OCEAN STUDIES BOARD

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1993

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Ocean Studies Board

Commission on Geosciences, Environment, and Resources

National Research Council

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MASTER

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Preface

The ocean has a profound influence on human life and activities. For eight years the Ocean Studies Board (OSB) has been the focal point within the National Research Council for ocean science issues. The Board has advised the nation on the health of ocean sciences research, application of knowledge for the protection and wise use of the ocean and its resources, and the use of ocean science research to ensure continued national security. In each of these areas, the Board concentrates on the basic science aspects and, where appropriate, how the science relates to policy decisions and applications. The ever-expanding scope of marine-related activities and the resulting need to maintain both breadth and depth of expertise has presented a great challenge to the Board and to the NRC.

A central tenet of the OSB's strategy is that maintaining the health of the basic sciences is necessary for wise policy decisions and for understanding of potential applications. During my tenure as OSB chairman, the Board conducted or began a number of studies focused on basic ocean science issues. In 1992, the Board published a report, *Oceanography in the Next Decade: Building New Partnerships*, that reviewed the present health and future directions of oceanography in the United States. The report was intended to stimulate a discussion of where U.S. marine science is headed, its strengths and weaknesses, and to explore how the nation can sustain a vigorous, exciting, and ultