necessarily preclude effective coordination among research programs. In practice, broader planning activities are more time-consuming and less amenable to completion on strict schedules; hence, they can be more difficult to coordinate. In addition, unless there are strong incentives, agencies may not make effective collaboration a priority.

Three examples of agency planning will be discussed: NOAA-National Sea Grant College Program; the NOAA Coastal Ocean Program (COP); and the Louisiana-Texas Shelf Physical Oceanography Program (LaTex), a research program planned and executed by the U.S. Minerals Management Service (MMS) in the Gulf of Mexico.

National Sea Grant College Program

The National Sea Grant College Program is located within the Office of Oceanic and Atmospheric Research (OAR), NOAA's primary research arm (Figure 3-2a and b). Sea Grant is unusual among federal agencies in that its management structure includes both state and local elements. Created through the National Sea Grant College and Program Act of 1966 (as amended in 1976 and 1987), Sea Grant has established a unique network of ocean research and outreach partnerships between federal, state, and local governments, academic institutions, and the private sector. The Sea Grant Program provides funding to institutions in 29 states for improving the understanding of ocean resources and developing strategies for sustainable ocean resource development, management, and conservation. Research priorities are set through a combination of objectives established at the national level and the needs at the state level. Lately, National Sea Grant evaluation teams are placing greater emphasis on the need for programs to be responsive to state concerns. Under this recently adopted policy, a local Sea Grant College is required to be responsive to the needs of the state's coastal region as a whole and to support research among all qualified investigators in that state using strict peer-review and open-competition procedures. The local Sea Grant entity must be able to set strategic priorities that encompass university, state, and federal objectives, as opposed to the more narrow focus of an academic department or school. Many coastal states have benefited from the Sea Grant Program through research in fisheries, oceanography, mariculture, marine biotechnology, marine engineering, water quality, recreation, and ocean policy and management.

The fact that each coastal state has its own Sea Grant Program can cause difficulties in planning and funding regional marine research through Sea Grant. Typically, states are reluctant to contribute funds for research that crosses state boundaries. Also, individual Sea Grant Programs have fairly modest financial resources. Although Sea Grant awards are generally too small to support interdisciplinary oceanographic research over large geographic areas, some programs have filled an important role through consistent funding of projects that require a long-term commitment.

Sea Grant's mission includes an effort to provide effective communication between university-based research programs and the users, policymakers, educators, and public who can benefit from the information generated by these programs. Through Sea Grant's Outreach and Extension services, the results of scientific research are communicated to those that apply them; in turn, the problems and needs of these groups are communicated back to Sea Grant researchers. Thus, Sea Grant plays an important role in identifying problems, finding potential solutions, and providing education for a wide range of people.

Coastal Ocean Program

In 1999, NOAA's COP became part of the Center for Sponsored Coastal Ocean Research, within the National Centers for Coastal Ocean Science administered by the National Ocean Service, one of NOAA's five line offices (Figure 3-2b). However, COP was established in 1989 as a cross-line office program (Figure 3-2a), with the objective of coordinating activities within a subject area common to the other NOAA line offices (NRC, 1994a). The COP was formed to provide information for decisionmakers to enable the nation to realize the full potential of its coastal resources, while protecting them for the future. The more specific goal was to distinguish between natural variability and the impact of human activities on fisheries, environmental quality, and coastal hazards to improve our ability to predict future impacts. The operational goals were to promote cooperation among NOAA line offices in coastal ocean research and to enable more effective collaboration among NOAA and academic scientists. To accomplish this role, the COP administration and budget were initially independent of the five NOAA line offices. In 1990, the NRC was asked to assemble a panel on the NOAA COP. This panel was formed to provide recommendations to strengthen the coastal ocean activities at NOAA, with specific reference to COP, and was composed principally of academic scientists who were not directly affiliated with NOAA. The panel was tasked to:

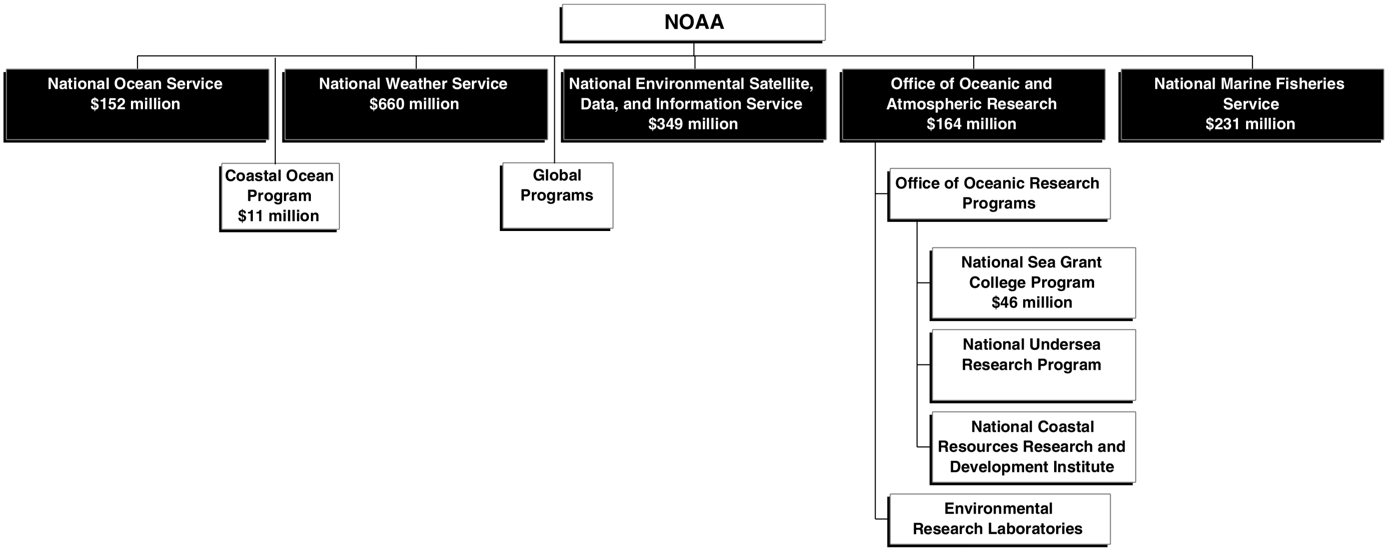

FIGURE 3-2A National Oceanic and Atmospheric Administration (FY 1994 Organization and Budget Allocations)

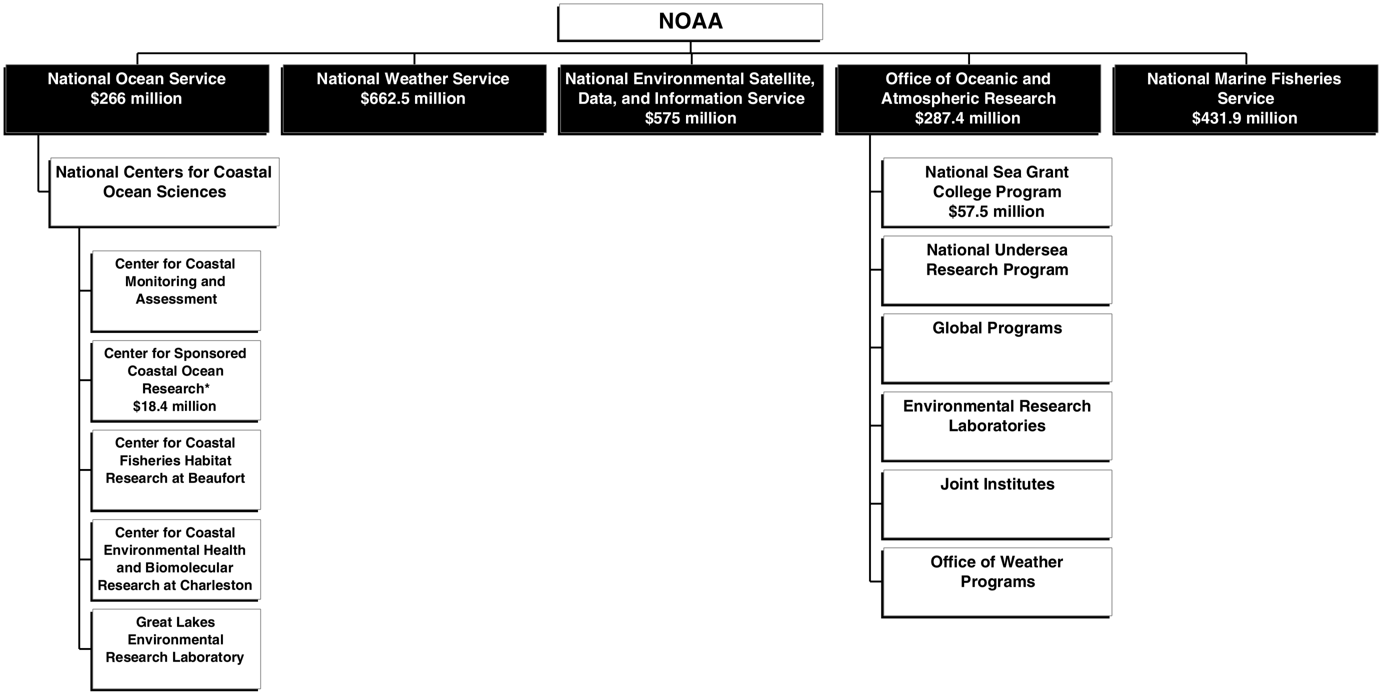

FIGURE 3-2B National Oceanic and Atmospheric Administration (FY 1999 Organization and Budget Allocations)
* Formerly the Coastal Ocean Program

- Provide broad scientific programmatic guidelines on coastal ocean pollution and degradation, living marine resources, and the protection of life and property in coastal areas;
- Assist in identifying the science and information needs of coastal decisionmakers;
- Suggest ways for NOAA to develop an efficient and cost effective program to complement coastal programs in other agencies; and
- Evaluate ongoing NOAA activities, plans, and institutional arrangements relevant to the goals and objectives of COP (NRC, 1994a).

In addition, COP implemented a management and review structure, which consisted of a Program Management Committee (PMC) and a TAC. The PMC consisted of a representative from NOAA National Marine Fisheries Service (NMFS), OAR, COP, and academia. In consultation with the director of COP, the committee was given responsibility for review, analysis, long-range planning, priority-setting, oversight, and implementation. TACs, which consist of NOAA and academic scientists, were formed to provide advice and guidance to the PMC on concepts, proposal, and research plans. In both planning and implementation more emphasis was placed on soliciting the advice of academic scientists than on consulting with coastal managers and decisionmakers. Also, it should be noted that the OSB review of COP (NRC, 1994a) emphasizes the impact of congressional earmarks on COP funding decisions. Over time, COP has spent an increasing portion of its resources on congressionally-mandated projects. This undermines the normal planning and peer-review process and risks funding poorer quality science and science that does not address problems of the highest regional or national priority.

The Nutrient Enhanced Coastal Ocean Productivity (NECOP) program was funded by COP and will be used as one of two in-depth case studies for Chapter 4. In addition, COP funds other regional programs around the United States, including Southeast Bering Sea Carrying Capacity, South Atlantic Bight Recruitment Experiment, South Florida Ecosystem Restoration Prediction and Modeling, and Pacific Northwest Coastal Ecosystem Regional Study (PNCERS; see Chapter 4 for description of PNCERS), among others. COP has participated in some of the activities of the CoOP and GLOBEC programs described above and the interagency program, Ecology and Oceanography of Harmful Algal Blooms (EcoHAB). In most cases, COP has sought and received substantial external contributions to the planning processes from scientists and, in some current programs, from resource managers. However, a considerable amount of program dollars are spent on research that is mission oriented. This can result in neglect of research on fundamental processes essential to understanding the regional system.

Louisiana-Texas Shelf Physical Oceanography Program

The primary goal of LaTex was to study the physical oceanography of the northern Gulf of Mexico. The study was commissioned by MMS in support of one of its missions, to assess potential environmental impacts of offshore oil and gas exploration and production. MMS perceived a need for specific information on currents in the coastal Gulf, so agency personnel designed the research in detail, to the extent of specifying locations and depths of current meter deployments. Despite the initial consideration of broader regional research needs in the context of possible cooperation with NECOP, in the end LaTex did not join in any collaborative effort, largely because the goals of NECOP did not fall within the specific mission set by MMS for LaTex.

LEGISLATIVE MANDATES

An increasing number of mandates for regional marine research stem from federal legislation. Sometimes, research is the focus of the legislation, as in the case of the RMRP. With this type of mandate, funding is usually provided to support the research, although it may not be sufficient to meet the requirements of the enabling legislation. Often, as was the case with RMRP, mechanisms for planning the research are specified. Other legislative mandates may prescribe either broad or quite specific research objectives. Such mandates typically are not based on a systematic effort among stakeholders, decisionmakers, and scientists to plan needed and effective research in the coastal zone. Rather, they tend to result from the efforts of focused interest groups, ranging from researchers seeking unconventional sources of research funding, to industries with specific resource issues, to conservationists seeking to protect a particular species or habitat. In other instances, although research is not the subject of the legislation, carrying out the legislative mandate may require extensive research.

An example of this latter situation is the 1976 Magnuson-Stevens Fishery Conservation and Management Act, as amended by the Sustainable Fisheries Act of 1996 (P.L. 104-267). This law established a new requirement to describe and identify essential fish habitat (EFH) within each regional fishery management plan. EFH is defined within the act as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." Only species managed under a federal fishery management plan are to be considered. The designation of EFH uses a four-tiered approach:

- *Level 1* includes presence/absence distribution data;
- *Level 2* examines habitat-related density data;
- *Level 3* analyzes growth, reproduction, or survival rate data within habitats; and
- *Level 4* includes an analysis of production rate data available for each habitat for each species.

The goals outlined in the Sustainable Fisheries Act are ambitious and require a considerable amount of research to understand the relationship between individual fish species and the habitat necessary to support their life stages. Also, detailed information from monitoring, coupled with modeling, is needed to assess the relative impact of proposed activities and to inform those involved in the subsequent consultative decisionmaking process.

The Endangered Species Act contains implicit mandates for research. For example, in 1997, the Steller sea lion was declared an endangered species in the western part of its range in the northern North Pacific; after earlier being listed as a threatened species in 1990. NMFS is bound by Section 7a(2) of the Endangered Species Act:

> Each Federal agency shall ensure that any action authorized, funded, or carried out by that agency is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of habitat of such species.

In a series of biological opinions issued or reviewed since 1991, NMFS identified pollock fishing as plausibly having adverse impact. Therefore, NMFS instituted restrictions on the fishery that included Steller sea lion buffer zones (no-trawl zones) near sea lion rookeries. In April 1998, an independent panel requested by the North Pacific Management Council reviewed the scientific justification for the NMFS opinions. The panel included the following statement in its report:

> It is the conclusion of the panel that, on the basis of the available scientific and commercial data, the possibility of competition between Steller sea lions and the pollock fisheries cannot be excluded. However, the panel emphasizes that this does not mean that the magnitude or effect of the competition has been determined. Quantification and causation have not been established.

On July 10, 1999, a federal judge ruled in a lawsuit brought by several environmental groups that current pollock fishing regulations issued by NMFS do not protect the Steller sea lion and, hence, violate the Endangered Species Act. The judge's decision emphasized that NMFS had not provided a quantitative rationale for the specific restrictions instituted; that is, they had not demonstrated that the restrictions were likely to be effective. In particular, the sea lions' numbers continued to decrease even after the fishery restrictions were in place. The 1998 independent panel review made it clear that the scientific information needed to justify the NMFS management measures was lacking. Therefore, the court decision, if upheld, will require substantial additional research on the causes of the Steller sea lion population decline and the effects of any remedial measures taken.

A regional marine research program that uses an ecosystem-based strategy should provide the necessary framework to support the decisionmaking processes outlined in the Sustainable Fisheries Act, the Endangered Species Act, and similar mandates. Ideally, clearly defined regional research priorities would help balance the arguments of special interest groups who promote particular research programs. Better coordination among NOAA programs responsible for coastal ocean research (COP and National Sea Grant), fisheries (NMFS), and endangered marine species (NMFS) would facilitate planning and implementation of research programs needed to support management decisions.

4

Regional Marine Research Programs

In this chapter, several regional marine research programs (RMRPs) are discussed in detail. The objective of this analysis is to identify aspects of the planning, implementation, and administration of these programs that either contributed to their success or proved an impediment. Success is considered not only in terms of scientific accomplishments, but also in terms of benefits to managers, agencies, and other consumers of scientific information.

NUTRIENT ENHANCED COASTAL OCEAN PRODUCTIVITY (NECOP) CASE STUDY

Goals

The NECOP program was initiated in 1989 as part of the Coastal Ecosystem Health theme of the newly established Coastal Ocean Program (COP) of the National Oceanic and Atmospheric Administration (NOAA). The major themes of COP are:

- fisheries management in an ecosystem context,
- ecosystem health, and
- coastal hazards (the coastal forecast system).

The long-term goal of NECOP was to "improve the environmental quality of coastal waters by predicting the harmful effects of nutrient over-enrichment" (NOAA, 1991). Immediate goals were to determine quantitatively the degree to which coastal primary productivity has been enhanced in areas receiving inputs of nutrients from terrestrial sources, determine the impact of enhanced production on water quality, and determine the fate of fixed carbon in coastal areas and its impact on living marine resources and the global carbon cycle. The northern Gulf of Mexico directly affected by the discharge of the Mississippi-Atchafalaya river system was the only region selected for this program, although originally, several studies of coastal ecosystems impacted by riverine inputs of nutrients were anticipated. This region was selected based on four criteria: a clear anthropogenic signal in the distribution of nutrients, elevated phytoplankton biomass, demonstrable impact on water quality due to enhanced productivity, and the presence of regional living resources of significant value.

It is interesting to compare the goals of NECOP with those established through the RMRP process that gave rise to the Gulf of Mexico Regional Marine Research (RMR) Plan. Through a series of workshops, the RMR Board for the Gulf of Mexico region identified 12 research priorities: freshwater and sediment inputs, saltwater intrusion, nutrient enrichment and cycling, toxic materials, trophic dynamics, population stability of marine organisms, nuisance and exotic species, habitat use and modification, physical modifications including dredging-dumping and alterations of freshwater flow, coastal erosion and sediment budgets, catastrophic events, and global change. The RMR Board identified the following research priorities:

- Develop a comprehensive ecosystem model of the Gulf of Mexico to guide the development of smaller scale predictive models, define information gaps, and track progress toward filling these gaps;
- Study physical, chemical, and ecological processes in the inshore zone (< 25 m);
- Study the offshore zone (> 25m) and the Loop Current as it influences the linkage between inshore and offshore processes.

The concept of a region as the next largest scale that must be studied to understand the local problem of interest and the importance of coastal circulation is clearly incorporated in these priorities. NECOP addressed research questions related to inputs of freshwater, nutrients and sediments, nutrient cycling, and trophic dynamics, and was primarily concerned with the inshore environment. Thus, the goals of NECOP were within the broader scope of the RMRP for the Gulf of Mexico.

Duration, Funding, and Principal Investigators

From 1989 to 1996, 49 scientists, 19 federal and 30 non-federal, from 14 institutions participated in an interdisciplinary study of the continental shelf of the northern Gulf of Mexico at a total funding of $9.5M (85% research, 14%

management, and 1% outreach). A final synthesis of results was completed in 1999 (Wiseman, 1999).

Program Management

NECOP was conceived at a National Oceanic and Atmospheric Administration (NOAA) workshop in Fiscal Year (FY) 1988 and initiated in 1989 by a NOAA Coastal Ocean Productivity/Nutrient Enhanced Workshop in Baton Rouge, Louisiana. Field studies began during summer 1990 and were completed in 1993. In consultation with the Director of COP, the Program Management Committee (PMC; established in 1989) developed and issued calls for proposals in FY 1989 for FY 1990-91 and in FY 1992 for FY 1992-93. The PMC was also responsible for proposal review and funding decisions.

The first call for proposals targeted five areas for funding: retrospective analyses received $375,000 for work on sediment cores, a Coastal Zone Color Scanner (CZCS) database, and synthesis of historical data; monitoring of dissolved oxygen received $175,000; synoptic measurements and process studies received $650,000 for studies focusing on productivity, development of hypoxia, and carbon transport; modeling was allocated $150,000 to develop mass balances for the inner shelf; and impacts on biota received $125,000. Fifteen proposals were funded. Information is not available on the number of proposals submitted during this first year. Funding was initiated in May 1990.

The second call for proposals targeted the following areas for funding: assess the importance of nitrogen, phosphorus, and silicon in limiting phytoplankton productivity and biomass; determine seasonal variation in the rates of new and regenerated productivity; enhance the modeling effort by determining fluxes and physical linkages among various study regions; enhance research on hypoxia by expanding studies on the effects of low oxygen on living resources; and assess the impact of hypoxia on socioeconomic conditions in the northern Gulf of Mexico. Of the 26 proposals submitted, 17 were funded. Funding was initiated in March 1992. The final three years (FY 1994-1996) of the project (Appendix D – NECOP spreadsheet) were funded at a reduced level of support for renewals and synthesis.

It is noteworthy that the 1994 Ocean Studies Board (OSB) review of COP (NRC, 1994a) found that the solicitation and review procedures were not uniform in terms of the treatment of proposals from NOAA and academic scientists. The panel recommended that procedures for solicitation and review of proposals be "standardized."

Data Management and Dissemination

In FY 1990, a data management center was established at NOAA, the Atlantic Oceanographic and Meteorological Laboratory (AOML). A workshop on data management was conducted in FY 1993 (the last year of field studies) to discuss data synthesis and data products. Synthesis and the development and calibration of a water quality model continued through 1996. Data submission to the NECOP data manager was completed in FY 1996 and all data were forwarded to the National Oceanographic Data Center (NODC).

External Reviews

The project was subjected to an external review in October 1991. The review committee concluded that:

- The problem of coastal nutrient enrichment is important and requires a focused, multidisciplinary study, such as NECOP;
- The rationale for defining the limits of the study area and selecting the current mix of funded projects was not clear;
- The sampling program is unlikely to provide the data needed to determine characteristic scales of variability in river discharge and plume dynamics;
- The project does not appear to be well coordinated.

Several recommendations were made as follows:

- Elect 3-5 principal investigators to serve on the Technical Advisory Committee (TAC) to effect better coordination between research needs, recommendations of the TAC, and decisions of the PMC;
- Enhance the effort to determine the history of hypoxia based on analysis of the sediment record;
- Make a serious effort to quantify the sources of nutrients (natural, fertilizer, sewage, etc.);
- Effect greater collaboration and coordination between the observational and modeling efforts; and
- Develop a more effective strategy for observing the system on time and space scales that are relevant to the goals of the program and for coordinating surveys with more intense and detailed process studies.

In response, NOAA reconstituted the TAC with representation by principal investigators, agreed to devote additional resources to retrospective analysis of the sediment record, and worked to develop more effective collaboration among field and monitoring efforts. Quantification of sources was not seen as a NECOP responsibility, and the U.S. Environmental Protection Agency (EPA) was expected to provide access to pertinent data. The availability and cost of ship time was a concern and a plan to address sampling issues was not articulated.

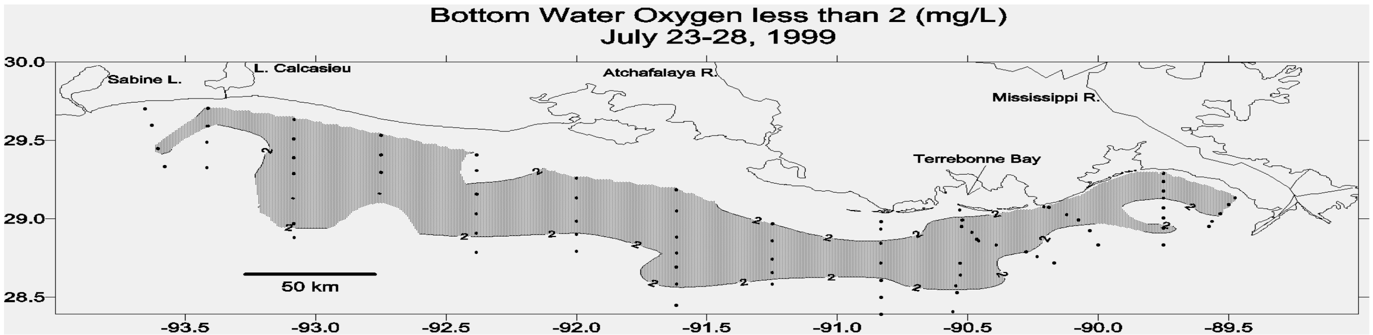

FIGURE 4-1 Hypoxia zone on the continental shelf of the northern Gulf of Mexico. Monitoring of dissolved oxygen in bottom waters contributes to research and management efforts to assess the impact of excess nutrient inputs from the Mississippi watershed on the coastal ecosystem. From: Rabalais, N.N., R.E. Turner, and W.J. Wiseman, Jr., unpublished data.

Extent to which the Goals were Achieved

Significant progress was made in understanding the relationships among nutrient loading, phytoplankton production, and the development of bottom water hypoxia. The project excelled in raising the level of public awareness of the problem. NECOP also provided a more complete historical perspective of the volume and areal extent of hypoxia in the region and showed that anthropogenic nutrient inputs and climate are important parameters of the spatial and temporal magnitude of hypoxia. However, based on the most recent synthesis, the original program goals were not achieved. It is obvious, from the nutrient fields alone, that increases in nutrient loading have resulted in an increase in phytoplankton production. However, the magnitude by which productivity has been enhanced, the quantitative impacts of the higher production, and the fate of phytoplankton production are still a matter of speculation. The program suffered in two important ways:

1. Excessive focus on the immediate mixing plume off Southwest Pass and inadequate attention to the shelf dynamics downcurrent and off the Atchafalaya, where hypoxia is produced and maintained, and
2. A sampling program that was inadequate for documenting important scales of variability and the physical and ecological dynamics of the coastal plume.

Among other things, variations in larger scale coastal circulation are likely to have a substantial impact on plume dynamics and the relationships between nutrient inputs, phytoplankton production, and oxygen depletion.

Relationships and Collaboration with other Programs

When the project was originally conceived, the field program was to be coordinated with the Louisiana-Texas Shelf Physical Oceanography Program (LaTex), a six-year project to determine the dynamics of circulation, transport, and cross-shelf mixing over the Texas-Louisiana shelf (sponsored by the U.S. Minerals Management Service [MMS]). Unfortunately, NECOP and LaTex were not well coordinated and, to date, the results of LaTex have been of limited value in defining the physical oceanographic setting and regional framework required for understanding plume dynamics and the fate of enhanced primary production.

Legacies, Impacts, and Public Awareness

NECOP was influential in bringing the problem of the seasonal occurrence of hypoxic bottom water in the northern Gulf of Mexico to the attention of decisionmakers and the public. Broader awareness of the issue has generated support for research and monitoring to address the causes of coastal eutrophication. Since the completion of NECOP in 1996, NOAA has continued to support the monitoring of dissolved oxygen during summer (Figure 4-1). This has sustained a monitoring effort that began in 1985 and was continued as part of NECOP. The occurrence of hypoxic bottom water during the summer is among the most pressing water quality issues in U.S. coastal waters. The first Gulf of Mexico Hypoxia Management Conference was convened by Natural Resources Hypoxia Work Group (CENR) in December 1995 to discuss the problem, and the Mississippi River-Gulf of Mexico Watershed Nutrient Task Force was formed in 1997 to discuss mitigation strategies. The Task Force initiated two parallel efforts: (1) an ecosystem-watershed management effort to identify actions that are acceptable to all concerned parties and can be taken immediately to reduce excess nutrient loads (CENR, 1998) and (2) an assessment of the causes and consequences of Gulf hypoxia to provide the scientific basis for the development of nutrient management strategies. Six technical reports are publicly available and a draft-integrated assessment has been released for public comment by NOAA (National Ocean Service, 1999).

GULF OF MAINE REGIONAL MARINE RESEARCH PROGRAM (GOM-RMRP) CASE STUDY

Goals

The broad goals of the RMRP and COP are very similar, in that they both emphasize the health of coastal ecosystems. However, the organizational structure of the RMRP was somewhat different. COP identified a specific region to study the environmental problem of nutrient enrichment and hypoxia and emphasized the collaboration between NOAA and academic scientists. In contrast, the emphasis of the RMRP was on the regional coordination of research and monitoring projects and the promotion of more effective collaborations between scientists and managers.

The goals of the GOM-RMRP were stated within the Gulf of Maine Research Plan (GOM-RMRP, 1992). The 10-year program goal was to "work toward development of a suite of models that collectively simulate how the Gulf of Maine ecosystem and its interacting components function naturally and under stress." Achievement of these ambitious goals was still below the horizon when the program terminated after 5 years. The broad societal concerns to be addressed by the GOM-RMRP were that contamination of the Gulf of Maine degrades living marine resources or alters ecosystem structure and that physical changes to habitats in the Gulf of Maine alter ecosystem structure and functioning. The scientific questions identified as being appropriate for study under the GOM-RMRP included:

1. What are the sources, pathways, fates, and effects of contaminants on living marine resources in the Gulf of Maine?
2. What are the causes and effects of noxious and/or excessive phytoplankton concentrations?
3. What is the relative importance of natural and human-induced changes to the physical environment on ecosystem structure and function?
4. How susceptible are various parts of the Gulf to dissolved oxygen depletion?

It was recognized that the limited resources available would not permit all of these questions to be addressed immediately.

Questions 1 and 2 were given the highest priority for initial funding based on consideration of the kinds of information needed to address these issues and the feasibility and importance of acquiring and using this information to achieve predictive capability for the Gulf of Maine system. The highest priority information needs were contaminant transport and cycling for Question 1 and causes of noxious algal blooms for Question 2.

Duration, Funding, and Principal Investigators

From 1993 to 1998, 49 investigators from 17 institutions participated in the GOM-RMRP. Total funding was just over $7 million (82% research, 17% management, and 1% outreach). Because of their geographic proximity to the Gulf of Maine, all of these institutions (and many of the individual investigators) had a substantial record of previous research in the region and most were members of Regional Association for Research on the Gulf of Maine (RARGOM). While NECOP focused on the effects of nutrient enrichment on the production and fate of phytoplankton biomass, the GOM-RMRP exhibited more diversity as a consequence of the process by which proposals were selected for funding. As far as can be inferred from the titles of the proposals, 19% of the research funding went to projects explicitly concerned with harmful algal blooms (HABs), 22% to contaminant-related studies, 26% to physical oceanography, and 22% to studies of primary productivity and chemical oceanography not specifically related to HABs or contaminants. Data management received 5% of the funding, an ecosystem model received 3%, and the remaining 4% of funds went to other research areas (Appendix D – GOM-RMRP spreadsheet). The GOM-RMRP funding pattern indicates that better understanding of such fundamentals as circulation and links between physical processes and primary productivity were deemed essential to addressing questions related to HABs and contaminants. The investments in data management and integrative modeling were quite modest, probably reflecting the short duration of the program.

Program Management

Unlike some of the other regions constituted by the RMRP legislation, the Gulf of Maine had a long tradition of collaborative research activities among regional institutions, and joint research planning activities had occurred from at least the mid-1980s. The broad scientific questions presented in the GOM-RMR Plan (GOM-RMRP, 1992) were identified based on input from a broad cross section of the scientific community, resource managers, agencies concerned with environmental conservation, environmental policymakers, and others (see Chapter 3). RARGOM, an association of marine research institutions and federal, state, and provincial agencies from the United States and Canada, was founded in 1991 to coordinate, facilitate, and stimulate research on the Gulf of Maine. At about the same time, a tri-state task group was formed to assist the Governors of Maine, New Hampshire, and Massachusetts in the formation of an RMR Board for the Gulf of Maine. The task group recommended involvement of the scientific community in developing the regional plan, so prior to the appointment of the RMR Board, its Chairman (Dr. Robert Wall) asked RARGOM to assist in drafting the RMR plan.

In December 1991, after the passage of the RMRP legislation, a Gulf of Maine Scientific Workshop was held in Woods Hole, Massachusetts. The workshop proceedings summarized current knowledge of the Gulf of Maine, identified major gaps in understanding, and made recommendations for future research activities. The Woods Hole workshop was a valuable tool for identifying research needs and informing institutional leaders about the RMRP. Also, it stimulated the formation of a regional association of marine research institutions, RARGOM, from the previously state-only Association for Research on the Gulf of Maine (ARGO-Maine). The RMR Board, which included representatives from universities, state, and federal agencies, developed the RMR Plan based on the draft prepared by RARGOM and other regional planning activities. The RMR Plan was submitted to NOAA and EPA for approval in June 1992, and the RMR Board immediately issued an Announcement of Research Opportunity (ARO) based on the Plan.

The development of the Plan was guided by the following questions:

1. What are the priority marine issues at the scale of the Gulf of Maine, from a societal perspective, that science can address with a predictive capability?
2. What are the scientific questions that are posed by these issues, and what specific information needs are thus implied?

Within the context of the broad scientific questions listed under *Goals*, priorities were set by the RMRP based upon the answers to these questions:

1. How much of this information is either already available, presently being generated in other programs, and fits the purview of this specific legislation?
2. What are the most important of these information needs in order to bring about usable predictive capability over a decadal time span?
3. Which of these issues need to be addressed earlier versus later in this decadal time span?

Based on these criteria, the RMR Plan included a table of research priorities related to the four major scientific questions. The highest priority issues were listed in the ARO; and reviewers were instructed to consider the table of priorities when evaluating the proposals. The reviewers also considered the normal criteria of scientific quality of the proposed research, qualifications of personnel, and suitability of facilities. In addition, linkages to ongoing work and to existing and projected databases contributed to a favorable evaluation. Interdisciplinary research approaches and multidisciplinary modeling efforts were identified as deserving support; however, the latter ultimately received very little funding. In all, four AROs were issued; all were similar, although later ones included information on projects that had already been funded.

Following mail review, submitted proposals were further evaluated by a review panel convened by the RMR Board. Based upon their recommendations, the Board selected proposals for funding. From 1993-96, Dr. David Townsend was chosen by the RMR Board to serve as Executive Director of the GOM-RMRP. He was responsible for overseeing the proposal solicitation and review process, disbursement of funds, and other Program oversight. After the RMRP authorizing legislation expired in 1996, Dr. Townsend continued unofficially as Director for one year. However, since 1997, which also saw the retirement of Board Chairman Dr. Robert Wall, there has been no administrative office for the GOM-RMRP.

Data Management and Dissemination

A small proportion (5%) of the total research funding of the RMRP was specifically allocated to data management. In addition, a fraction of the effort of the program scientists was also directed toward these activities. The main, unified presentation of the data and accomplishments of the GOM-RMRP is contained in a web site (USGS, 1999), entitled Research Environmental Data and Information Management System (REDIMS) for the Gulf of Maine. Although the original RMRP funding for this site has ended, it is still maintained by U.S. Geological Survey (USGS), Woods Hole. In addition to project descriptions, data, and, for a few projects, final reports from the RMRP, there are links to many sources of data, models, and other information. The RMRP data archived so far consists mainly of descriptive physical oceanography. The database is "distributed," that is, individual investigators maintain their own data sites linked to REDIMS. This raises some concern for the future survival of this dataset as a coherent entity.

The main avenues for dissemination of the RMRP results appear to be the website (Anderson et al., 1998) and traditional avenues of scientific publication (Appendix E). The website is geared to a professional audience, but could be useful to the scientific staff of local, state, or federal government agencies. There was little information available on public outreach.

External Reviews

There were no comprehensive, formal external reviews of the GOM-RMRP.

Extent to which the Goals were Achieved

Since funding for many of the major components continued into 1998, it is somewhat premature to evaluate the scientific impact of the GOM-RMRP. Although the website compilation of research results and publications is probably not completely current, it provides an initial basis for assessing the GOM-RMRP accomplishments. GOM-RMRP grant recipients identified 88 publications that were supported by the funds from the program (Appendix E). Of the 28 projects funded, 10 now have associated data links on the website. However, there has been no final synthesis of the results.

There has not been much tangible progress toward the 10-year goal stated in the RMR Plan, "to work toward development of a suite of models that collectively simulate how the Gulf of Maine ecosystem and its interacting components function naturally and under stress." With funding provided for only 5 of the 10 years of the program, completion of the goals cannot be expected.

The RMRP convened, organized, and sponsored a number of workshops and symposia intended to foster interactions among research groups and synthesis of research findings. These included principal investigator (PI) meetings in the Fall 1994 and 1995 and workshops on physical circulation modeling (1993) and ecosystem modeling (1995), but they occurred before most of the data were gathered and before PIs had thoroughly analyzed their own data. Because funding for the RMRP ended early, opportunities for taking the next step toward synthesis and interdisciplinary modeling were limited.

The GOM-RMRP has resulted in clear progress toward a better understanding of Gulf of Maine circulation and the role of wind forcing (Brown, 1998). Better understanding of the circulation will also certainly contribute to future understanding of contaminant transport, although that linkage has not yet been made. So far, interdisciplinary synergism is best illustrated by the work on the dinoflagellate *Alexandrium* (Anderson, 1997), where the inflow of freshwater, winds, and the resultant coastal circulation have been found to strongly influence the spatial and temporal distribution of this toxic species (Figure 4-2). Hence,

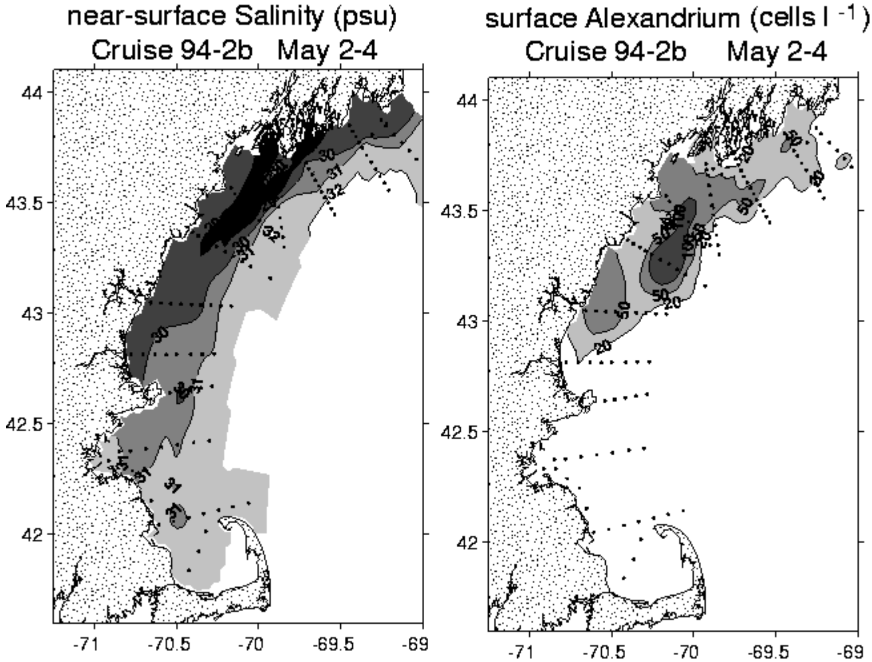

FIGURE 4-2 Salinity and dinoflagellate (*Alexandrium*) distributions during the first cruise (Leg II) of 1994 (May 2-4). These observations indicate a correlation between the inflow of freshwater (decreasing salinity shown by darker shading) and blooms of this toxic dinoflagellate (increasing density of dinoflagellates shown by darker shading). From: D.M. Anderson, unpublished data.

substantial progress has been made on the question: what are the causes of noxious phytoplankton concentrations? Another accomplishment of the RMRP has been to lay a foundation for further studies of harmful algae, such as those sponsored by The Ecology and Oceanography of Harmful Algal Blooms (EcoHAB) Program.

In conclusion, the GOM-RMRP had, and continues to have, many of the key elements necessary to address the guiding questions concerning contaminant transport and occurrences of phytoplankton. These include a clear definition of programmatic goals that all proposals were required to address; the decision to selectively fund a small number of projects (rather than underfund many projects), and the emphasis on interdisciplinary research (physical, biological, and chemical oceanography) that provides the fundamental context for interpretation of contaminant and phytoplankton data. Problems arose from the lack of a long-term, continuing state and federal commitment for the RMRP. This resulted in the unexpected, early termination of funding after 5 years of what was originally designed to be 10-year project. As a consequence, there was a lack of 'sunset' management funds needed to bring the program to an organized conclusion. Although many of the PIs continue to interact on other collaborative research projects and at planning exercises for future Gulf of Maine research, there is no impetus or funding to work on syntheses of RMRP data. Only minor funding (some from the harmful algal bloom proposals, some from a stand-alone project) was ever provided for interdisciplinary modeling. Judging from the somewhat limited participation in efforts to attain an RMRP "final product," in terms of providing data, final reports, or publication citations to the website, this program is rapidly falling off participants' priority list. Although PIs are making good progress toward publishing the results of the individual projects in peer-reviewed journals (at least 77 publications to date), it is likely that future accomplishments will be limited to individual and small group publications, with little of the interdisciplinary synthesis envisioned by the original plan.

Relationships To and Collaborations With Other Programs

The original authorizing legislation for the RMRP called for an assessment of how the GOM-RMRP would incorporate existing research and management programs. Two specific programs, the National Estuarine Research Reserve (NERR) and the National Estuaries Programs (NEP) were cited in the act as potential linkage programs. However, the GOM-RMR Plan indicates that the research needs of each program were (1) site-specific rather than regional in scope and (2) driven by individual mission-oriented goals. While the assessment may be accurate to some degree, the GOM-RMR planning process did not attempt to identify regional opportunities for collaboration with these legislatively mandated programs. At a minimum, the GOM-RMRP should have included specific research needs that are regional in scope and pertinent to both NERR and NEP, such as assessment of coastal habitat loss and water quality.

The GOM-RMRP planning process did take steps to gather insight from multiple-user groups before and during assembly of the plan. Workshops and conferences were held to understand, in the broadest sense, the work needed to sustain the integrity of the Gulf of Maine ecosystem. Beginning with the 1989 "Sustaining Our Common Heritage" conference, state and local leaders, non-governmental organization (NGO) representatives, and the research community worked to establish a list of research priorities and identify opportunities for collaboration among resource agencies within the region. Subsequent scientific workshops were held to continue to gather more detailed research needs and develop a framework for the final RMR plan. Subsequent collaboration efforts narrowed to those parties directly involved in the research plan and activities.

Legacies, Impact, and Public Awareness

The impact of the GOM-RMRP is difficult to assess from scientific and policy perspectives because of the lack of external reviews. In presentations to this committee, individuals did indicate that research detailing Gulf of Maine circulation patterns and processes initiating and sustaining HABs provided valuable insights. The data and information also served as a basis for understanding the linkages between Massachusetts Bay and the Gulf of Maine, particularly as studies were under way for the proposed Massachusetts Water Resources Authority wastewater outfall. Also, the current effort to design and implement the Gulf of Maine Observing System (RARGOM Report 98-1) is an important legacy that may form one of the building blocks of the U.S. integrated ocean observing system currently under consideration by Congress.

It is no surprise that little is known of the GOM-RMRP publicly. Less than 1% of the budget was devoted specifically to outreach activities. As a result of the early efforts to reach out to many user groups during development of the plan, coastal managers and advocates are aware of the GOM-RMRP process, plan, and specific studies. Yet, they would not necessarily recall specific findings of the studies and actions that might have been taken as a result of these findings. The only avenue for individuals to gain access to information from the GOM-RMRP is through the website that inventories the studies supported and provides access to a distributed data base (REDIMS). Since no RMRP or NOAA funds are allocated to the maintenance of this site, it survives through the grace of the host agency (USGS, Woods Hole).

OTHER SELECTED REGIONAL MARINE RESEARCH PROJECTS

Following are brief descriptions of several other regional programs, for comparison to those already discussed above. The intent is to highlight unique characteristics of these programs that were not represented in the earlier examples. In particular, each of these had different approaches and a varying commitment to involving a broader community in the research planning process and disseminating research findings. All achieved substantial interagency cooperation but differed in their emphasis on local, state, and federal participation.

Long-Term Management Strategy for San Francisco Bay

Dredging of approximately four million cubic yards of San Francisco Bay sediments annually is necessary to maintain shipping channels, terminal facilities, and some recreational activities. This dredging is subject to state permits issued by the Bay Conservation and Development Commission and the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB) and federal permits from the Army Corps of Engineers and other federal agencies. All federal permits issued for projects that affect the Bay must also be found to be consistent with the San Francisco Bay Conservation Development Commission's (BCDC) management program and the Seaport Plan that is developed by BCDC and the Metropolitan Transit Commission. The dilemma facing Bay ports, maritime shipping, and environmental protection interests was how best to balance the needs of maritime commerce with the protection and management of the Bay's significant aquatic and wildlife resources.

The competing needs of industry, ports, fishermen, and the environment caused a debate over where and how to dispose of dredged material, which halted certain harbor deepening projects. In response to these concerns, representatives from the U.S. Army Corps of Engineers (USACE), EPA, State Water Resources Control Board, SFBRWQCB, BCDC, the U.S. Navy, and approximately 40 other concerned public agencies embarked on a Long-Term Management Strategy (LTMS) to establish solutions to these issues. The program is highly visible by design and it functions with substantial regional input from dredgers, industry, environmental groups, and concerned members of the public. It was used to form a regional strategy for managing dredging within San Francisco Bay for the next 50 years.

The study plan for the program was adopted in 1991 and technical studies were completed by 1996. The budget was estimated to be $16 million. The technical studies were evaluated by a Technical Panel composed of five technical reviewers not associated with the LTMS program. This review was adequate, but the efforts were limited by budget constraints (Steve Goldbeck, San Francisco Bay Conservation and Development Commission, via telephone conversation and electronic mail in April 1999). Despite these limitations, the studies have provided a technical basis for designating the ocean disposal site, evaluating upland disposal options, helping to determine the best locations for limited in-bay disposal, and providing information for the policy environmental impact statement (EIS)/programmatic impact report (EIR).

One of the weaknesses of the program was the lack of a coherent data management strategy. Each agency and study established the parameters of their particular study, but consistency between the efforts was not always achieved. A central repository was not established and much of the information generated is now not easily available to third parties (although some of the results are now summarized in the EIS/R, which is available on the Internet; USACE et al., 1998).

The structure agreed to by the participating agencies at the beginning of the program has been surprisingly effective. Most of the problems and delays that were encountered can be attributed to the ad hoc beginnings of the effort, staffing shortages, data management concerns, the controversial nature of the subject matter, and the ambitious goals established for the program. The LTMS was developed through a series of long and sometimes difficult strategy sessions that ultimately succeeded, but were time consuming and expensive. The reward for this effort was the development of a strategy for dredging, environmental protection, and resource enhancement that is intended to provide guidance for the next 50 years. Future programs of this type would benefit from a research coordination structure, developed at the beginning that incorporates the necessary data management, technical review panels, and other organizational elements.

Chesapeake Bay Land Margin Ecosystem Research (LMER)

LMER was initiated by the National Science Foundation (NSF) in 1990 to address scientific and societal questions concerning the causes and consequences of changes in the structure and function of estuarine and coastal marine ecosystems. The overarching goals of this program are to assess: (1) the roles of these ecosystems in modulating the fluxes of materials between terrestrial and oceanic systems and (2) the influences of climate, land-use practices, and oceanic processes on trophic dynamics and biogeochemical cycles in ecosystems at the land-sea interface. Achievement of these goals requires an understanding of interactions among terrestrial, estuarine, and marine ecosystems. They require regional approaches that transcend political, disciplinary, and ecological boundaries. Projects were competitively funded through the NSF peer and panel review process.

The Chesapeake Bay LMER began in 1990 and ends in September 2000. The central hypothesis is that high primary production and fish production (relative to other coastal and estuarine systems), scaled in terms of annual nitrogen input, are consequences of the pulsed nature of nutrient inputs, the long residence time of nutrients in the system, benthic-pelagic coupling, and physical processes that enhance trophic transfer efficiencies. From 1990-1994, the project focused on responses to point-source and diffuse nutrient inputs to the estuary, in terms of nutrient cycling, the production and fate of phytoplankton biomass, water quality, and the development of a nutrient budget that identified major pathways of nitrogen and phosphorus input and export and major sinks within the system. In 1995, the emphasis shifted to the effects of physical processes on scales of meters on the coupling between primary and secondary production. Results from this research have:

- Elucidated relationships between nutrient enrichment, phytoplankton production, and oxygen depletion;
- Enabled the development of a coupled hydrodynamic-water quality model that generates realistic simulations of ecosystem dynamics, and is used to evaluate how nutrient control strategies will affect water quality (and will be used to calculate total maximum daily loads [TMDLs]);
- Provided the scientific basis for continued support of the nutrient management strategy for Chesapeake Bay;
- Revealed important linkages between convergence zones (including the turbidity maximum), the concentrations of phytoplankton and particulate organic

matter, and grazing patterns of zooplankton and fish larvae that have important implications for fisheries management and dredging practices in Chesapeake Bay.

The success of this project can be attributed to a great extent to the Chesapeake Bay observing system implemented in 1984 as part of the EPA Chesapeake Bay Program (see "Problems Transcend Geopolitical Boundaries, Agencies, and Disciplines," in Chapter 2). The Chesapeake Bay LMER was conceived and conducted in the context of a sustained, regional-scale observing system, a Bay-wide, EPA-NOAA-State collaboration that provides data on the distributions of temperature, salinity, nutrients, oxygen, sediments, toxic chemicals, plankton, macrobenthic organisms, finfish and shellfish, submerged attached vegetation, and tidal marshes throughout the Bay and its tributaries. These data are based on measurements of environmental and ecological properties and processes at 165 stations at monthly and bimonthly intervals. The constructive interaction between monitoring and research has led to rapid progress in the understanding and prediction of environmental variability. The existence of the observing system and the wealth of data it provides set the stage for a multi-institutional research effort that is unparalleled for an estuarine system. In FY 1998, this amounted to 169 programs in research, education, and outreach totaling $8.3 million in extramural funding, for studies of living resources, water quality, ecosystems, smart growth and development, as well as public education and environmental governance. It is noteworthy that ecosystem research accounted for nearly 40% of FY 1998 expenditures and that federal agencies accounted for about 60% of extramural funding (principally EPA, NSF, NOAA, and U.S. National Aeronautics and Space Administration [NASA]).

Pacific Northwest Coastal Ecosystem Regional Study (PNCERS)

PNCERS is a program entirely funded by NOAA's COP. The planning was a joint effort of the Oregon Coastal Management Program, the Washington Sea Grant Program, and the National Marine Fisheries Service, who are represented on the Program Management Team (PMT). In part, PNCERS emerged as a result of the planning activities undertaken as part of the Pacific Northwest Regional Marine Research Program. Oregon Sea Grant also cooperates. PNCERS perceives itself as "a five-year, multi-investigator, interdisciplinary approach to identifying the physical and human-mediating factors affecting the estuarine and near shore ecosystems . . ." (Parrish and Breslow, 1999). Its focus is five estuaries in Oregon and Washington State. The history and subsequent development of PNCERS are best viewed as a two-step process. In 1995, the COP provided $2.5 million to "greater" PNCERS. The initial grant was to determine the boundary conditions in which research programs would operate:

- How far into watersheds should the research programs penetrate?
- What are the limits to "coastal" research?
- What are the geopolitical limits (i.e., whether to include California and British Columbia or restrict the program to Oregon and Washington)?

To better target research funds, a workshop held during August 1996 further developed the conceptual model and presented a science plan. In late 1996, the PMT further refined the program goal and objectives based on the workshop. The new program goal is "to improve the understanding of natural variability and anthropogenic stressors on coastal ecosystems that support Pacific salmon, and to translate that understanding into improved management of resources and activities that affect coastal ecosystems." The program was further focused as follows: (1) because long-term coastal research programs existed in both California (e.g., California Cooperative Oceanic Fisheries Investigations [CalCOFI]) and British Columbia (La Perouse Bank), PNCERS research funding was limited to Oregon and Washington; (2) the near shore domain was set by the inner limits of NSF's Global Ocean Ecosystems Dynamics (GLOBEC) program, with the intent that the dual research efforts would prove complementary; (3) the research program had to include the social sciences, be multidisciplinary, and address the socioeconomic state of the local human communities.

The PMT then wrote a request for proposals, which outlined these boundary conditions and general goals. Eight pre-proposals were received, and two of these were selected for a "winner take all" competition with full proposals. The single successful proposal, as specified, was a team effort judged on the merits of its focus and integration. This strategy is in contrast to the approach of funding individual investigators based on scientific merit, with integration achieved as a byproduct of the program. Future reviews of the PNCERS program should include evaluation of the team investigator approach to funding. The initial research grant was for a five-year period and totaled approximately $5.0-5.2 million, with $4.6 million designated for research.

COP now funds two interrelated administrative entities. One, the Oregon Department of Environmental Quality, has hired a full-time program administrator. It also funds outreach programs to resource managers and, in that sense, will disseminate PNCERS research products. This includes annual workshops where input from coastal resource managers is solicited and participation by PNCERS researchers is required. The second, at the University of Washington, has a one-quarter time person in charge of research administration who coordinates the research program through the University of Washington. The research monies are dispersed to the PIs at both Oregon and Washington universities and the Battelle Marine Science Laboratory.

PNCERS currently funds 12 PIs. Pacific salmon were an obvious central theme, involving both coastal ecosystems and human communities. The integrated research effort proposes to identify and explore factors influencing local ecosystem health and sustainability. One goal is to define the nature of both natural and anthropogenic factors, and then design tools for addressing and mediating these factors. A unique feature of the original design is a "carrot and stick" approach to continued funding. In this approach, an increasing fraction of the remaining monies is reserved (approximately $600,000 unallocated for years four and five) to give the program the flexibility to fund research on identified data gaps and integration. Thus, in the annual research evaluations, participation in the integrated program is a major criterion for renewal without which even excellent science might not receive further funding from PNCERS.

Collaboration with other on-going programs was viewed as highly desirable, even necessary. Physical oceanographers involved in PNCERS have sought liaisons with GLOBEC. Investigators focused on Oregon and Washington estuaries have collaborated with the relevant state agencies and researchers on plankton, fishes, and seabirds in the near shore domain have developed ties with both state and federal (NOAA National Marine Fisheries Service [NMFS], U.S. Fish and Wildlife Service [FWS]) agencies.

5

Barriers To and Constraints On Regional Marine Research

Much of the difficulty in designing and implementing regional marine research in coastal environments is related to fragmentation and poor coordination at all levels of government (Weisberg et al., 1999). Nowhere do the jurisdictions of so many state and federal agencies overlap as in the coastal zone. At least eight federal agencies (U.S. Department of Commerce, U.S. Navy, U.S. Department of Interior, U.S. Department of Transportation, U.S. Department of Energy, the National Science Foundation [NSF], the U.S. National Aeronautics and Space Administration [NASA], and the U.S. Environmental Protection Agency [EPA]) have responsibilities for collecting ocean data and supporting environmental research; and these all have budgets and programs that are reviewed by different Congressional committees and subcommittees. Similar problems exist at the state level, where the problem is compounded by the reality that meaningful regional boundaries usually do not conform to state boundaries. Responsibilities for compliance monitoring, environmental protection, habitat restoration, fisheries management, and land-use management typically reside in different agencies or line offices with little programmatic coordination and collaboration to make the most effective use their combined resources. This ad hoc approach to environmental science and management has led to the implementation of a bewildering array of research and monitoring efforts by state and federal agencies (Malone and Nemazie, 1996). Consequently, individual programs are often underfunded and limited in scope; measurement programs and data management activities often duplicate each other; and monitoring and research are not sufficiently coordinated to effect comprehensive programs that meet societal needs in a timely fashion. These problems can lead to the perception by stakeholders that regional issues are not of sufficient importance to command the attention and funding of government agencies and thus exacerbates the problem.

A related barrier involves the interface between state and federal agencies. In the absence of a national framework for coordination, coastal states find it difficult to engage federal agencies in the development of regional approaches that can be sustained. States are forced to approach individual offices or programs on a case-by-case basis. This requires knowledge of the function of each office or program, how budget priorities are established, how it processes incoming requests, and who the key contacts are. Opportunities for collaboration are further inhibited by competition among federal offices and agencies. Such fragmentation and lack of coordination at the federal level makes the challenge of developing regional programs formidable.

Another constraint relates to the geopolitical boundaries faced by state agencies. Regional research is often difficult to fund at the state level because the region encompassed by the problem of interest crosses state lines. The resulting fragmentation of research effort and resources is wasteful and, when funds are scarce, can prevent the mounting of the type of integrated regional effort that many believe is essential to meet the demand for new knowledge and information.

In addition to barriers caused by intra- and interagency disputes and lack of coordination, there are constraints related to federal legislation and policies. The Migratory Bird Act (MBA; 1918), the National Environmental Policy Act (NEPA; 1969), the Marine Mammal Protection Act (MMPA; 1972), the Endangered Species Act (ESA; 1973), and the Magnuson-Stevens Act (MSA; 1976) as amended by the Sustainable Fisheries Act (SFA; 1996), identify the responsibility for federal and state agencies to maintain and improve the quality of the nation's ecosystems. However, they also challenge managers with the task of balancing competing social values and rendering decisions based on little or no scientific knowledge. Further, legislation is often couched in loosely defined terms (Limburg et al., 1986), with little agreement on definitions of environmental health, ecosystem stability, or biodiversity. As shown below, these can lead to conflicting goals with "winners" and "losers," complicating both management efforts and research planning in support of these efforts.

Human interference with the cascade of trophic influences from sea otters through sea urchins to benthic algae (Estes and Palmisano, 1974; Estes and Duggins, 1995) provides a textbook example of ecological principles (Levin, 1988). Management challenges arise at every trophic level. Sea otters compete with human harvesters for sea urchins and abalone but are themselves in steep population decline, perhaps due to killer whale predation (Estes et al., 1998). However, the white abalone are nearing extinction, which invokes the ESA. Hence protection for one species, sea otters, will threaten the survival of another species, the abalone, and contribute to the loss of the valuable sea urchin and abalone fisheries. In Alaskan waters, changes in the walleye pollock and northern sea lion populations may also be involved. This makes the situation almost intractable, with most major species protected by the MMPA or ESA. As Levin (1988) noted, the web of ecological interactions, where sea otters play a central role, provides a classic example "in which multiple uses of the ecosystem are at odds and in which the diverse interests of different segments of society must be accommodated equitably."

Another example is afforded by interactions involving the bald eagle and the peregrine falcon, both of which have been de-listed from ESA protection, having recovered from steep declines in population abundance caused by dichlorodiphenyltrichloroethane (DDT)-induced egg shell thinning and subsequent nesting failures. Both species are "apex" predators and now enjoy protection under the MBA, with their recovery often highlighted as conservation success stories. However, the consequences of this success to their prey species are rarely considered. Paine et al. (1990) identified peregrine predation as the likely cause of the decline of two seabird populations. Parrish et al. (personal communication) suggest eagle presence and to a lesser degree predation, as the likely cause for the decline in Washington State common murre populations.

The management dilemma is whether or not successful restoration of apex predators, benefitting from and protected by federal laws, is compatible with the maintenance of sustainable prey populations. It is unlikely that bald eagles will ever be culled like wolves, and peregrine management has gone little beyond trapping the offending bird and releasing it elsewhere. In another instance, management actions to protect another predator, the California sea lion, contributed to the decline of the native steelhead salmon.

The implications of federal legislation for both the nature and implementation of research, and any subsequent management initiatives derived from regional marine research programs, are uncertain. Effective management will probably remain difficult, if not impossible, as long as certain species are "off limits." In such circumstances, the imposing body of legislation, while achieving some desired goals, also creates substantial challenges, which can act as a constraint to regional marine research programs.

In this period of limited resources and more powerful technology, it is incumbent on researchers and managers to work together to share resources, research platforms, data, personnel, and expertise. There are greater opportunities for these exchanges, within a regional research framework. Individual agency or institutional research programs often impose limits on specific research endeavors. Limits can be posed by contracting and personnel protocols or other logistic elements that are often not designed with research objectives as a goal. The collective skills and talents within a regional research framework can help compensate for these obstacles. A regional framework can help address the issues that arise from fragmented approaches including: (1) the cost in time and money required to integrate data from disparate sources (different databases, data collected on different time and space scales, different methods, etc.); (2) the lack of data of sufficient resolution, duration, and spatial extent to detect patterns of variability; (3) the lack of a data management infrastructure to disseminate and archive data of known quality; and (4) the lack of analytical capabilities to assimilate large volumes of data, to visualize the current status of ecosystems, and to predict change. Federal and state agencies can and should work to improve regional coordination of research, monitoring, and data management in support of environmental science and management, public education, and private sector applications.

On a practical level, the framework of a regional research program can enhance coordinated multiagency and institution responses to both short- and long-term environmental crises (e.g., oil spill, harmful algal bloom). Well-organized and knowledgeable regional research teams can take advantage of environmental crises or forecasted climatic events to examine the ecosystems response during and following a perturbation.

6

Conclusions and Recommendations

CONCLUSIONS

Regional Marine Research Supports Effective Environmental Policies

Coastal and marine regions include some of the nation's most complex and valuable environments. The intersection of terrestrial and oceanic influences makes these areas particularly vulnerable to the impacts of human activities and changing climate. High nutrient runoff from agricultural lands, toxic contamination, drainage of wetlands, disposal of dredge material, global climate change, rising sea level, and severe coastal storms (e.g., hurricanes) all present environmental challenges for preserving natural resources, protecting human health and safety, and maintaining the esthetic and economic value of coastal areas; challenges that will become more pronounced over the next several decades. The formulation and implementation of sound environmental policies to meet these challenges requires programs that integrate research and monitoring to develop the ability to predict the consequences of human actions on these valuable but vulnerable coastal ecosystems.

Detecting, assessing, predicting, and mitigating the effects of natural perturbations and human-induced stresses on coastal ecosystems sometimes requires a broader, regional perspective to evaluate local changes in marine ecosystems that may be influenced by larger scale changes in climate, ocean circulation, fishing activities, and land-use practices[1]. The need for regional marine research is rooted

[1]One example is the impact of nutrient over-enrichment on coastal water quality, which is the subject of an ongoing NRC study. The tentative title of this report is *Nutrient Over-Enrichment in Coastal Waters: Strategies for Managers and Scientists.* The report is expected to be released in late-January 2000.

in the need to address issues based on the geographic scale of the system, rather than on political boundaries. Scientifically-based management of the environment and living resources depends on the ability to understand the system as a whole; often this may be accomplished through regional-scale research and monitoring. Regional approaches also promote coordination of the efforts of local, state, and federal programs; enable the timely analysis of data; and supply the information needs of resource managers and policymakers. Regional programs can provide resource managers and policymakers with better information to respond to stresses in coastal aquatic ecosystems, for example, tracing the fates of nutrients and chemical contaminants, identifying the causes of fish kills or mass mortalities of birds and marine mammals, or predicting the impacts of habitat loss, alterations of freshwater flows, or dredging (see also Table 1-1).

Despite these advantages, there is a dearth of regional programs with approaches to research and monitoring that are integrated and sustained sufficiently to develop an understanding of processes and changes that occur on the timescale of decades. The primary barriers to the development of such programs have been fragmentation of effort and poor coordination among and within government agencies, lack of public awareness and support, and the unpredictable nature of funding. These factors have decreased the cost effectiveness of existing programs and reduced their ability to serve a broad spectrum of user needs in a timely fashion. By formulating and implementing plans for regional marine research and monitoring that are nationally coordinated and locally relevant, a wider array of users will be served more effectively.

Processes for Defining Regional Research Needs

Responsibility for identifying research needs, setting priorities, and defining goals typically falls to some combination of scientists, educators, legislators, representatives of industries, conservation groups, and the state and federal agencies involved in environmental research and management. Chapter 3 of this report describes three approaches to developing regional research plans that emphasize the involvement of one or more of these groups:

Community Plans

Community-based planning is the most inclusive approach, relying on bottom-up[2] stakeholder involvement in all stages of the planning process from defining information needs, to setting goals and priorities, to assessing the effective-

[2] In this report, "bottom up" refers to the broad spectrum of users in the target region and "top-down" refers to the program offices in the relevant federal agencies.

ness of the program. Benefits of this approach include improved communication and mutual education among the groups of stakeholders, development of community support, and better coordination among local, state, and federal agencies. However, such a process tends to be more time consuming, and plans for research and monitoring may lack focus because of the disparate views of the community. Elements of this style of planning have been used in the Regional Marine Research Program (RMRP) run by the National Oceanic and Atmospheric Administration's (NOAA) Sea Grant Program, and in the National Estuary Program, run by the U.S. Environmental Protection Agency (EPA).

Scientists' Plans

Planning within the scientific community is a less inclusive, bottom-up approach that primarily involves funding agencies and scientists. The agencies specify the topics of interest, provide guidelines, and manage the competition for funds, while the scientists define the goals and develop the research plans. This process excels in developing cutting-edge research programs through a competitive process dependent primarily on peer review, but represents the interests of scientists and agencies and is not necessarily responsive to the priorities of other stakeholders. Most of these programs are organized through the National Science Foundation (NSF); a few are discussed in this report, including Land Margin Ecosystems Research (LMER), Coastal Ocean Processes (CoOP), and Global Ocean Ecosystems Dynamics (GLOBEC).

Agency Plans

Agency planning, a top-down approach, emphasizes the responsibilities of program managers for defining research topics, setting priorities, and establishing goals for research programs. Frequently, these programs involve researchers from within the agencies as well as academic researchers. The process may involve substantial input from scientists, resource managers, or elected officials, and frequently includes some level of peer review. Although this approach allows mission agencies such as NOAA and EPA to maintain focus on their responsibilities as defined by Congress, it is also more susceptible to political manipulation in the budget process. Such manipulation can derail the efforts of federal agencies to coordinate more efficient and less redundant regional research programs. In this report, the Coastal Ocean Program (COP) of NOAA and the Louisiana-Texas Shelf Physical Oceanography (LaTex) program of the U.S. Minerals Management Service (MMS) serve as examples of Agency Plans. The NOAA Sea Grant program is a hybrid of agency and community-based planning with research objectives set at the national level and research needs determined at the state level.

Each of these approaches has components that should be incorporated into the design and implementation of new regional marine research programs. The goal is to develop a balanced process that incorporates elements from both top-down and bottom-up approaches. Community-based planning helps develop programs that effectively address issues that are locally relevant, and helps promote continued public and political support for sustained funding. Agency planning is needed to maintain the linkage between research and the application of new knowledge to address societal needs and to enable national coordination for timely data analysis and information exchange. Science-based planning is required to incorporate the most recent scientific knowledge, methods, and technology.

In addition to these three types of planning activities, legislative mandates are recognized as another process that defines regional marine research needs. There are at least two categories of legislatively-mandated research. The first involves legislation that explicitly establishes a research program with defined goals and guidelines for funding. The RMRP is an example of a program established by law. In the second category, research is not the target of the law, but is implicit because research is required to achieve the legislative mandate. Examples include the Sustainable Fisheries Act and the Endangered Species Act. These examples also illustrate the problem of “unintended consequences,” and the importance of understanding costs and benefits in terms of the effects of legislation on both the research agenda and the ability to control environmental impacts and manage living resources. Regional marine research that embraces an ecosystem-based strategy should provide the knowledge required to support the decisionmaking processes required by environmental legislation.

RECOMMENDATIONS

Enabling Regional Marine Research

The review of regional marine research programs and the barriers to their implementation revealed essential elements and actions that will be required for the successful development of a regional approach to marine research and monitoring in coastal ecosystems. A program for regional marine research should incorporate the following elements:

- Involve all stakeholders in the planning and implementation of regional programs through workshops, advisory councils, and boards;
- Build a program that is more than the sum of its parts through more effective use of existing resources and research projects, and facilitate multiple uses of data to serve the needs of a variety of users;
- Facilitate ongoing interactions among monitoring programs (to reveal spatial and temporal patterns of change), hypothesis-driven research (to determine underlying causes of change), and modeling (to predict change and the consequences of change);

- Provide the flexibility to define the boundaries of the program to match the geography of the issue to be addressed;
- Develop an integrated data management system that uses common protocols and formats, provides quality assurance, enables timely dissemination and analysis of data, allows rapid access to integrated data from disparate sources, and provides long-term data archiving;
- Develop procedures to react to unanticipated events with a coordinated and rapid response;
- Establish a communications network that effectively links political, social, economic, and environmental interests in the design, implementation, and evolution of the program for more effective science education, public outreach, economic development, and management of ecosystems and living resources;
- Facilitate adaptive management strategies by assessing the efficacy of environmental policies and testing alternative approaches.
- Ensure sustained public and political support for stable funding through outreach activities that increase awareness of current research activities, describe changes in the health of coastal ecosystems, and explain how the results of research and monitoring are used to support environmental decisionmaking.

This last element, building public and political support, is essential to the success of regional research programs. The proponents of regional marine research must clearly articulate the ecological, economic, and social benefits of a regional approach to overcome the general lack of awareness of the potential benefits of research among decisionmakers and the public. In many cases, environmental research does not require a regional approach. Smaller, less comprehensive projects that produce quick results and have time scales consistent with annual budget processes are easier to fund, provide less financial exposure, and require less effort to promote and organize. In short, proponents of regional marine research need to clearly and concisely explain why an issue cannot be addressed from a local perspective, but requires a regional approach, to justify spending substantial and continuing funds for these programs.

Governance Structures to Support Regional Marine Research

Integration of the diversity of interests, missions, and priorities of all the stakeholders (local, state, and federal governments, the scientific community, industry, conservation groups, and others) presents formidable challenges. Also, regional marine research must serve many needs, including those of science education, basic research, and the application of scientific information for the purposes of society. At present, there is no governance structure that contains all of the elements of a regional program as recommended above. Regional programs require a governance structure that enables both bottom-up programmatic development through regional organizations of stakeholders and top-down coordination by federal agencies and national organizations.

Bottom-up regional organizations of stakeholders provide integration of efforts at the local, state, and regional level and should be involved in the establishment of research priorities, research planning and implementation, program evaluation, and product development. Through the participation of stakeholders, this approach also may contribute to efforts to develop support for regional programs, establish programs for public education on environmental issues, and provide avenues of communication for distribution of research products.

Top-down coordination of federal and state agencies is necessary to develop national environmental policies, to promote cross-fertilization of information and technology development, and to enable efficiencies in the design and implementation of regional programs. National leadership will be needed to manage the data resources developed through regional programs, to ensure long-term archiving of data, and to establish national standards for measurements, metadata, and dissemination.

Robert Wall, former Chairman of the Gulf of Maine Regional Marine Research Board (GOM-RMRP), in a letter to this committee, described some of the problems faced by the RMRP that will need to be overcome in future programs for regional marine research:

> There were also some limitations in the RMRP that should be recognized and dealt with in developing any successor program. One was the lack of a long-term, continuing state and national commitment. Both the scientific and resource management arguments for such a commitment are persuasive now and becoming more so as time passes. A second and more fundamental limitation derived from the RMRP's origins as a congressional initiative. Then Senator Mitchell held several hearings on the need for regional marine research and purposefully made the RMRP a national initiative. However, it suffered from the lack of a supportive home agency, turf battles within the Senate and NOAA, and the zero-sum budgeting mentality prevailing (understandably) at that time. I also believe its unusual and multi-faceted partnership character made it unattractive for any entity to seriously push for it.

The lack of a stable funding mechanism prevented implementation of the RMRP nationally, and limited the accomplishments of the GOM-RMRP by funding this program for only 5 of the 10 years planned. The success of a regional approach will depend on programs that are comprehensive in design and enjoy continuity of support beyond the annual funding cycles of state and federal governments. All decisions should be open to public scrutiny, and funding should be allocated based on peer review by experts who do not stand to benefit directly from the allocation of funds. Funding must be performance-based, sustained, and predictable to reap the optimal benefits from a regional effort. At the same time, the program must enable individual agencies and institutions to fulfill their respective missions. One, or some combination, of the following funding mechanisms could be adapted to support regional programs:

- Funding provided by a single "lead agency" with a commitment from the Office of Management and Budget (OMB) and Congress that funds are for an interagency, nationally-coordinated network of regional programs. A single agency would be responsible for leadership, budget planning, and the allocation of funds. Implementation would involve an interagency committee, perhaps together with a federal advisory committee to include non-federal user groups. NOAA's RMRP provides a possible model for such an approach.
- Multiagency funding committed via an interagency Memorandum of Agreement (MOA) and coordinated by an interagency committee with agency-specific funding of projects.
- Funding decisions made by an interagency program office with funds provided by participating agencies. Policies and procedures for the operation of the office and allocations of funds would be established by a steering committee. The office would be operated under the auspices of a host agency.

The last two of these funding options require coordination through an interagency program. The National Oceanographic Partnership Program (NOPP) is one example of an interagency group that could serve as a vehicle for implementing a coordinated, comprehensive program of regional marine research and monitoring. The National Oceanographic Partnership Act (P.L. 104-201) established NOPP to "advance economic development, assure national security, protect the quality of life, and strengthen science and education through improved knowledge of the oceans." To achieve these goals, NOPP was established as a partnership of government agencies (U.S. Navy, NSF, U.S. Department of Energy, U.S. National Aeronautics and Space Administration, NOAA, EPA, U.S. Geological Survey, MMS, U.S. Coast Guard, OMB, and the Office of Science and Technology Policy), that is guided by the Ocean Research Advisory Panel of non-government experts. The role of NOPP is to integrate national efforts and coordinate national investments in ocean research and education. If NOPP were to implement regional marine research, a formal interagency MOA would need to be signed by participating agencies to define roles and responsibilities and to ensure balanced and sustained funding. Additionally, regional programs will require funding partnerships with coastal states in the target regions.

While NOPP is a promising mechanism for interagency coordination of regional marine research initiatives, it is still a new program and hence lacks a record of successful agency cooperation. Also, it is uncertain that NOPP, with its very broad mandate, will have sufficient resources to address the specific organizational needs of regional marine research programs. These programs will require a regional governance structure similar to the management framework established for the Chesapeake Bay Program or the GOM-RMRP.

In all three of the funding models described, leadership at the national level will be required to ensure the quality of the research and coordination of regional and national programs. NOAA has run a variety of regional programs and has extensive experience with, and responsibility for, addressing coastal issues. However, the diffusion of effort throughout several NOAA offices creates challenges both for establishing stable funding for regional initiatives and for developing cooperative programs with other federal and state agencies as envisioned in this report.

Previous NOAA programs have not fulfilled the goals for regional research as envisioned by this committee. Research supported by the National Sea Grant College Program tends to be limited in geographic scope, and Sea Grant has institutional barriers that hinder or preclude research efforts that span state or international borders. Although the RMRP planning process was regional in scope, in most cases it was also constrained by political boundaries. Valuable information and perspectives can be found in the RMRP plans, hence, it is disappointing that there was so little follow-through on the extensive RMRP planning efforts, and research effort in the case of the GOM-RMRP. **It is important that regional marine research programs be structured, planned, and implemented for the long-term**.

The COP has planned and implemented several regional-scale, interdisciplinary research programs, such as Nutrient Enhanced Coastal Ocean Productivity (NECOP), South Atlantic Bight Recruitment Experiment, and Southeast Bering Sea Carrying Capacity. All of these programs have produced valuable research findings. However, these programs are limited in time (usually to five years), and sometimes lack context due to insufficient emphasis on sustained observations. Research planning has been less inclusive of stakeholders for the COP than for the RMRP or the National Estuary Program sites. There have been problems in integrating research planning, implementation, and resources with those of other agencies working within the target regions. Also, there is no mechanism to ensure that research efforts are distributed among the different regions of the country, and COP has not implemented a balanced national program. **A national program for regional research should integrate the efforts of the various agencies at local, state, and federal levels through cooperative planning and should make a programmatic commitment to distribute funds to meet the research needs of each coastal region.**

Recommendations for NOAA

Regional marine research presents special challenges in its planning and implementation, but it is essential for resolving urgent and serious problems of the coastal ocean. Many federal and state agencies, universities, and private groups contribute to coastal research, but none have NOAA's broad mandate for marine environmental research. Therefore, the committee concludes that it is NOAA's responsibility to provide leadership in developing regional marine research programs. Because neither NOAA nor any other group has the resources to do the entire task, part of NOAA's leadership responsibility is to promote interagency cooperation and coordination at the federal level and to muster the assets of the many interested organizations at local and state levels to achieve the most effective regional research programs.

No one program within NOAA is the obvious choice to spearhead this effort. NOAA has devoted substantial resources to coastal ocean research and management, and has achieved some success in addressing coastal ocean problems from a regional perspective, such as the GOM-RMRP and NECOP initiatives described in this report. However, it is unlikely that NOAA can implement the recommendations in this report unless senior NOAA management designates responsibility for regional marine research to a single office within NOAA. Although several NOAA programs have important resources to contribute, a single office should be given the responsibility, as well as sufficient authority, to provide direction, overall coordination, and oversight to create regional initiatives that best serve local, state, and national interests.

In summary, the governance of a regional marine research program depends on: (1) coordination and collaboration among agencies at state and federal levels to provide the capacity to plan and support regional research; (2) integration of effort at the federal level to ensure national credibility and timely exchange of information and technology among regions; (3) planning that involves stakeholders at the local, state, and regional level to develop programs that address regional needs; and (4) mechanisms to enable federal and multi-state collaboration in the allocation of funds for regional research.

References

Anderson, D. M. 1997. Bloom dynamics of toxic *Alexandrium* species in the northeastern U.S. *Limnology and Oceanography* 42, no. 5 II: 1009-22.

Anderson, D. M., W. R. Geyer, Bradford Butman, Richard P. Signell, Peter J. S. Franks, and Theodore C. Loder III. 1998. "RMRP Final Technical Progress Report, Project GMR-20." Web page, [accessed 13 September 1999]. Available at http://crusty.er.usgs.gov/wgulf/final_report/rmrp_final.htm.

Baumgartner, T. R., A. Soutar, and V. Ferreira-Bartrina. 1992. Reconstruction of the history of the Pacific sardine and northern anchovy populations over the past two millenia from sediments of the Santa Barbara Basin. *CalCOFI Reports* 33: 24-40.

Boesch, D. F. 1996. Science and management in four U.S. coastal ecosystems dominated by land-ocean interactions. *J. Coastal Conservation* 2: 103-14.

Boynton, W. R., W. M. Kemp, and C. W. Keefe. 1982. A comparative analysis of nutrients and other factors influencing estuarine phytoplankton production. *Estuarine Comparisons*. V. S. Kennedy, ed. New York, NY: Academic Press. pp. 69-90.

Brink, K. H., J. M. Bane, T. M. Church, C. W. Fairall, G. L. Geernaert, D. S. Gorsline, R. T. Guza, D. E. Hammond, G. A. Knauer, C. S. Martens, J. D. Milliman, C. A. Nittrouer, C. H. Peterson, D. P. Rogers, M. R. Roman, and J. A. Yoder. 1990. Coastal Ocean Processes (CoOP): Results of an Interdisciplinary Workshop. Woods Hole, MA: Woods Hole Oceanographic Institution. 51 pp.

Brink, K. H., J. M. Bane, T. M. Church, C. W. Fairall, G. L. Geernaert, D. E. Hammond, S. M. Henrichs, C. S. Martens, C. A. Nittrouer, D. P. Rogers, M. R. Roman, J. D. Roughgarden, R. L. Smith, L. D. Wright, and J. A. Yoder. 1992. Coastal Ocean Processes (CoOP): A Science Prospectus. Woods Hole, MA: Woods Hole Oceanographic Institution Technical Report. 88 pp.

Brodeur, R. D., B. W. Frost, S. R. Hare, R. C. Francis, and W. J. Ingraham, Jr. 1996. Interannual variations in zooplankton biomass in the Gulf of Alaska, and covariation with California Current zooplantkon biomass. *CalCOFI Reports* 37: 80-99.

Brown, W. S. 1998. Wind-forced pressure response of the Gulf of Maine. *Journal of Geophysical Research-Oceans* 103, no. C13: 30661-78.

California Cooperative Oceanic Fisheries Investigations (CalCOFI). 1950. Introduction. *CalCOFI Progress Report*. p. 7-8.

Carnegie Commission on Science, Technology, and Government. 1992. International Environmental Research and Assessment. Proposals For Better Organisation and Decision Making. New York.

Chelton, D. B., P. A. Bernal, and J. A. McGowan. 1982. Large-scale interannual physical and biological interaction in the California Current. *J. Mar. Res.* 40: 1095-125.

Chesapeake Bay Program (CBP). 1999. "Chesapeake Information Management System." Web page, [accessed 27 October 1999]. Available at http://cims.chesapeakebay.net.

Cloern, J. E. 1996. Phytoplankton bloom dynamics in coastal ecosystems: a review with some general lessons from sustained investigation of San Francisco Bay, California. *Reviews of Geophysics* 34: 127-68.

Committee on Environment and Natural Resources Hypoxia Work Group (CENR). 1998. "Gulf of Mexico Hypoxia Assessment Plan." Web page, [accessed 10 October 1999]. Available at http://www.cop.noaa.gov/HypoxiaPlan.html.

Culliton, T. J., M. A. Warren, T. R. Goodspeed, D. G. Remer, D. G. Blackwell, and J. MacDonough. 1990. 50 years of population change along the nation's coasts, 1960-2010. *Coastal Trend Series Report.* Rockville, Maryland: NOAA Strategic Assessments Branch. p. 41.

Estes, J. A., and D. O. Duggins. 1995. Sea otters and kelp forests in Alaska: generality and variation in a community ecology paradigm. *Ecological Monographs* 65: 75-100.

Estes, J. A., and J. F. Palmisano. 1974. Sea Otters: Their role in structuring nearshore communities. *Science* 185: 1058-60.

Estes, J. A., M. T. Tinker, T. M. Williams, and D. F. Doak. 1998. Killer whale predation on sea otters linking oceanic and nearshore ecosystems. *Science* 282: 473-76.

Francis, R. C., and S. R. Hare. 1994. Decadal-scale regime shifts in the large marine ecosystems of the North-east Pacific: a case for historical science. *Fish. Oceanography* 3: 279-91.

Gargett, A. E. 1997. The optimal stability 'window': a mechanism underlying decadal fluctuations North Pacific salmon stocks? *Fish. Oceanography* 6: 109-17.

Gulf of Maine Regional Marine Research Program (GOM-RMRP). 1992. Gulf of Maine Research Plan. Orono, ME: The Land Grand University and Sea Grant College of Maine. 133 pp.

H. John Heinz III Center for Science, Economics and the Environment. 1999. "The H. John Heinz III Center for Science, Economics and the Environment Home Page." Web page, [accessed 27 October 1999]. Available at http://www.heinzctr.org.

Hennessey, T. M. 1994. Governance and adaptive management for estuarine ecosystems: The case of Chesapeake Bay. *Coastal Management* 22: 119-45.

Hinrichsen, D. 1998. Coastal Waters of the World: Trends, Threats, and Strategies. Washington, D.C.: Island Press. 275 pp.

Kazancigil, A. 1998. Governance and science: market-like modes of managing society and producing knowledge. *International Social Science Journal*: 69-79.

Lee, K. N. 1993. Greed, scale mismatch, and learning. *Ecological Applications* 3: 560-564.

Levin, S. A. 1988. Sea otters and nearshore benthic communities: a theoretical perspective. *The Community Ecology of Sea Otters.* G. R. Van Blaricom and J. A. Estes, eds. Berlin, Germany: Springer-Verlag. pp. 202-9.

Limburg, K. E., S. A. Levin, and C. C. Harwell. 1986. Ecology and estuarine impact assessment: lessons learned from the Hudson River USA and other estuarine experiences. *J. Environmental Management* 22: 255-80.

Malone, T. C., and L. W. Botsford. 1998. "Interactions and exchanges among coastal ecosystems on multiple spatial and temporal scales." Ocean Ecology, Understanding and Vision for Research (OEUVRE). An NSF-Sponsored Workshop on the Future of Biological Oceanography.

Malone, T. C., W. Boynton, T. Horton, and C. Stevenson. 1993. Nutrient loading to surface waters: Chesapeake Bay case study. *Keeping Pace With Science and Engineering*. M.F. Uman, ed. Washington, DC: National Academy Press. pp. 8-38.

Malone, T. C., and D. A. Nemazie. 1996. Toward a national agenda for research in the coastal zone: where are we? *Biological Bulletins* 190: 245-51.

McGowan, J. A. 1985. El Niño 1983 in the Southern California Bight. *El Niño North: Niño Effects in the Eastern Subarctic Pacific Ocean.* W.P. Wooster, and D. L. Fluharty, eds.. University of Washington Press. pp. 166-84.

Morris, I., and W. H. Bell. 1988. Coastal seas governance: an international project for management policy on threatened coastal sea. *Maryland Law Review* 47: 481-96.

National Ocean Service. 1999. "Publications and Products: National Centers for Coastal Ocean Science Gulf of Mexico Hypoxia Assessment." Web page, [accessed 29 October 1999]. Available at http://www.nos.noaa.gov/products/pubs_hypox.html.

National Oceanic and Atmospheric Administration (NOAA). 1991. NOAA's Coast Ocean Program: Science for Solutions, Prospectus for Fiscal Years 1993-1997. Washington, DC: U.S. Department of Commerce.

———. 1998. "Population: Distribution, Density and Growth. NOAA's State of the Coast Report." Web page, [accessed 10 December 1999]. Available at http://state-of-coast.noaa.gov/bulletins/html/pop-01/intro.html.

National Research Council (NRC). 1990a. Managing troubled waters, the role of marine environmental monitoring. Washington, DC: National Academy Press. 125 pp.

———. 1990b. Monitoring Southern California's Coastal Waters. Washington, DC: National Academy Press. 170 pp.

———. 1992. Oceanography in the Next Decade: Building New Partnerships. Washington, DC: National Academy Press. 202 pp.

———. 1994a. A Review of the Accomplishments and Plans of the NOAA Coastal Ocean Program. Washington, DC: National Academy Press. 115 pp.

———. 1994b. Priorities for Coastal Ecosystem Science. Washington, DC: National Academy Press. 106 pp.

———. 1995. Science, Policy and the Coast. Washington, DC: National Academy Press. 85 pp.

———. 1997. Striking a Balance: Improving Stewardship of Marine Areas. Washington, D.C.: National Academy Press. 177 pp.

———. 1998. Opportunities in Ocean Science: Challenges on the Horizon. Washington, DC: National Academy Press. 6 pp.

———. 1999. Building Ocean Science Partnerships: The United States and Mexico Working Together. Washington, D.C.: National Academy Press. 123 pp.

———. 2000. Nutrient Over-Enrichment in Coastal Waters: Strategies for Managers and Scientists. Washington, D.C.: National Academy Press.

Nixon, S. W. 1996. Regional coastal research - What is it? Why do it? What role should NAML play? *Biological Bulletins* 190: 252-59.

Orth, R. J., and K. A. Moore. 1983. Chesapeake Bay: Unprecedented decline in submerged aquatic vegetation. *Science* 222: 51-53.

Paine, R. T., J. T. Wooton, and P. D. Boersma. 1990. Direct and indirect effects on peregrine falcon predation on seabird abundance. *The Auk* 107: 1-9.

Parrish, J. K., and S. Breslow. 1999. PNCERS 1998 Annual Report. Submitted to Coastal Ocean Program, NOAA. 54 pp. + Append

Parrish, J. K., M. Marvier, and R. T. Paine. In preparation. Changing significance of direct and indirect effects at a Common Murre colony subjected to increasing Bald Eagle predation.

Polovina, J. J., G. T. Mitchum, and G. T. Evans. 1995. Decadal and basin-scale variation in mixed layer depth and the impact on biological production in the Central and North Pacific, 1960-1988. *Deep-Sea Research* 42: 1701-16.

Powell, Thomas. 1989. Physical and Biological Scales of Variability in Lakes, Estuaries, and the Coastal Ocean. *Perspectives in Theoretical Ecology*. J. Roughgarden, R.M. May, and S.A. Levin, eds. Princeton, N.J.: Princeton University Press. pp. 157-80.

Public Law (P.L.) 101-593. 1990. South Carolina Fish Hatchery Act, Amendment to Marine Protection Research and Sanctuaries Act. *Title III-IV - Regional Marine Research Programs.*

Public Law (P.L.) 104-201. 1996. National Oceanographic Partnership Act.

Public Law (P.L.) 104-267. 1996. Sustainable Fisheries Act.

———. 1995. The Santa Monica Bay Restoration Plan - Public Summary. Los Angeles, California.

Scheiber, H. N. 1990. California marine research and the founding of modern fisheries oceanography: CalCOFI's early years, 1947-1964. *CalCOFI Reports.* 31: 63-83.

———. 1995. Success and Failure in Science-Policy Interactions: Cases from the History of California Coastal and Ocean Studies, 1945-1973. *Improving Interactions Between Coastal and Science Policy: Proceedings of the California Symposium.* Washington, D.C.: National Academy Press. pp. 97-122

Smith, P. E. 1995. A warm decade in the Southern California Bight. *CalCOFI Reports.* 36: 120-126.

Soutar, A., and J. D. Isaacs. 1974. Abundance of pelagic fish during the 19th and 20th centuries as recorded in anaerobic sediments off the Californias. *Fish. Bull.* 74: 257-94.

Steele, J. H. 1985. A comparison of terrestrial and marine ecological systems. *Nature* 313: 355-58.

U.S. Army Corps of Engineers (ACE), U.S. Environmental Protection Agency (EPA), San Francisco Bay Conservation and Development Commission (BCDC), San Francisco Bay Regional Water Quality Control Board (SF BRWQCE), and State Water Resources Control Board (SWRCB). 1998. "Long-Term Management Strategy (LTMS) for the Placement of Dredged Material in the San Francisco Bay Region." Web page, [accessed 16 September 1999]. Available at http://www.spn.usace.army.mil/ltms/.

U.S. Department of Agriculture (DOA), U. S. Environmental Protection Agency (EPA), U. S. Department of the Interior (DOI), U. S. Department of Defense (DOD) including U. S. Army Corps of Engineers, U. S. Department of Commerce (DOC), Tennessee Valley Authority, U. S. Department of Energy (DOE), U. S. Department of Transportation (DOT), and U. S. Department of Justice (DOJ). 1999. "U.S. Clean Water Action Plan (CWAP) First Anniversary Report." Web page, [accessed 5 November 1999]. Available at http://cleanwater.gov/anniv/.

U.S. Department of Commerce. 1992. Our living oceans: Report on the status of U.S. living marine resources. 147 pp.

U.S. Geological Survey (USGS). 1999. "Research Environmental Data and Information Management System (REDIMS) for the Gulf of Maine." Web page, [accessed 29 October 1999]. Available at http://oracle.er.usgs.gov/GoMaine/index.htm.

U.S. GLOBEC. 1991. Initial Science Plan. Report Number 1. 93 pp.

Weisberg, S. B., T. L. Hayward, and M. Cole. 1999. Towards a U.S. Global Ocean Observing System: A synthesis of lessons learned from previous coastal monitoring efforts. Challenges and Promise of Designing and Implementing an Ocean Observing System for U.S. Coastal Waters. U.S. Coastal GOOS Workshop Report.

Wiseman Jr., W. J., ed. 1999. Nutrient Enhanced Coastal Ocean Productivity in the Gulf of Mexico - Understanding the Effects of Nutrients on a Coastal Ecosystem. Silver Spring, MD: NOAA Coastal Ocean Office.

Wolf, P. 1992. Recovery of the Pacific sardine and the California sardine fishery. *CalCOFI Reports* 33: 76-86.

Appendixes

A

Committee and Staff Biographies

COMMITTEE MEMBERS

Thomas Malone received his Ph.D. in biology from Stanford University in 1971. He currently serves both as a professor at the University of Maryland and as the director of the University of Maryland's Center for Environmental Science Horn Point Laboratory. Dr. Malone is the president of the American Society of Limnology and Oceanography and the chair of a United Nations Panel for the Coastal Module of the Global Ocean Observing System. His primary areas of research are phytoplankton ecology, nutrient cycling in aquatic systems, and the dynamics of coastal ecosystems.

Brian Baird received his B.A. in environmental studies from the University of California at Santa Barbara in 1977. He manages California's Ocean Resources Management Program, featured in the U.S. Pavilion at World Expo 98 held in Lisbon, Portugal. Mr. Baird is chair of the Resources Agency Sea Grant Advisory Panel, co-chair of the NOAA/States Science Working Group, and was a Vice-Chair for the international conference, "California and the World Ocean '97." His primary area of expertise is ocean resource management.

Margaret Mary Brady received her M.S. in botany from the University of Rhode Island in 1982. She served as the director of the Massachusetts Office of Coastal Zone Management and assistant secretary for the Massachusetts Office of Environmental Affairs from 1993 to 1999. She is currently with the Bureau of Strategic Policy and Technology at the Massachusetts Department of Environmental Protection. Ms. Brady's expertise is in coastal zone management, including aquaculture, coastal pollution remediation, and wetlands protection regulation programs.

Robert Dean received his Sc.D. in civil engineering from the Massachusetts Institute of Technology in 1959. He is currently a graduate research professor in the Coastal and Oceanographic Engineering Department of the University of Florida, Gainesville. Dr. Dean's research interests include: physical oceanography, coastal engineering, beach erosion problems, sea level changes, and tidal inlets and coastal structures.

D. Jay Grimes received his Ph.D. in microbiology from Colorado State University in 1971. He currently serves as the director of the Institute of Marine Sciences at the University of Southern Mississippi. Dr. Grimes was the Director of the Sea Grant College Program at the University of New Hampshire from 1987-1990 and was a program manager at the Department of Energy from 1990-1996. Dr. Grimes research interests include the microbiology of waste disposal and environmental contaminants and the microbiological quality of water resources.

Susan Henrichs received her Ph.D. from the Woods Hole Oceanographic Institution-Massachusetts Institute of Technology Joint Program in 1980. She is currently a professor of marine science at the University of Alaska, Fairbanks. Dr. Henrichs' primary areas of research are organic matter decomposition and carbon and nutrient cycles in the marine environment.

John Knauss received his Ph.D. in oceanography from the Scripps Institution of Oceanography, University of California in 1959. He was the Dean of the University of Rhode Island's Graduate School of Oceanography from 1962 to 1987 and the NOAA Administrator from 1989 to 1993. Dr. Knauss is currently a research associate at the Scripps Institution of Oceanography and is still associated with the University of Rhode Island. He also serves as the current president of the American Geophysical Union. Dr. Knauss' research interests include ocean circulation, law of the sea, and marine affairs. He is a member of the Ocean Studies Board.

John Bradford Mooney, **Jr**. served in the U.S. Navy for 38 years, 9 as an Admiral. During that time he served as Chief of Naval Research (1983-1987), a position in which he managed the research program for the Navy. From 1981-1983, Admiral Mooney was the Oceanographer of the Navy and Navy Deputy to NOAA where he directed the U.S. Navy Oceanography, Meteorology and Hydrographic Survey organization. Admiral Mooney also served as the President and Managing Director of Harbor Branch Oceanographic Institution, Inc. from 1989-1992. He is currently an International Consultant, and his interests include marine technology and engineering. He is a member of the National Academy of Engineering.

Michael Mullin received his Ph.D in 1964 in biology from Harvard University. He currently serves as a professor and research biologist with the Scripps Institution of Oceanography (SIO) and as the director of the Marine Life Research Group at SIO. Dr. Mullin's research interests include the ecology of marine plankton, especially energetics and population dynamics of zooplankton.

Robert O'Boyle received his B Sc. and M Sc. from McGill and Guelph University in 1972 and 1975, respectively. He joined the Department of Fisheries and Oceans at the Bedford Institute of Oceanography in 1978 as a stock assessment biologist. Since then, he has conducted assessments on most of the Maritime region's fish resources, including herring, capelin, cod, haddock, pollock, the flatfishes, and more recently, the sharks. In 1987, Mr. O'Boyle became Chief of the Marine Fish Division (MFD) where he directs programs for management of the region's finfish and marine mammal resources. Since 1996, Mr. O'Boyle has served as coordinator of the Regional Advisory Process (RAP) where he is responsible for peer review of the science and advice on the Maritimes Region's finfish, invertebrate and marine mammal resources, on its ocean and habitat management, and on its ocean management practices and approaches.

Robert Paine received his Ph.D. in 1961 from the University of Michigan. He currently serves as a professor in the Department of Zoology at the University of Washington. Dr. Paine's research focuses on the ecological processes producing community structure in marine habitats, particularly the rocky intertidal zone. He has examined the roles of predation and disturbance in promoting coexistence and biodiversity. Dr. Paine is a member of the National Academy of Sciences.

Leslie Rosenfeld received her Ph.D. from the Massachusetts Institute of Technology/Woods Hole Oceanographic Institution Joint Program in Oceanography. She is currently a research associate professor at the Naval Postgraduate School and an adjunct scientist at the Monterey Bay Aquarium Research Institute. She serves on the Research Activities Panel for the Monterey Bay National Marine Sanctuary. Her primary research area is coastal physical oceanography, including such processes as internal waves, tides, and upwelling.

NATIONAL RESEARCH COUNCIL STAFF

Susan Roberts (Study Director) received her Ph.D. in Marine Biology from the Scripps Institution of Oceanography. Dr. Roberts is a program officer for the National Research Council's Ocean Studies Board. Dr. Roberts staffs studies on marine resources and health effects of climate change at the National Research Council. Her research interests include marine microbiology, fish physiology, marine biotechnology, and biomedicine.

Shari Maguire (Research Assistant) received her B.A. from Miami University in 1994. She currently serves as a research assistant with the Ocean Studies Board. Ms. Maguire is studying biological sciences at the University of Maryland in preparation for medical school.

B

Public Meeting Speakers and Presentation Topics

MEETING 1

Radisson Hotel
1500 Canal Street
New Orleans, Louisiana
March 4-6, 1999

Dr. Ronald Baird, Director
National Sea Grant College Program
1315 East-West Hwy, SSMC3, Room 11716
Silver Spring, MD 20910
Topic: *Sponsor Presentation*

Dr. George Crozier
Dauphin Island Sea Lab
101 Bienville Boulevard
Dauphin Island, AL 36528
Topic: *Gulf of Mexico Marine Research Plan*

Dr. Michael Dagg
Louisiana Universities Marine Consortium (LUMCON)
DeFelice Marine Center
8124 Highway 56
Chauvin, LA 70344-2124
Topic: *Scientific Background on Nutrient Enhanced Coastal Ocean Productivity Program (NECOP)*

Dr. James Giattina
U.S. Environmental Protection Agency
Region 4 Gulf of Mexico Program Office
Building 1103, Room 202
Stennis Space Center, MS 39529-6000
Topic: *EPA Gulf of Mexico Program*

Dr. Susan Henrichs
University of Alaska, Fairbanks
Institute of Marine Science
137 Irving II
Fairbanks, AK 99775-7220
Topic: *Review of the Coastal Ocean Processes (CoOP) Program*

Dr. Terry Howey, Director, Coastal Programs and
Dr. Gregory DuCote, Coastal Resources Program Manager
State of Louisiana Department of Natural Resources
Coastal Management Division
P.O. Box 44487
Baton Rouge, LA 70804-4487
Topic: *Impact of Regional Programs on Coastal Zone Management*

Dr. David Johnson
National Oceanic and Atmospheric Administration
1315 East-West Hwy.
Room 9608, Bldg. 3
Silver Spring, MD 20910
Topic: *Coastal Ocean Programs (NECOP and others)*

Dr. Alexis Lugo-Fernandez
Gulf of Mexico OCS Region (MS 5433)
1201 Elmwood Park Blvd.
New Orleans, LA 70123-2394
Topic: *Louisiana-Texas Shelf Physical Oceanography Program (LaTex)*

Dr. Donald Scavia, Director, National Centers for Coastal Ocean Science
National Oceanic and Atmospheric Administration
1305 East-West Highway
Rm. 13508, Bldg. SSNC4
Silver Spring, MD 20910-3281
Topic: *Sponsor Presentation*

Additional Meeting Participant

Dr. Gene Meier
U.S. Environmental Protection Agency
Region 4 Gulf of Mexico Program Office
Building 1103, Room 202
Stennis Space Center, MS 39529-6000

MEETING 2

Park Plaza Hotel
64 Arlington Street
Boston, Massachusetts
June 4-5, 1999

Dr. Donald Anderson
Woods Hole Oceanographic Institution
Biology Department
266 Woods Hole Road, MS 32
Wood Hole, MA 02543-1049
Topic: *"Funding for Harmful Algal Bloom (HAB) Science in the Gulf of Maine: RMRP Versus other Options."*

Dr. Wendell Brown
University of New Hampshire
Ocean Process Analysis Laboratory/EOS
142 Morse Hall, 21 Emerson Road
Durham, NH 03824-3525
Topic: *"RMRP: Prototype for a Science-based National Coastal Ocean Observing System."*

Mr. Paul Howard, Chairman
New England Regional Fishery Management Council
5 Broadway, Route 1 South
Suite 3
Saugus, MA 01906
Topic: *Research Needs of the New England Fishery Management Council*

Dr. Matt Liebman
U.S. Environmental Protection Agency
1 Congress Street, Suite 1100
Boston, MA 02114-2023
Topic: *The EPA's Participation in Regional Programs*

Dr. Judy Pederson
Massachusetts Institute of Technology
MIT Sea Grant College Program
292 Main Street, C38-300
Cambridge, MA 02139
Topic: *Accomplishments of the Gulf of Maine Regional Marine Research Program*

Mr. Peter Shelley
Conservation Law Foundation
120 Tilson Avenue
Rockland, ME 04841
Topic: *The Need for Regional Research to Support Conservation*

Dr. David Townsend
University of Maine
School of Marine Sciences
5741 Libby Hall
Orono, ME 04469-5741
Topic: *History of the Regional Marine Research Program*

Dr. Gordon Wallace
University of Massachusetts
Boston Harbor Campus, 100 Morrisey Blvd.
Environmental, Coastal, and Ocean Sciences Program
Boston, MA 02125
Topic: *Regional Association for Research on the Gulf of Maine (RARGOM)*

Ms. Dolores Wesson, Assistant Director
University of California, San Diego
California Sea Grant College, Bldg. T16
8602 La Jolla Shores Drive
La Jolla, CA 92037
Topic: *The Southwest Regional Marine Research Program*

Additional Meeting Participant

Dr. Lewis Incze
Bigelow Laboratory for Ocean Sciences
P.O. Box 475
McKown Pt. Rd.
West Boothbay Harbor, ME 04575

C

Gulf of Maine Regional Marine Research Program (GOM-RMRP) and Nutrient Enhanced Coastal Ocean Productivity (NECOP) Program Funding Spreadsheets

Gulf of Maine Regional Marine Research Program (GOM-RMRP)

	Funding/Year						
	1993	1994	1995	1996	1997	1998	TOTALS
Research (RFP1)		$1,030,000	$650,000	$396,000			$2,076,000
Research (RFP2)		$499,000	$337,000	$215,000			$1,051,000
Research (RFP3)			$588,000	$434,000	$255,000		$1,277,000
Research (RFP4)*				$601,000	$688,000	$81,000	$1,370,000
Management	$245,000	$300,000	$310,000	$131,000	$153,000	$112,000	$1,251,000
Outreach**	$3,055	$16,804		$23,939	$5,375	$2,000	$51,172
TOTAL/YEAR	$248,055	$1,840,804	$1,890,000	$1,800,939	$1,101,375	$195,000	$7,076,172

RFP – Request for Proposals
* Includes funding ($300K) for special call for data and information management
** Outreach expenses include only RARGOM related activities (workshops and general operating support/sponsorship)

Gulf of Maine RMRP

	RFP1	RFP2	RFP3	RFP4	Total
# of Awards	8	5	5	10	28
# of Investigators	24	9	10	27	70

GOM-RMRP	RFPs					
	1	2		3	4	
Year	Jun-92	Feb-93	Sept-93*	Jan-94	Spring 94**	Oct-94
# of Proposals submitted	20	15	1	18	2	18
# of Proposals funded	8	4	1	5	1	9
Success Rate (%)	40	27	100	28	50	50

* Special call for physical oceanography
** Special call for data and information management

Nutrient Enhanced Coastal Ocean Productivity (NECOP) Program

	Funding/Year Initiated							
	1990	1991	1992	1993	1994	1995	1996	Total
Research (RFP1)	$6,903,289	$50,000						$6,953,289
Research (RFP2)			$1,895,454	$241,400				$2,136,854
Renewal/Synthesis					$70,680	$58,180	$300,000	$428,860
Management	$1,331,609							$1,331,609
Outreach						$70,680		$70,680
TOTAL/YEAR	$8,234,898	$50,000	$1,895,454	$241,400	$70,680	$128,860	$300,000	$10,921,292

NECOP Program

	RFP1	RFP2	Renewal/ Synthesis	Total
# of Awards	17	9	7	33
# of Investigators	44	22	15	81

NECOP	RFPs	
	1	2
Year	1990-91	1992-93
# of Proposals submitted	na	26
# of Proposals funded	15	17
Success Rate (%)		65

na = not available

D

Acronyms and Abbreviations

AOML	Atlantic Oceanographic and Meteorological Laboratory
ARGO-Maine	Association for Research on the Gulf of Maine
ARO	Announcement of Research Opportunity
BCDC	Bay Conservation Development Commission
CalCOFI	California Cooperative Oceanic Fisheries Investigations
CBP	Chesapeake Bay Program
CoOP	Coastal Ocean Processes
COP	Coastal Ocean Program
CoPO	Coastal Physical Oceanography
CRETM	Columbia River Estuarine Turbidity Maximum
CWAP	Clean Water Action Plan
czcs	Coastal Zone Color Scanner
DDT	Dichlorodiphenyltrichloroethane
DOA	U.S. Department of Agriculture
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
EcoHAB	Ecology and Oceanography of Harmful Algal Blooms
EIR	Environmental Impact Report
EIS	Environmental Impact Statement

EMAP	Environmental Monitoring and Assessment Program
ENSO	El Niño/Southern Oscillation
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FWS	U.S. Fish and Wildlife Service
FY	Fiscal Year
GLOBEC	Global Ocean Ecosystems Dynamics
GOM-RMRP	Gulf of Maine Regional Marine Research Program
GOOS	Global Ocean Observing System
HAB	Harmful Algal Bloom
LaTex	Louisiana-Texas Shelf Physical Oceanography Program
LMER	Land Margin Ecosystems Research
LTER	U.S. Long Term Ecological Research Network
LTMS	Long-Term Management Strategy
MBA	Migratory Bird Act
MMPA	Marine Mammal Protection Act
MMS	DOI Minerals Management Service
MOA	Memorandum of Agreement
MRPA	Marine Resources Protection Act
MSA	Magnuson-Stevens Act
NAML	National Association of Marine Laboratories
NAS	National Academy of Sciences
NASA	U.S. National Aeronautics and Space Administration
NECOP	Nutrient Enhanced Coastal Ocean Productivity
NEP	National Estuary Programs
NEPA	National Environmental Policy Act
NERRS	National Estuarine Research Reserve System
NGO	Non-Government Organization
NMFS	NOAA National Marine Fisheries Service
NMS	National Marine Sanctuary
NOAA	National Oceanic and Atmospheric Administration
NODC	National Oceanographic Data Center
NOPP	National Ocean Partnership Program
NOS	National Ocean Service
NRC	National Research Council
NSF	National Science Foundation

OAR	Office of Oceanic and Atmospheric Research
OMB	Office of Management and Budget
ONR	U.S. Office of Naval Research
OSB	Ocean Studies Board
PI	Principal Investigator
PMC	Program Management Committee
PMT	Program Management Team
PNCERS	Pacific Northwest Coastal Ecosystem Study
POC	particulate organic carbon
PoCO	Panel on the NOAA Coastal Ocean Program
RARGOM	Regional Association for Research on the Gulf of Maine
REDIMS	Research Environmental Data and Information Management System
RFP	Request for Proposals
RMR	Regional Marine Research
RMRP	Regional Marine Research Program
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SFA	Sustainable Fisheries Act
SMBRP	Santa Monica Bay Restoration Project
SRMRP	Southwest Regional Marine Research Program
SSC	Scientific Steering Committee
TAC	Technical Advisory Committee
TMDLs	Total Maximum Daily Loads
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WHOI	Woods Hole Oceanographic Institution

E

Gulf of Maine RMRP and NECOP Publications

GULF OF MAINE REGIONAL MARINE RESEARCH PROGRAM(GOM-RMRP)

Anderson, D. M. 1997. Bloom dynamics of toxic *Alexandrium* species in the northeastern U.S. *Limnology and Oceanography* 42, no. 5 II: 1009-22.

———. 1999. Physiology and bloom dynamics of toxic Alexandrium species, with emphasis on life cycle transitions. The Physiological Ecology of Harmful Algal Blooms ed., Heidelberg, Germany: Springer-Verlag. D. M. Anderson, A. D. Cembella, and G. M. Hallegraeff, eds.

Balch, W. M., D. T. Drapeau, T. L. Cucci, R. D. Vaillancourt, K. A. Kilpatrick, and J. J. Fritz. 1999. Optical backscattering by calcifying algae: Separating the contribution by particulate inorganic and organic carbon fractions. *J. Geophys. Res*. 104:1571-1588.

Barnhardt, W. A., D. F. Belknap, and J. T. Kelley. 1997. Sequence stratigraphy of submerged river-mouth deposits in the northwestern Gulf of Maine: responses to relative sea-level changes. *Society of America Bulletin* 109: 612-30.

Barnhardt, W. A., J. T. Kelley, D. F. Belknap, S. M. Dickson, and A. R. Kelley. 1996. Surficial geology of the inner continental shelf of the northwestern Gulf of Maine: Piscataqua River to Biddeford Pool. *Maine Geological Survey Geologic Map*, no. 1:100,000: 96-6.

———. 1996. Surficial geology of the inner continental shelf of the northwestern Gulf of Maine: Ogunquit to the Kennebec River. *Maine Geological Survey Geologic Map*, no. 1:100,000: 96-7.

———. 1996. Surficial geology of the inner continental shelf of the northwestern Gulf of Maine: Cape Elizabeth to Pemaquid Point. *Maine Geological Survey Geologic Map*, no. 1:100,000: 96-8.

———. 1996. Surficial geology of the inner continental shelf of the northwestern Gulf of Maine: Boothbay Harbor to North Haven. *Maine Geological Survey Geologic Map*, no. 1:100,000: 96-9.

———. 1996. Surficial geology of the inner continental shelf of the northwestern Gulf of Maine: Rockland to Bar Harbor. *Maine Geological Survey Geologic Map*, no. 1:100,000: 96-10.

———. 1996. Surficial geology of the inner continental shelf of the northwestern Gulf of Maine: Mt. Desert Island to Jonesport. *Maine Geological Survey Geologic Map*, no. 1:100,000: 96-11.

———. 1996. Surficial geology of the inner continental shelf of the northwestern Gulf of Maine: Petit Manan Point to West Quoddy Head. *Maine Geological Survey Geologic Map*, no. 1:100,000: 96-12.

Barnhardt, W. A., J. T. Kelley, S. M. Dickson, and D. F. Belknap. 1998. Mapping the Gulf of Maine with side-scan sonar: A new bottom-type classification for complex seafloors. *Journal of Coastal Research* 14: 646-59.

Bricelj, V. Monica, and Sandra E. Shumway. 1998. Paralytic Shellfish Toxins in Bivalve Molluscs: Occurrence, Transfer Kinetics and Biotransformation. *Reviews in Fisheries Science* 6, no. 4: 315-83.

Brown, Wendell S. 1998. Chapter 15: Boundary Flux Measurements in the Coastal Ocean. The Sea ed., 399-418. Vol. 10. John Wiley & Sons, Inc. Brink, Kenneth H. and Allan R. Robinson, eds.

———. 1998. Wind-forced pressure response of the Gulf of Maine. *Journal of Geophysical Research* 103, no. C13: 30,661-30,678.

Brown, Wendell S., and Karen Garrison. 1997. Integrated Environmental Data and Information Management Systems for Marine Research and Resource Management in the Gulf of Maine. *Eco-Informa '96*.

Bub, F. L., Wendell S. Brown, and Mupparapu P. 1999. Circulation Variability in the Western Gulf of Maine: Wilkinson Basin. *OPAL Tech. Report*, no. UNH-OPAL-1999-001: XX.

Buesseler, K. O., J. Bauer, R. Chen, T. Eglinton, O. Gustafsson, W. M. Landing, K. Mopper, S. B. Moran, P. H. Santschi, and M. Wells. 1996. An intercomparison of cross-flow filtration techniques used for sampling marine colloids: overview and organic carbon results. *Marine Chemistry* 55: 1-31.

Buesseler, K. O., and S. B. Moran. 1994. In-situ collection of marine colloids and their thorium isotopic signature. American Chemical Society Symposium, San Diego, CA, March 13-18, 1994.

Charette, M. A. 1998. Carbon cycling in the Gulf of Maine and the Arctic using the natural tracer Thorium-234. Thesis, Graduate School of Oceanography, University of Rhode Island.

Charette, M. A., S. B. Moran, S. M. Pike, C. H. Pilskaln, and J. N. Smith. 1998. Investigating the carbon cycle in the Gulf of Maine using natural tracer 234-Thorium. Fall 1998 AGU Meeting, Program of Abstracts. *EOS* 79, no. 45: 495-96.

Charette, M. A, S. B. Moran, and C. H. Pilskaln. 1996. Particulate organic carbon export fluxes in the central Gulf of Maine estimated from $^{234}Th/^{238}U$ disequilibria. *Gulf of Maine Ecosystem Dynamics Symposium and Workshop, Program of Abstracts*: 20.

Dai, M., Ripple P., Andrews J. A., Buesseler K. O., Gustafsson O., and S. B. Moran 1998. A comparison of two cross-flow filtration methods for sampling marine organic colloids. *Marine Chemistry* 62: 117-36.

Feng, H. 1996. Wind-Induced Responses of the Western Coastal Gulf of Maine During Spring and Summer 1994. Master's Thesis.

Feng, H., and Wendell S. Brown. 1996. Hindcasting the Gulf of Maine Wind Field: A Case Study. *OPAL Tech. Report*, no. UNH-OPAL-1996-003: 21.

Feng, H., F. L. Garrison, and Wendell S. Brown. 1995. Hydrography Survey Report: Western Gulf of Maine - Regional Marine Research Program R/V Gulf Challenger Cruises - 16 March 1994/ 21 March 1994, 23 May 1994, 3 August 1994, 31 October 1994, 16 March 1995/ 20 March 1995. *OPAL Tech. Report*, no. UNH OPAL-1996-001: 136.

Fong, D. A., W. R. Geyer, and R. P. Signell. 1997. The wind-forced response of a buoyant coastal current: observations of the western Gulf of Maine plume. *Journal of Marine Systems* 12: 69-81.

Franks, P. J. S. 1997. Coupled physical-biological models for the study of harmful algal blooms. *Ocean Research* 19: 153-60.

———. 1997. Models of harmful algal blooms. *Limnology and Oceanography* 42: 1273-82.
———. 1998. Spatial patterns in dense algal blooms. *Limnology and Oceanography* 42: 1297-3105.
Garside, C., J. C. Garside, M. D. Keller, and M. E. Sieracki. 1996. The formation of high nutrient low salinity water in the Gulf of Maine: A nutrient trap? *Estuar. Coastal Shelf Sci.* 42: 617-28.
Greenamoyer, J. M. 1995. An Investigation of Cadmium, Copper and Nickel in the Colloidal Size Range in Seawater. Thesis, Graduate School of Oceanography, University of Rhode Island.
Greenamoyer, J. M., Gustafsson O., and Moran S. B. 1995. An investigation of trace metal partitioning of colloids in seawater using cross-flow filtration. The Oceanography Society Meeting, Newport, R.I., March 17-21, No. co-16.
Greenamoyer, J. M., and S. B. Moran. 1996. Evaluation of a spiral wound cross-flow filtration system for colloidal size-fractionation in Cu, Ni and Cd in seawater. *Marine Chemistry* 55: 153-63.
Greenamoyer, J. M., and S. B. Moran 1996. Evaluation of a spiral wound Osmonics cross-flow filtration system for trace metal sampling in seawater. *EOS, Trans, Amer. Geophys. Union* 76, no. 3: OS172.
Greenamoyer, J. M., and S. B. Moran. 1997. Investigation of Cd, Cu, Ni and 234Th in the colloidal size range in the Gulf of Maine. *Marine Chemistry* 57: 217-26.
Greenamoyer, J. M., S. B. Moran, and P. A. Yeats. 1994. Trace metals solid-solution partitioning on colloids in the Gulf of Maine. *EOS, Trans, Amer. Geophys. Union* 75, no. 44: 325.
Gustafsson, Ö., K. O. Buesseler, W. R. Geyer, S. B. Moran, and P. M. Gschwend. 1998. An assessment of the relative significance of horizontal and vertical transport of particle-reactive chemicals in the coastal ocean. *Continental Shelf Research* 18: 805-29.
Gustafsson, Ö., K. O. Buesseler, W. R. Geyer, S. B. Moran, and P. M. Gschwend. 1998. An assessment of the relative importance of horizontal and vertical transport of particle-reactive chemicals in the coastal ocean. *Continental Shelf Research* 18: 805-29.
Gustafsson, Ö., K. O. Buesseler, and P. M. Gschwend. 1996. On the integrity of cross-flow filtration for collecting marine organic colloids. *Marine Chemistry* 55: 93-111.
Gustafsson, Ö., K. O. Buesseler, S. B. Moran, and P. M. Gschwend. 1994. Physical speciation and 234Th-derived transfer rates of individual hydrophobic compounds in coastal seawater. American Chemical Society Symposium, San Diego, CA, March 13-18, 1994.
Gustafsson, Ö., and P. M. Gschwend. 1997. Aquatic Colloids: Concepts, definitions, and current challenges. *Limnol. Oceanogr.* 42: 519-28.
———. 1997. Soot as a Strong Partition Medium for Polycyclic Aromatic Hydrocarbons in Aquatic Systems, Chapter 24. Molecular Markers in Environmental Geochemistry ed., 365-81. Vol. 671. American Chemical Society, ASC Symposium Series. Eganhouse, R. P., ed.
———. 1998. The flux of black carbon to surface sediments on the New England Continental shelf. *Geochim. Cosmochim. Acta* 62: 465-72.
———. 1999. Hydrophobic organic compound partitioning from bulk water to the water/air interface. *Atmos. Environ.* 33: 163-67.
———. 1999. Phase Distributions of Hydrophobic Chemicals in the Aquatic Environment: Existing Partitioning Models Are Unable to Predict the Dissolved Component in Several Common Situations. Bioavailability of Xenobiotics in the Environment ed., NATO-ASI.
Gustafsson, Ö., P. M. Gschwend, and K. O. Buesseler. 1997. Settling removal rates of PCBs into the northwestern Atlantic derived from 238U-234Th disequilibria. *Environ. Sci. Technol.* 31: 3544-50.
———. 1997. Using 234Th disequilibria to estimate the vertical removal rates of polycyclic aromatic hydrocarbons from the surface ocean. *Marine Chemistry* 57: 11-23.
Incze, L. S., and C. E. Naimie. 1999. Modeling the transport of lobster (Homarus americanus) larvae and postlarvae in the Gulf of Maine. *Fish. Oceanogr.* 9(1): in press.

Jordan, C. E., R. W. Talbot, and B. W. Mosher. 1998. Fog deposition of nitrogen in the coastal marine environment of the Gulf of Maine. Proceedings: First International Conference on Fog and Fog Collection, 19-24 July 1998 ed., 157-60. Vancouver, Canada. R. S. Schemenauer, and H. Bridgman, eds.

Keller, M. D. 1996. Bloom dynamics and physiology of *Phaeocystis*. Invited plenary at NATO ASI on the Physiological Ecology of Harmful Algal Blooms, Bermuda, May 1996.

Keller, M. D., and E. M. Haugen. 1996. Abundance and distribution of *Phaeocystis* sp. in the Gulf of Maine, U.S.A.: Spring bloom dynamics and bloom initiation. ASLO/AGU Ocean Sciences meeting, San Diego CA, February 1996.

Kelley, J. T., W. A. Barnhardt, D. F. Belknap, S. M. Dickson, and A. R. Kelley. 1998. The Seafloor revealed: The geology of Maine's inner continental shelf. A report to the Regional Marine Research Program. *Maine Geological Survey Open-File Report* 98-6: 55.

———. 1999. Physiography of the inner continental shelf of the northwestern Gulf of Maine. *Maine Geological Survey Open-File Report*, no. 1:100,000.

Lancelot, C., M. D. Keller, V. Rousseau, W. O. SmithJr., and S. Mathot. 1998. Autecology of the marine haptophyte, *Phaeocystis* sp. Physiological ecology of harmful algal blooms ed., 209-24. Berlin, Germany: Springer Verlag. D. M. Anderson, A. D. Cembella and G. M. Hallegraeff, eds.

Milliman, J., P. J. Troy, W. Balch, A. K. Adams, Y. H. Li, and F. T. MacKenzie. 1999. Biologically-mediated dissolution of calcium carbonate above the chemical lysocline. *Deep-Sea Research* 46: 1653-1669.

Moran, S. B. 1995. Progress in geochemical flux studies in the Gulf of Maine. GOM-RMRP P.I. Workshop, Orono, ME, October 23-24.

Moran, S. B., M. A. Charette, S. M. Pike, and C. A. Wicklund. 1999. Differences in seawater particulate organic carbon concentration in samples collected using small-volume and large-volume methods: the importance of DOC adsorption to the filter blank. *Marine Chemistry* 67: 33-42.

Moran, S. B., P. A. Yeats, and P. W. Balls 1996. On the role of colloids in trace metal solid-solution partitioning in continental shelf waters: a comparison of model results and field data. *Continental Shelf Research* 16: 397-408.

Mupparapu, P. 1999. The Role of Convection in Winter Gulf of Maine Mixed Layer Formation. Master's Thesis.

Panchang, V. G., L. Zhao, and Z. Demirbilek. 1999. Estimation of Extreme Wave Heights using GEOSAT Measurements. *Ocean Engineering* 26: 205-25.

Pettigrew, N. R., D. W. Townsend, H. Xue, J. P. Wallinga, P. J. Brickley, and R. D. Hetland. 1998. Observations of the eastern Maine coastal current and its offshore extensions in 1994. *J. Geophys. Res.* 103, no. C13, 30: 623-30, 639.

Pike, S. M. 1998. Atmospheric Deposition and Water Column Fluxes of Trace Metals in the Gulf of Maine. Thesis, Graduate School of Oceanography, University of Rhode Island.

Pike, S. M., M. A. Charette, S. B. Moran, and C. H. Pilskaln. 1998. Water column removal of trace metals in the Gulf of Maine. *EOS, Trans, Amer. Geophys. Union* 79, no. 17: S188.

Pike, S. M., M. A. Charrette, S. B. Moran, and C. H. Pilskaln. 1996. Geochemical mass balance model for lead in the Gulf of Maine. *Gulf of Maine Ecosystem Dynamics Symposium and Workshop, Program of Abstracts*: 71.

Pike, S. M., and S. B. Moran. 1997. Use of Poretics 0.7 μm glass fiber filters for determination of particulate organic carbon and nitrogen in aquatic systems. *Marine Chemistry* 57: 355-60.

———. 1998. Atmospheric input of trace metals to the Gulf of Maine. *EOS, Trans. Amer. Geophys. Union* 79, no. 17: S24.

Pilskaln, C. H. 1997. Seasonal biogeochemical particle fluxes and sediment resuspension in the Gulf of Maine: preliminary results from an ongoing study. *Fifth Meeting of The Oceanography Society, Program of Abstracts*: 67.

Pilskaln, C. H., W. Arnold, C. Lehmann, and L. E. Watling. 1996. Particulate flux dynamics in Jordan and Wilkinson Basins: seasonal POC export and particle resuspension. *Gulf of Maine Ecosystem Dynamics Symposium and Workshop, Program of Abstracts*: 73.

Pilskaln, C. H., J. H. Churchill, and L. M. Mayer. 1998. Resuspension of sediment by bottom trawling in the Gulf of Maine and potential geochemical consequences. *Journal of Conservation Biology* 12: 1223-30.

Pilskaln, C. H., and C. Lehmann. 1998. Seasonal biogeochemical particle fluxes and sediment resuspension processes in a coastal sea: The Gulf of Maine. *The Oceanography Society Meeting on Coastal and Marginal Seas, Program of Abstracts*: 42-43.

Pilskaln, C. H., L. E. Watling, and J. H. Churchill. 1997. Effects of bottom trawling on biogeochemical particle fluxes in a deep Gulf of Maine basin environment. *Society for Conservation Biology Annual Meeting, Program of Abstracts*: 163.

Siddabathula, M., and V. G. Panchang. 1997. Quality Control of Geosat Wave Data for Engineering Applications. *Proceedings of the 1996 International Conference on Coastal Engineering, Orlando, Florida. Am. Soc. Civ. Engrs.*: 81-94.

Sieracki, M. E., M. D. Keller, T. L. Cucci, and W. K. Bellows. 1997. Microbial food web dynamics during the spring bloom in the Gulf of Maine. ASLO Aquatic Sciences meeting, Santa Fe, NM., February 1997.

Townsend, D. W., and N. R. Pettigrew. 1996. The role of frontal currents in larval fish transport on Georges Bank. *Deep-Sea Research* 43: 1773-92.

———. 1997. Nitrogen limitation of secondary production on Georges Bank. *J. Plankton Res.* 19: 221-35.

Xue, H., F. Chai, and N. R. Pettigrew. 1999. A Model Study of the Seasonal Circulation in the Gulf of Maine. *J. Phys. Oceanogr.*

NUTRIENT ENHANCED COASTAL OCEAN PRODUCTIVITY (NECOP) PROGRAM

Ackerman, A. 1995. An optimized flow field determination for the Louisiana inner shelf using conservation of water mass and salinity and its application to a simple dissolved oxygen model. Master's thesis, Department of Oceanography & Coastal Sciences, Louisiana State University. Baton Rouge, Louisiana.

Ackerman, D. C., W. J. Wiseman Jr., V. J. Bierman Jr., N. N. Rabalais, and R. E. Turner. 1997. An optimization method for determining flow fields in multidimensional water quality models applied to the Louisiana shelf. In: Water Environment Federation 70th Annual Conference and Exposition, Alexandria, Virginia. *Surface Water Quality and Ecology* 4 - Parts I and II, Paper 9759003: 527-36.

Ammerman, J. W. 1991. Rapid phosphate cycling in the Mississippi River plume region (abstract). *Second scientific meeting of The Oceanography Society*.

———. 1991. Rapid phosphate utilization (abstract) . *Annual meeting of the American Society for Microbiology*.

———. 1992. Seasonal variation in the phosphate turnover in Mississippi River plume and the inner Gulf shelf: Rapid summer turnover. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings*, pp. 69-75. Texas A&M University Sea Grant Program.

———. 1994. Enzymology on the run: Continuous underway measurement of microbial enzyme activity in aquatic environments (abstract). *NATO Advanced Study Institute, Molecular Ecology of Aquatic Microbes*.

Ammerman, J. W., and W. Glover. 1997. Increased nitrogen loading in the Mississippi River may have enhanced phosphorus deficiency in the Gulf of Mexico (abstract) . *Contributed talk presented at the American Society of Limnology and Oceanography Aquatic Sciences Meeting*.

Ammerman, J. W., W. B. Glover, R. H. Sada Ruvalcaba, and M. J. D. McRae. 1995. Continuous underway measurement of microbial enzyme activities in surface waters of the Mississippi River plume and the Louisiana shelf. *Nutrient-Enhanced Coastal Ocean Productivity, Proceedings of the Synthesis Workshop*, pp. 1-8. Baton Rouge, Louisiana: Louisiana Sea Grant College Program, Louisiana State University.

Amon, R. M. W., and R. Benner. 1994. Rapid cycling of high-molecular-weight dissolved organic matter in the ocean. *Nature* 369: 549-52.

———. 1996. Bacterial utilization of different size classes of dissolved organic matter. *Limnol. Oceanogr.* 41: 41-51.

———. 1998. Seasonal patterns of bacterial abundance and production in the Mississippi River plume and their importance for the fate of enhanced primary production. *Microb. Ecol.* 35: 289-300.

Arwood, D. 1993. The influence of environmental variables on portioning of the end products of phytoplankton photosynthesis in the Mississippi River plume. 58. M.S. Thesis; Donald Redalje, advisor. University of Southern Mississippi, Stennis Space Center, Mississippi.

Atwood, D. K., A. Bratkovich, M. Gallagher, and G. L. Hitchcock. 1994. Introduction to the dedicated issue. *Estuaries* 17, no. 4: 729-31.

———. 1994. Papers from NOAA's nutrient enhanced coastal ocean productivity study. *Estuaries* 17, no. 4: 729-911.

Atwood, D. K., W. F. Graham, and C. B. Grimes. 1995. Nutrient enhanced coastal ocean productivity. *Proceedings of a 1994 synthesis workshop, Louisiana State University*, pp. 119. Baton Rouge, La.: Louisiana Sea Grant College Program, Louisiana State University.

Benner, R. 1991. Ultra-filtration for concentration of bacteria, viruses, and dissolved organic matter. *Marine Particles: Analysis and Characterization, Geophysical Monograph* 63, American Geophysical Union: 181-85.

Benner, R., G. Chin-Leo, W. Gardener, B. Eadie, and J. Cotner. 1992. The fates and effects of riverine and shelf-derived DOM on Mississippi River plume/Gulf shelf processes. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings*, pp. 84-94. Galveston, Texas: Texas A&M University Sea Grant Program.

Benner, R., J. D. Pakulski, M. McCarthy, J. I. Hedges, and P. G. Hatcher. 1992. Bulk chemical characteristics of dissolved organic matter in the ocean. *Science* 225: 1561-64.

Benner, R., and M. Strom. 1993. A critical evaluation of the analytical blank associated with DOC measurements by high temperature catalytic oxidation. *Marine Chemistry* 41, no. 1-3: 153-60.

Bierman, V. J. Jr. 1997. Estimated responses of water quality on the Louisiana inner shelf to nutrient load reduction in the Mississippi and Atchafalaya Rivers. *Proceedings of the First Gulf of Mexico Hypoxia Management Conference*, pp. 114-24. Stennis Space Center, Mississippi: U.S. Environmental Protection Agency, Gulf of Mexico Program Office.

Bierman, V. J. Jr., S. C. Hinz, W. J. Wiseman Jr., N. N. Rabalais, and R. E. Turner. 1992. Mass balance modeling of hypoxia and associated water quality parameters in the Mississippi River plume/inner Gulf shelf region. *Proceedings: Water Environment Federation 65th Annual Conference & Exposition*, pp. 237-48. Alexandria, Virginia: Water Environment Federation.

———. 1992. Mass balance modeling of water quality constituents in the Mississippi River. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings*, pp. 27-36. Galveston, Texas: Texas A&M University Sea Grant Program.

———. 1994. Mass balance modeling of the impacts of nutrient load reductions in the Mississippi River on water quality in the northern Gulf of Mexico. *WEFTEC '94. Proceedings of the Water Environment Federation 67th Annual Conference and Exposition*, pp. 413-24. Alexandria, Virginia: Surface Water Quality and Ecology, Water Environment Federation.

Bierman, V. J. Jr., S. C. Hinz, W. Zhu, W. J. Wiseman Jr., N. N. Rabalais, and R. E. Turner. 1994. A preliminary mass balance model of primary productivity and dissolved oxygen in the Mississippi River Plume/Inner Gulf shelf region. *Estuaries* 17, no. 4: 886-89.

———. 1995. Primary production and dissolved oxygen in the Mississippi River Plume/inner Gulf shelf region: Components analysis and sensitivity to changes in physical transport. *Nutrient-Enhanced Coastal Ocean Productivity, Proceedings of the Synthesis Workshop*, pp. 9-20. Baton Rouge, Louisiana: Louisiana Sea Grant College Program.

Blackwelder, P., T. Hood, C. Alvarez-Zarikian, T. A. Nelsen, and B. McKee. 1996. Benthic foraminifera from the NECOP study area impacted by the Mississippi River plume and seasonal hypoxia. *Quaternary International* 31: 19-36.

Bode, A., and Q. Dortch. 1996. Uptake and regeneration of inorganic nitrogen in coastal waters influenced by the Mississippi River: Spatial and seasonal variations. *Journal of Plankton Research* 18: 2251-68.

Bratkovich, A S., P. Dinnel, and D. A. Goolsby. 1994. Variability and prediction of freshwater and nitrate fluxes for the Louisiana-Texas shelf: Mississippi and Atchafalaya River source functions. *Estuaries* 17, no. 4: 776-78.

Bratkovich, A., and S. P. Dinnel. 1992. Lower Mississippi River historical influx nitrate flux and Mississippi River outflow buoyancy flux. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings*, pp. 37-42. Galveston, Texas: Texas A&M University Sea Grant Program.

Cavaletto, J. F., J. B. Cotner Jr., and J. R. Johnson. 1997. Effects of natural light on nitrogen cycling rates in the Mississippi River plume. *Limnology and Oceanography* 42, no. 2: 273-81.

Chen, B. 1993. The effects of light and nutrient conditions on primary production and chemical composition for high density phytoplankton cultures. M. S. Thesis; Donald Redalje, advisor. University of Southern Mississippi, Stennis Space Center, Mississippi.

Chin-Leo, G., and R. Benner. 1992. Enhanced bacterioplankton production and respiration at intermediate salinities in the Mississippi River plume. *Marine Ecology Progress Series* 87, no. 1-2: 87-103.

Chmura, G. L., A. Smirnov, and I. D. Campbell. 1999. Pollen transport through distributaries and depositional patterns in coastal waters. *Palaeogeography, Palaeoclimatology, Palaeoecology* 149: 257-70.

Cotner, J. B. Jr., and W. S. Gardner. 1993. Heterotrophic bacterial mediation of ammonium and dissolved free amino acid fluxes in the Mississippi River plume. *Marine Ecology Progress Series* 93: 75-87.

Cruz-Kaegi, M. E. 1992. Microbial abundance and biomass in sediments of the Texas-Louisiana shelf. Master's thesis, Texas A&M University, College Station, Texas.

Cruz-Kaegi, M. E., and G. T. Rowe. 1992. Benthic biomass gradients on the Texas-Louisiana Shelf. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings*, pp. 145-49. Galveston, Texas: Texas A&M University Sea Grant Program.

Dagg, M. J. 1995. Copepod grazing and the fate of phytoplankton in the northern Gulf of Mexico. *Cont. Shelf Res* 15: 1303-17.

Dagg, M. J., E. P. Green, B. A. McKee, and P. B. Ortner. 1996. Biological removal of fine grain lithogenic particles from a large river plume. *J. Mar. Res.* 54: 149-60.

Dagg, M. J., C. B. Grimes, S. Lohrenz, B. McKee, R. Twilley, and W. Wiseman Jr. 1991. Continental shelf food chains of the northern Gulf of Mexico. *Food chains, yields, models and management of large marine ecosystems.* K. Sherman, L. M. Alexander, and B. D. Gold (eds.), pp. 67-106. Boulder, Colorado: Westview Press.

Dagg, M. J., and P. B. Ortner. 1992. Mesozooplankton grazing and the fate of carbon in the northern Gulf of Mexico. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings*, pp. 117-21. Galveston, Texas: Texas A&M University Sea Grant Program.

———. 1995. Zooplankton grazing and the fate of phytoplankton in the northern Gulf of Mexico. *Nutrient-Enhanced Coastal Ocean Productivity, Proceedings of the Synthesis Workshop*, pp. 21-27. Baton Rouge, Louisiana: Louisiana Sea Grant College Program.

Dagg, M. J., and T. E. Whitledge. 1991. Concentrations of copepod nauplii in the nutrient-rich plume of the Mississippi River. *Cont. Shelf Res.* 11: 1409-23.

Dinnel, S. P., and A. Bratkovich. 1990. Statistical characterization of riverine fluxes of mass, buoyancy, and nutrients for the Mississippi River out flow region (abstract). *Eos, Transactions* American Geophysical Union 71, no. 43: 1407.

———. 1991. Freshwater fill-times and seasonal distribution of hydrographic data in the Mississippi River outflow region (abstract). *Eos, Transactions* American Geophysical Union 72, no. 51: 90.

Dinnel, S. P., T. E. Whitledge, A. Bratkovich, and B. H. Jones. 1995. Buoyancy and nutrient exchange in the Mississippi River outflow region. *Nutrient-Enhanced Coastal Ocean Productivity, Proceedings of the Synthesis Workshop*, pp. 28-33. Baton Rouge, Louisiana: Louisiana Sea Grant College Program.

Dong, D. Y., A. W. Bratkovich, and S. P. Dinnel. 1993. *Nutrient enhanced coastal ocean productivity (NECOP): CTD observations from R/V Longhorn cruise*, p. 109. Ann Arbor, Mich.: National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory.

Dong, D., and T. Whitledge. 1992. *Nutrient enhanced coastal ocean productivity (NECOP): CTD observations from R/V Longhorn cruise*, p. 150. Port Aransas, Texas: University of Texas, Marine Science Institute Report.

Dortch, Q. 1994. Changes in phytoplankton numbers and species composition. *Coastal Oceanographic Effects of Summer 1993 Mississippi River Flooding. Special NOAA Report.* M. J. Dowgiallo (ed.), 46-49. Silver Spring, Maryland: National Oceanic and Atmospheric Administration, Coastal Ocean Office/National Weather Service.

———. 1994. Phytoplankton survey. *Mississippi River Plume Hydrography: Annual Report.* S. P. Murray, and J. Donley (eds.), pp. 124-42. Vol. OCS Study/MMS 94-0028. New Orleans, Louisiana: U. S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Regional Office.

Dortch, Q., A. Bode, and R. R. Twilley. 1992. Nitrogen uptake and regeneration in surface waters of the Louisiana continental shelf influenced by the Mississippi River. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings*, pp. 52-56. Galveston, Texas: Texas A&M University Sea Grant Program.

Dortch, Q., D. Milsted, N. N. Rabalais, S. E. Lorenz, D. G. Redalje, Dagg M. J., R. E. Turner, and T. E. Whitledge. 1992. Role of silicate availability in phytoplankton species composition and the fate of carbon. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings*, pp. 76-83. Galveston, Texas: Texas A&M University Sea Grant Program.

Dortch, Q., D. M. Nelsen, R. E. Turner, and N. N. Rabalais. 1995. Silicate limitation on the Louisiana continental shelf. *Nutrient-Enhanced Coastal Ocean Productivity, Proceedings of the Synthesis Workshop*, pp. 34-39. Baton Rouge, Louisiana: Louisiana Sea Grant College Program.

Dortch, Q., M. L. Parsons, N. N. Rabalais, and R. E. Turner. 1999. What is the threat of harmful algal blooms in Louisiana coastal waters? *Recent Research in Coastal Louisiana: Natural System Function and Response to Human Influences*. Louisiana Sea Grant, Baton Rouge, Louisiana.

Dortch, Q., C. Pham, N. N. Rabalais, and R. E. Turner. 1992. Respiration rates in bottom waters of the Louisiana Shelf. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings*, pp. 140-144. Galveston, Texas: Texas A&M University Sea Grant Program.

Dortch, Q., N. N. Rabalais, R. E. Turner, and G. T. Rowe. 1994. Respiration rates and hypoxia on the Louisiana Shelf. *Estuaries* 17, no. 4: 862-72.

Dortch, Q., R. Robichaux, S. Pool, D. Milsted, G. Mire, N. N. Rabalais, T. M. Soniat, G. A. Fryxell, R. E. Turner, and M. L. Parsons. 1997. Abundance and vertical flux of *Pseudo-nitzschia* in the northern Gulf of Mexico. *Marine Ecology Progress Series* 146, no. 1-3: 249-64.

Dortch, Q., and T. E. Whitledge. 1992. Does nitrogen or silicon limit phytoplankton production in the Mississippi River plume and nearby regions? *Continental Shelf Research* 12: 1293-309.

Dowgiallo, M. J. (ed.). 1994. Coastal oceanographic effects of summer 1993 Mississippi River flooding. Silver Spring, Maryland: NOAA Coastal Ocean Office/National Weather Service.

Downing, J. A. (chair), N. N. Rabalais, Diaz R., R. Zimmerman, J. L. Baker, and M. D. Duffy. 1999. Gulf of Mexico. Hypoxia: Land-Sea Interactions. *Council for Agricultural Science and Technology* No. 134: 40 pp.

Eadie, B. J.*, and others*. 1994. Records of nutrient enhanced coastal ocean productivity in sediments from the Louisiana continental shelf (abstract). *American Geophysical Union/American Society of Limnology and Oceanography*.

Eadie, B. J., R. Amon, R. Benner, J. Cavaletto, J. B. Cotner, W. S. Gardner, M. Lansing, and D. Pakulski. 1995. Organic matter decomposition, nitrogen recycling, and oxygen consumption in the Mississippi River plume/Gulf shelf region. *Nutrient-Enhanced Coastal Ocean Productivity, Proceedings of the Synthesis Workshop*, pp. 40-55. Baton Rouge, Louisiana: Louisiana Sea Grant College Program.

Eadie, B. J., G. L. Bell, J. A. Robbins, and P. A. Meyers. 1992. Carbon flux and remineralization in Lake Michigan, 1978-1992 (abstract). *American Geophysical Union*.

Eadie, B. J., and M. Lansing. 1992. Stable isotope shifts in POM and DOM across the salinity gradient off the Mississippi delta (abstract). *American Society of Limnology and Oceanography*.

Eadie, B. J., M. Lansing, and R. Benner. 1997. Biogeochemical and stable isotope transformations in the POM and DOM across the salinity gradient off the Mississippi delta (abstract). *American Society of Limnology and Oceanography*.

Eadie, B. J., B. A. McKee, M. B. Lansing, J. A. Robbins, S. Metz, and J. H. Trefry. 1994. Records of nutrient-enhanced coastal productivity in sediments from the Louisiana continental shelf. *Estuaries* 17, no. 4: 754-65.

Eadie, B. J., J. A. Robbins, P. Blackwelder, S. Metz, J. H. Trefry, B. McKee, and T. A. Nelsen. 1992. A retrospective analysis of nutrient enhanced coastal ocean productivity in sediments from the Louisiana Continental Shelf. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings*, pp. 7-14. Galveston, Texas: Texas A&M University Sea Grant Program.

Fahnensteil, G. L., M. H. Markowitz, M. J. McCormick, D. G. Redalje, S. E. Lorenz, H. J. Carrick, and M. J. Dagg. 1992. High growth and microzooplankton-grazing loss rates for phytoplankton populations from the Mississippi River plume region. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings*, pp. 111-16. Galveston, Texas: Texas A&M University Sea Grant Program.

Fahnensteil, G. L., M. J. McCormick, G. A. Lang, D. G. Redalje, S. E. Lohrenz, M. H. Markowitz, B. Wagoner, and H. J. Carrick. 1995. Taxon-specific growth and loss rates for dominant phytoplankton populations from the northern Gulf of Mexico. *Marine Ecology Progress Series* 117: 229-23.

Fahnensteil, G. L., D. G. Redalje, and S. Lorenz. 1994. Has the importance of photoautotrophic picoplankton been overestimated? *Limnology and Oceanography* 39, no. 2: 432-38.

Fahnenstiel, G., M. H. Markowitz, M. J. McCormick, S. Lorenz, and D. Redalje. 1992. Taxon-specific production and growth rates of dominant phytoplankton from the northern Gulf of Mexico (abstract). *J. Phycol.* 28: 13.

Gardner, W. S., R. Benner, R. Amon, J. B. Cotner Jr., J. Cavaletto, and J. Johnson. 1996. Effects of high molecular weight dissolved organic matter on nitrogen dynamics in the Gulf of Mexico Mississippi River Plume. *Marine Ecology Progress Series* 133: 287-97.

Gardner, W. S., R. Benner, G. Chin-Leo, J. B. Cotner Jr., B. J. Eadie, J. F. Cavaletto, and M. B. Lansing. 1994. Mineralization of organic material and bacterial dynamics in Mississippi River plume water. *Estuaries* 17, no. 4: 816-28.

Gardner, W. S., E. E. Briones, E. Cruz-Kaegi, and G. T. Rowe. 1993. Ammonium excretion by benthic invertebrates and sediment-water nitrogen flux in the Gulf of Mexico near the Mississippi River outflow. *Estuaries* 16, no. 4: 799-808.

Gardner, W. S., J. B. Cotner Jr., and L. R. Herche. 1993. Chromatographic measurement of nitrogen mineralization rates in marine coastal waters with ^{15}N. *Marine Ecology Progress Series* 93: 65-73.

Gardner, W. S., L. R. Herche, P. A. St. John, and S. P. Seitzinger. 1991. High performance liquid chromatographic determination of $^{15}NH_4$: [$^{15}NH_4$ + $^{14}NH_4$] ion ratios in seawater for isotope dilution experiments. *Anal. Chem.* 63: 1838-43.

Gardner, W. S., and P. A. St. John. 1991. High-performance liquid chromatographic method to determine ammonium ion and primary amines in seawater. *Anal. Chem.* 63: 537-40.

Grimes, C. B. 1997. Distribution, abundance, feeding growth and mortality of fish larvae associated with the Mississippi River discharge plume, and the potential impacts of hypoxia. *Proceedings of the First Gulf of Mexico Hypoxia Management Conference*, pp. 76-85. Stennis Space Center, Mississippi: U.S. Environmental Protection Agency, Gulf of Mexico Program Office.

Gulf of Mexico Program Office, Louisiana Department of Environmental Quality, Lower Mississippi River Conservation Committee, and Mississippi Soil and Water Conservation Commission. 1997. *Proceedings of the first Gulf of Mexico hypoxia management conference*, Stennis Space Center, Mississippi: United States Environmental Protection Agency, Gulf of Mexico Program Office.

Harper, D. E. Jr., and N. N. Rabalais. 1997. Responses of benthonic and nektonic organisms, and communities, to severe hypoxia on the inner continental shelf of Louisiana and Texas. *Proceedings of the First Gulf of Mexico Hypoxia Management Conference*. Stennis Space Center, Mississippi: U.S. Environmental Protection Agency, Gulf of Mexico Program Office.

Hendee, J C. 1994. Data management for the Nutrient Enhanced Coastal Ocean Productivity program. *Estuaries* 17, no. 4: 900-903.

———. 1994. Object-oriented database management systems and their application to oceanography. *Earth System Monitor* 4, no. 4: 6-9.

Hitchcock, G., and T. Whitledge. 1992. Nutrient/pigment variability in the Mississippi River plume and adjacent waters. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings*, pp. 43-51. Galveston, Texas: Galveston, Texas.

Hitchcock, G. L., W. J. Wiseman, Jr., W. C. Boicourt, A. J. Mariano, N. Walker, T. A. Nelsen and E. Ryan. Property fields in an effluent plume of the Mississippi River. J. Marine Systems 12: 109-126.

Justic, D., N. N. Rabalais, and R. E. Turner. 1994. Riverborne nutrients, hypoxia and coastal ecosystem evolution: Biological responses to long-term changes in nutrient loads carried by the Po and Mississippi Rivers. *Changes in Fluxes in Estuaries: Implications from Science to Management. Proc. Joint ECSA/ERF Conference. International Symposium Series.* K. R. Dyer and R. J. Orth, pp. 161-67. Fredensborg, Denmark: Olsen & Olsen.

———. 1995. Stoichiometric nutrient balance and origin of coastal eutrophication. *Marine Pollution Bulletin* 30, no. 1: 41-46.

———. 1996. Effects of climate change on hypoxia in coastal waters: A doubled CO_2 scenario for the northern Gulf of Mexico. *Limnology and Oceanography* 41, no. 5: 992-1003.

———. 1997. Impacts of climate change on net productivity of coastal waters: Implications for carbon budget and hypoxia. *Climate Research* 8: 225-37.

Justic, D., N. N. Rabalais, R. E. Turner, and Q. Dortch. 1995. Changes in nutrient structure of river-dominated coastal waters: Stoichiometric nutrient balance and its consequences. *Estuarine, Coastal and Shelf Science* 40: 339-56.

———. 1997. Stoichiometric nutrient balance and eutrophication in the coastal waters influenced by the Mississippi River. *Proceedings, Clean Enough? Mississippi River Conference*, pp. 44-46. Lake Pontchartrain Basin Foundation.

Justic, D., N. N. Rabalais, R. E. Turner, and W. J. Wiseman Jr. 1993. Seasonal coupling between riverborne nutrients, net productivity and hypoxia. *Marine Pollution Bulletin* 26, no. 4: 184-89.

Limno-Tech, Inc. 1995. Estimated responses of water quality on the Louisiana Inner Shelf to nutrient load reductions in the Mississippi and Atchafalaya Rivers. Appendices. John C. Stennis Space Center, Mississippi: U.S. Environmental Protection Agency, Gulf of Mexico Program Office. Prepared for Louisiana State University and A&M College Sea Grant College Program, Louisiana State University, Baton Rouge, Louisiana. Limno-Tech, Inc., Ann Arbor, Mich., and South Bend, Ind.

Lohrenz, S. E. (ed.). 1993. *Proceedings of the 1993 NECOP Data Workshop.* Stennis Space Center, Mississippi: University of Southern Mississippi, Center for Marine Science.

Lohrenz, S. E., M. J. Dagg, and T. E. Whitledge. 1990. Enhanced primary production at the plume/oceanic interface of the Mississippi River. *Cont. Shelf Res.* 10: 639-64.

Lohrenz, S. E., G. L. Fahnenstiel, and D. G. Redalje. 1994. Spatial and temporal variations of photosynthesis parameters in relation to environmental conditions in coastal waters of the northern Gulf of Mexico. *Estuaries* 17, no. 4: 779-95.

Lohrenz, S. E., G. L. Fahnenstiel, D. G. Redalje, G. A. Lang, X. Chen, and M. J. Dagg. 1997. Variations in primary production of northern Gulf of Mexico continental shelf waters linked to nutrient inputs from the Mississippi River. *Marine Ecology Progress Series* 155: 45-54.

Lohrenz, S. E., G. L. Fahnenstiel, D. G. Redalje, G. A. Lang, Dagg M. J., T. E. Whitledge, and Q. Dortch. 1999. Nutrients, irradiance and mixing as factors regulating primary production in coastal waters impacted by the Mississippi River plume. *Continental Shelf Research.* 19(9): 1113-1141.

Lohrenz, S. E., D. G. Redalje, and G. L. Fahnenstiel. 1995. Optical properties of Mississippi River plume and adjacent waters during March 1991. *Nutrient-Enhanced Coastal Ocean Productivity, Proceedings of the Synthesis Workshop*, pp. 67-74. Baton Rouge, Louisiana: Louisiana Sea Grant College Program.

Lohrenz, S. E., D. G. Redalje, G. L. Fahnenstiel, and G. A. Lang. 1992. Regulation and distribution of primary production in the northern Gulf of Mexico. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings*, pp. 95-104. Galveston, Texas: Texas A&M University Sea Grant Program.

Lohrenz, S. E., D. G. Redalje, G. L. Fahnenstiel, M. J. McCormick, G. A. Lang, K. Prasad, X. Chen, D. A. Atwood, and B. Chen. 1995. Phytoplankton rate processes in coastal waters of the Northern Gulf of Mexico and relationships to environmental conditions. *Nutrient-Enhanced Coastal Ocean Productivity, Proceedings of the Synthesis Workshop*, pp. 56-66. Baton Rouge, Louisiana: Louisiana Sea Grant College Program.

Lohrenz, S. E., D. A. Wiesenburg, R. A. Arnone and X. Chen. 1999. What controls primary production in the Gulf of Mexico? Pages 151-170 in H. Kumpf, K. Steidinger and K. Sherman (eds.), *The Gulf of Mexico Large Marine Ecosystem Assessment, Sustainablility, and Management*. Blackwell Science, Malden, Massachusetts, 697 pp.

Lopez-Veneroni, D., and L. A. Cifuentes. 1992. Dissolved organic nitrogen distribution and transport in the continental shelf of the northwest Gulf of Mexico. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings*, pp. 57-68. Galveston, Texas: Texas A&M University Sea Grant Program.

———. 1994. Transport of dissolved organic nitrogen in Mississippi River plume and Texas-Louisiana continental shelf near-surface waters. *Estuaries* 17, no. 4.

Lopez-Veneroni, D., L. A. Cifuentes, and R. B. Coffin. 1995. An isotopically-constrained model for denitrification and nitrogen burial in the continental shelf of the NW Gulf of Mexico. *Nutrient-Enhanced Coastal Ocean Productivity, Proceedings of the Synthesis Workshop*, pp. 75-80. Baton Rouge, Louisiana: Louisiana Sea Grant College Program.

MacNaughton, A. 1998. The evolution of inshore hydrography of the west Louisiana inner shelf, 1992. Master's thesis, Department of Oceanography & Coastal Sciences, Louisiana State University, Baton Rouge, Louisiana.

MacRae, M. J. D., W. Glover, J. W. Ammerman, and R. H. Sada Ruvalcaba. 1994. Seasonal phosphorus deficiency in the Mississippi River Plume: Unusually large areal extent during the record flood of 1993 (abstract). *AGU/ALSO Ocean Sciences Meeting*.

Mallini, L. J. 1992. Development of kinetic-colorimetric flow analysis technique for determining dissolved manganese and iron and an assessment of the behavior of dissolved manganese in the far-field plume of the Mississippi River. Master's thesis, Center for Marine Science, University of Southern Mississippi, Stennis Space Center, Mississippi.

McKee, B. A., and M. Baskaran. 1999. Sedimentary processes of Gulf of Mexico estuaries. *Biogeochemistry of Gulf of Mexico Estuaries* pp. 63-85. New York, NY: John Wiley and Sons. T. Bianchi, J. Pennock, and R. Twilley (eds.).

McNeil, C. S., and C. B. Grimes. 1995. Diet and feeding ecology of striped anchovy, *Anchoa hepsetus*, along environmental gradients associated with the Mississippi River discharge plume. *Nutrient-Enhanced Coastal Ocean Productivity, Proceedings of the Synthesis Workshop*, pp. 81-89. Baton Rouge, Louisiana: Louisiana Sea Grant College Program.

Miller-Way, T., G. S. Boland, G. T. Rowe, and R. R. Twilley. 1994. Sediment oxygen consumption and benthic nutrient fluxes on the Louisiana continental shelf: A methodological comparison. *Estuaries* 17, no. 4: 809-15.

Morse, J. W., and G. T. Rowe. 1999. Benthic biogeochemistry beneath the Mississippi River plume. *Estuaries* 22(2A): 206-214.

National Oceanic and Atmospheric Administration (NOAA). 1991-1994. NECOP Newsletter (Jun.91-Jun.94). Miami, Florida: National Oceanic and Atmospheric Administration, Atlantic Oceanographic and Meteorological Laboratory, Ocean Chemistry Division.

National Oceanic and Atmospheric Administration (NOAA), Coastal Ocean Program. 1992. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings.* Galveston, Texas: Texas A&M University Sea Grant Program.

National Oceanic and Atmospheric Administration (NOAA), and Atlantic Oceanographic and Meteorological Laboratory (AOML). 1993. *The proceedings of a workshop on future research, monitoring and modeling of coastal interactions in the Northern Gulf of Mexico*, 54 pp. National Oceanic and Atmospheric Administration, Atlantic Oceanographic and Meteorological Laboratory, Ocean Chemistry Division.

Nelsen, T. A., P. Blackwelder, T. Hood, B. McKee, N. Romer, C. Alvarez-Zarikian, and S. Metz. 1994. Time-based correlation of biogenic, lithogenic and authigenic sediment components with anthropogenic inputs in the Gulf of Mexico NECOP study area. *Estuaries* 17, no. 4: 873-85.

Nelsen, T. A., P. Blackwelder, T. Hood, C. Zarikian, J. H. Trefry, S. Metz, B. Eadie, and B. McKee. 1995. Retrospective analysis of NECOP area sediments: biogenic, inorganic and organic indicators of anthropogenic influences since the turn of the century. *Nutrient-Enhanced Coastal Ocean Productivity, Proceedings of the Synthesis Workshop*, pp. 90-101. Baton Rouge, Louisiana: Louisiana Sea Grant College Program.

Nelson, D. M., and Q. Dortch. 1996. Silicic acid depletion and silicon limitation in the plume of the Mississippi River: Evidence from kinetic studies in spring and summer. *Marine Ecology Progress Series* 136, no. 1-3: 163-78.

Ortner, P. B., and M. J. Dagg. 1995. Nutrient-enhanced coastal ocean productivity explored in the Gulf of Mexico. *Eos, Transactions* American Geophysical Union 76, no. 10: 97, 109.

Pakulski, D*., and others*. 1994. Nutrient regeneration, carbon remineralization and bacterial productivity in the Mississippi River Plume (abstract). *American Geophysical Union/American Society of Limnology and Oceanography*.

Pakulski, J. D., R. Benner, R. Amon, B. J. Eadie, and T. Whitledge. 1995. Community metabolism and nutrient cycling in the Mississippi River plume: Evidence for intense nitrification at intermediate salinities. *Marine Ecology Progress Series* 117: 207-18.

Pakulski, J. D., R. Benner, T. Whitledge, R. Amon, B. J. Eadie, L. A. Cifuentes, and D. Stockman. 1996. Microbial metabolism and nutrient cycling in the Mississippi and Atchafalaya River plumes (abstract). *American Geophysical Union Ocean Science Meeting*.

Parsons, M. L., Q. Dortch and G. A. Fryxell. 1998. A multi-year study of the presence of potential domoic acid-producing *Pseudo-nitzschia* speices in the coastal and estuarine waters of Louisiana, USA. Pages 184-187 in B. Reguera, J. Blanco, M. L. Fernandez and T. Wyatt (eds.), Harmful Algae. Xunta de Galicia and Intergovernmental Oceanographic Commission of UNESCO, GRAFISANT, Santiago de Compostela, Spain.

Parsons, M. L., C. Scholin, G. Doucette, G. Fryxell, Q. Dortch and T. Soniat. 1999. *Pseudo-nitzschia* species (Bacillariophyceae) in Louisiana coastal waters: molecular probe field trials, genetic variability and domoic acid analyses. Journal of Phycology 35: 1368-1378.

Powers, S. P. 1997. Recruitment of soft bottom benthos. Ph.D. dissertation, Department of Marine Biology, Texas A&M University at Galveston.

Powers, S. P., D. E. Harper Jr., and N. N. Rabalais. 1995. Underwater research methods for studying larval recruitment of benthic invertebrates. *Diving for Science. Proceedings of the American Academy of Underwater Sciences, Fifteenth Annual Scientific Diving Symposium.* D. E. Harper Jr., pp. 83-94.

Qureshi, N. A. 1995. The role of fecal pellets in the flux of carbon to the sea floor on a river-influenced continental shelf subject to hypoxia. Ph.D. dissertation, Department of Oceanography and Coastal Sciences, Louisiana State University, Baton Rouge, Louisiana.

Qureshi, N. A., N. N. Rabalais, and Q. Dortch. 1992. Seasonal differences in the sedimentation of zooplankton fecal pellets in the northern Gulf of Mexico. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings*, pp. 122-52. Galveston, Texas: Texas A&M University Sea Grant Program.

Rabalais, N. N. Hypoxia studies in the Mississippi River plume area, 1993. *Proceedings, Thirteenth Annual Gulf of Mexico Information Transfer Meeting*, pp. 312-141994: U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region.

———. 1992. Hypoxia component: Mississippi River plume hydrography, LATEX physical oceanography program. *Proceedings, Twelfth Annual Gulf of Mexico Information Transfer Meeting. U.S. Minerals Management Service, Gulf of Mexico OCS Region*, pp. 479-82.

———. 1992. Influence of hypoxia on the interpretation of effects of petroleum production activities. *Proceedings, Twelfth Annual Gulf of Mexico Information Transfer Meeting. U.S. Minerals Management Service, Gulf of Mexico OCS Region*, pp. 255-59.

———. 1994. Hypoxia vs. production activities: Which influences the benthic community? *Proceedings, Thirteenth Annual Gulf of Mexico Information Transfer Meeting*, pp. 157-61. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region.

———. 1994. Nutrient Enhanced Coastal Ocean Productivity (NECOP): Predicting hypoxia and effects on benthic populations. *Proceedings, NOAA 1994 Summer Colloquium on Operational Environmental Predication, National Oceanic and Atmospheric Administration*, 9 pp.

———. 1996. Mississippi River Water Quality: Status, Trends, and Implications. *Proceedings of the 1996 Environmental State of the State Conference.* L. Durant, 13 pp. Environmental Research Consortium of Louisiana.

———. 1997. Dead Zone in the Gulf of Mexico Expanding. *Living Oceans News.*, 6. Vol. Fall 1997. National Audubon Society's Living Oceans Program.

———. 1998. Hypoxia and the Magnuson-Stevens Act for Sustainable Fisheries. *Sustainable Fisheries for the 21st Century? A Critical Examination of Issued Associated with Implementing the Sustainable Fisheries Act.* J. Speir, pp. 231-35. New Orleans, Louisiana: Tulane Institute for Environmental Law and Policy, Tulane University.

———. 1998. Hypoxia in the Gulf of Mexico. *Proceedings, 1998 Louisiana Environmental State of the State-III*, pp. 26-29. Environmental Research Consortium of Louisiana.

———. 1998. "Oxygen Depletion in Coastal Waters. In the National Oceanic and Atmospheric Administration's (NOAA) State of the Coast Report." Web page. Available at http://state_of_coast.noaa.gov/bulletins/html/hyp_09/hyp.html.

———. 1998. Testimony to the U.S. Senate Subcommittee on Oceans and Fisheries, Senate Committee on Commerce, Science, and Transportation. Hearing on S. 1480, Harmful Algal Bloom Research and Control Act of 1997, with specific comments on hypoxia and nutrient enrichment. 16 pp.

———. 1999. Hypoxia in the Gulf of Mexico. Tulane Environmental Law Journal 12(2): 321-329.

Rabalais, N. N., and L. M. DiPinto. 1993. Nutrient Enhanced Coastal Ocean Productivity (NECOP): Predicting hypoxia and effects on benthic populations. *Proceedings, NOAA 1993 Summer Colloquium on Operational Environmental Prediction.* Silver Spring, Maryland: National Oceanic and Atmospheric Administration.

Rabalais, N. N., and D. E. Harper Jr. 1991. Studies of the benthic oxygen phenomenon off Louisiana. *International Pacific Scientific Diving....1991. Proceedings of the American Academy of Underwater Sciences, Eleventh Annual Scientific Diving Symposium.* H. J. Krock, and D. E. Harper Jr., pp. 57-63.

———. 1992. Studies of benthic biota in areas affected by moderate and severe hypoxia. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings*, pp. 150-153. Galveston, Texas: Texas A&M University Sea Grant Program.

Rabalais, N. N., R. S. Carney and E. G. Escobar-Briones. 1999. Overview of continental shelf benthic communities of the Gulf of Mexico. Pages 171-195 in H. Kumpf, K. Steidinger and K. Sherman (eds.), *The Gulf of Mexico Large Marine Ecosystem Assessment, Sustainablility, and Management*. Blackwell Science, Malden, Massachusetts, 697 pp.

Rabalais, N. N., L. E. Smith, D. E. Harper, Jr. and D. Justic. 1995. The effects of bottom water hypoxia on benthic communities of the southeastern Louisiana continental shelf. MMS/OCS Study 94-0054, U.S. Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, Louisiana, 105 pp.

Rabalais, N. N., L. E. Smith, E. B. Overton, and A. L. Zoeller. 1993. Influence of hypoxia on the interpretation of effects of petroleum production activities. OCS Study /MMS 93-0022, U.S. Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, Louisiana, 158 pp.

Rabalais, N. N., R. E. Turner, D. Justic, Q. Dortch, W. J. Wiseman, Jr. and B. K. Sen Gupta, in press. Gulf of Mexico biological system responses to nutrient changes in the Mississippi River. In J. E. Hobbie (ed.), Estuarine Science: A Synthetic Approach to Research and Practice, Island Press.Reichmuth, J. 1999. The influence of the Bay of Fundy on sediment particle dynamics in the Jordan Basin, eastern Gulf of Maine. Thesis, University of Maine, Graduate Program in Oceanography, MS, Oceanography.

Rabalais, N. N., R. E. Turner, and Q. Dortch. 1992. Louisiana continental shelf sediments: indicators of riverine influence. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings*, pp. 131-35. Galveston, Texas: Texas A&M University Sea Grant Program.

Rabalais, N. N., R. E. Turner, D. Justic, Q. Dortch, and W. J. Wiseman Jr. 1999. Gulf of Mexico Hypoxia Assessment. Topic #1, Characterization of Hypoxia. *Report to White House Office of Science and Technology Policy, Committee on Environment and Natural Resources, Hypoxia Work Group, Mississippi River/Gulf of Mexico Watershed Nutrient Task Force*: 219 pp.

Rabalais, N. N., R. E. Turner, D. Justic, Q. Dortch, W. J. Wiseman Jr., and B. K. Sen Gupta. 1996. Nutrient changes in the Mississippi River and system responses on the adjacent continental shelf. *Estuaries* 19, no. 2B: 386-407.

———. 1998. Mississippi River nutrient changes and consequences to hypoxia on the Louisiana shelf. *Proceedings, Clean Enough? Mississippi River Conference*, pp. 37-39. Metairie, Louisiana: Lake Pontchartrain Basin Foundation.

Rabalais, N. N., R. E. Turner, and W. J. Wiseman Jr. 1992. Distribution and characteristics of hypoxia on the Louisiana Shelf in 1990 and 1991. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings*, pp. 15-20. Galveston, Texas: Texas A&M University Sea Grant Program.

———. 1994. Hypoxic conditions in bottom waters on the Louisiana-Texas shelf. *Coastal Oceanographic Effects of Summer 1993 Mississippi River Flooding, Special NOAA Report.*, pp. 50-54. Silver Spring, Maryland: National Oceanic and Atmospheric Administration, Coastal Ocean Office/National Weather Service. M. J. Dowgiallo (ed.).

———. 1997. Hypoxia in the northern Gulf of Mexico: Causes and Consequences. *Proceedings, North Central Extension - Industry Soil Fertility Conference*, pp. 73-84.

———. 1997. Hypoxia in the northern Gulf of Mexico: Past, present and future. *Proceedings of the First Gulf of Mexico Hypoxia Management Conference*, pp. 25-38. Stennis Space Center, Mississippi: U.S. Environmental Protection Agency, Gulf of Mexico Program Office.

———. 1997. The hypoxic zone in the Gulf of Mexico. *Proceedings From the Corn Belt to the Gulf...Agriculture & Hypoxia in the Mississippi River Watershed.* American Farm Bureau Federation.

———. 1998. Excess nutrients from the Mississippi River degrade water quality in the Gulf of Mexico. *1998 Proceedings Illinois Agricultural Pesticides Conference*, pp. 94-102.

———. 1999. Hypoxia in the Gulf of Mexico. *Proceedings, Special Symposium on Hypoxia Around the World - Causes and Consequences.* Organization for Economic and Cooperative Development and Soil Science Society of America.

———. Hypoxia in the northern Gulf of Mexico: Linkages with the Mississippi River. Pages 297-322 in H. Kumpf, K. Steidinger and K. Sherman (eds.), *The Gulf of Mexico Large Marine Ecosystem Assessment, Sustainablility, and Management.* Blackwell Science, Malden, Massachusetts, 697 pp.

Rabalais, N. N., R. E. Turner, W. J. Wiseman Jr., and D. F. Boesch. 1991. A brief summary of hypoxia on the northern Gulf of Mexico continental shelf: 1985-1988. *Modern and Ancient Continental Shelf Anoxia.* pp. 35-47. Vol. Geological Society Special Publication No. 58. London: The Geological Society. R. V. Tyson and T. H. Pearson (eds.).

Rabalais, N. N., R. E. Turner, W. J. Wiseman Jr., and Q. Dortch. 1998. Consequences of the 1993 Mississippi River Flood in the Gulf of Mexico. *Regulated Rivers: Research & Management* 14: 161-77.

Rabalais, N. N., R. E. Turner, W. J. Wiseman Jr., D. Justic, Q. Dortch, and B. K. Sen Gupta. 1995. Hypoxia on the Louisiana Shelf and system responses to nutrient changes on the Mississippi River: A brief synopsis. *Nutrient-Enhanced Coastal Ocean Productivity, Proceedings of the Synthesis Workshop*, pp. 106-13. Baton Rouge, Louisiana: Louisiana Sea Grant College Program.

Rabalais, N. N., W. J. Wiseman Jr., and R. E. Turner. 1994. Comparison of continuous records of near-bottom dissolved oxygen from the hypoxia zone along the Louisiana coast. *Estuaries* 17, no. 4: 850-861.

Redalje, D. G. 1993. The labeled chlorophyll a technique for determining photoautotrophic carbon specific growth rates and carbon biomass. *Handbook of Methods in Aquatic Microbial Ecology.*, 563-72. Boca Raton, Florida: Lewis Publishers. P. F. Kemp, B. F. Sherr, E. B. Sherr, and J. J. Cole (eds.).

Redalje, D. G., S. E. Lohrenz, and G. L. Fahnensteil. 1992. Phytoplankton dynamics and the vertical flux of organic carbon in the Mississippi River plume and inner Gulf of Mexico shelf region. *Primary Productivity and Biogeochemical Cycles in the Sea (abstract).* 526 pp. New York: Plenum Press. P. G. Falkowski and A. D. Woodhead (eds.).

———. 1992. The relationship between primary production and the export of POM from the photic zone in the Mississippi River plume and inner Gulf of Mexico shelf regions. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings*, pp. 105-10. Galveston, Texas: Texas A&M University Sea Grant Program.

———. 1992. Temporal variability in the relationship between production and the vertical flux of particulate matter in a river impacted coastal ecosystem (abstract). *Journal of the Mississippi Academy of Sciences* 37, no. 1: 49.

———. 1994. The relationship between primary production and the vertical export of particulate organic matter in a river-impacted coastal ecosystem. *Estuaries* 17, no. 4: 829-38.

Robichaux, R. J., Q. Dortch, and J. H. Wrenn. 1998. Occurrence of *Gymnodinium sanguineum* in Louisiana and Texas coastal waters, 1989-1994. *NOAA Technical Report* NMFS 143: 19-25.

Rowe, G. T., G. S. Boland, and W. C. Phoel. 1992. Benthic community oxygen demand and nutrient regeneration in sediments near the Mississippi River plume. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings*, pp. 136-39. Galveston, Texas: Texas A&M University Sea Grant Program.

Rowe, G. T., J. W. Morse, G. S. Boland, and M. E. Cruz-Kaegi. 1995. Sediment metabolism and heterotrophic biomass associated with the Mississippi River plume. *Nutrient-Enhanced Coastal Ocean Productivity, Proceedings of the Synthesis Workshop*, pp. 102-5. Baton Rouge, Louisiana: Louisiana Sea Grant College Program.

Rowe, G., J. W. Morse, B. J. Eadie, L. A. Cifuentes, and G. S. Boland. 1993. Oxygen demand underestimates sediment heterotrophic activity (abstract). *American Geophysical Union Ocean Sciences Meeting*.

Sawyer, T. K., T. A. Nerad, N. N. Rabalais, and S. P. McLaughlin. 1997. Protozoans isolated from Louisiana shelf sediments subject to hypoxia/anoxia with an emphasis on freshwater amoebae and marine flagellates. *Bulletin of Marine Science* 61, no. 3: 859-67.

Sen Gupta, B. K., R. E. Turner, and N. N. Rabalais. 1996. Seasonal oxygen depletion in continental-shelf waters of Louisiana: Historical record of benthic foraminifers. *Geology* 24, no. 3: 227-30.

Smith, S. M. 1993. Nutrient Regulation of Phytoplankton on the Louisiana Shelf. Master's thesis, University of Miami, May 1993. Miami, Florida.

Smith, S. M., and G. L. Hitchcock. 1994. Nutrient enrichments and phytoplankton growth in surface waters of the Louisiana Bight. *Estuaries* 17, no. 4: 740-753.

Stumpf, R. P., and T. D. Leming. 1994. Mississippi/Atchafalaya River plume features. *Coastal oceanographic effects of 1993 Mississippi River flooding. Special NOAA Report*, pp. 30-31. Silver Spring, Maryland: National Oceanic and Atmospheric Administration, Coastal Ocean Office/National Weather Service. M. J. Dowgiallo (ed.).

Trefry, J. H., S. Metz, T. A. Nelsen, R. P. Trocine, and B. J. Eadie. 1994. Transport of particulate organic carbon by the Mississippi River system and its fate in the Gulf of Mexico. *Estuaries* 17, no. 4: 839-49.

Trefry, J. H., R. P. Trocine, S. Metz, T. A. Nelsen, and N. Hawley. 1992. Suspended particulate matter on the Louisiana Shelf: Concentrations, composition and transport pathways. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings*, pp. 126-30. Galveston, Texas: Texas A&M University Sea Grant Program.

Turner, R. E., N. Qureshi, N. N. Rabalais, Q. Dortch, D. Justic, R. F. Shaw, and J. Cope. 1998. Fluctuating silicate:nitrate ratios and coastal plankton food webs. *Proceedings National Academy of Sciences, USA* 95: 13048-51.

Turner, R. E., and N. N. Rabalais. 1991. Changes in Mississippi River water quality this century: Implications for coastal food webs. *BioScience* 41, no. 3: 140-147.

———. 1994. Changes in the Mississippi River nutrient supply and offshore silicate-based phytoplankton community responses. *Changes in Fluxes in Estuaries: Implications from Science to Management. Proc. Joint ECSA/ERF Conference. International Symposium Series.* K. R. Dyer, and R. J. Orth, pp. 147-50. Fredensborg, Denmark: Olsen & Olsen.

———. 1994. Coastal eutrophication near the Mississippi river delta. *Nature* 368: 619-21.

———. 1994. Light conditions in the coastal boundary layer of the northern Gulf of Mexico. *Proceedings, Thirteenth Annual Gulf of Mexico Information Transfer Meeting*, pp. 314-18. New Orleans, Louisiana: U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region.

Turner, R. E., N. N. Rabalais, Q. Dortch, D. Justic, and B. K. Sen Gupta. 1997. Evidence for nutrient limitation and sources causing hypoxia on the Louisiana shelf. *Proceedings of the First Gulf of Mexico Hypoxia Management Conference*, pp. 106-12. Stennis Space Center, Mississippi: U.S. Environmental Protection Agency, Gulf of Mexico Program Office.

Twilley, R. R., T. Miller-Way, and B. McKee. 1995. Synoptic investigations of benthic-pelagic coupling within the Louisiana shelf ecosystem. *Nutrient-Enhanced Coastal Ocean Productivity, Proceedings of the Synthesis Workshop*, pp. 114-19. Baton Rouge, Louisiana: Louisiana Sea Grant College Program.

Whitledge, T. E. 1994. Nutrient concentrations at the Mississippi/Atchafalaya River outflows. *Coastal Oceanographic Effects of Summer 1993 Mississippi River Flooding, Special NOAA Report.* M. J. Dowgiallo, pp. 36-38. Silver Spring, Maryland: National Oceanic and Atmospheric Administration, Coastal Ocean Office/National Weather Service.

Wiseman, W. J. Jr., V. J. Bierman Jr., N. N. Rabalais, and R. E. Turner. 1992. Physical structure of the Louisiana Shelf hypoxic region. *Nutrient Enhanced Coastal Ocean Productivity, NECOP Workshop Proceedings*, pp. 21-26. Galveston, Texas: Texas A&M University Sea Grant Program.

Wiseman, W. J. Jr., and R. W. Garvine. 1995. Plumes and coastal currents near large river mouths. *Estuaries* 18, no. 3: 509-17.

Wiseman, W. J. Jr., and F. J. Kelly. 1993. Salinity variability within the Louisiana Coastal Current during the 1982 flood season. *Estuaries* 17, no. 4: 732-39.

Wiseman, W. J. Jr., N. N. Rabalais, R. E. Turner, S. P. Dinnel, and A. MacNaughton. 1997. Seasonal and interannual variability within the Louisiana Coastal Current: Stratification and hypoxia. *Journal of Marine Systems* 12: 237-48.

Wiseman, W. J. Jr., N. N. Rabalais, R. E. Turner, G. Hitchcock, and N. D. Walker. 1997. Physical variability in the Louisiana inner shelf hypoxic region. *Proceedings of the First Gulf of Mexico Hypoxia Management Conference*, pp. 57-62. Stennis Space Center, Mississippi: U.S. Environmental Protection Agency, Gulf of Mexico Program Office.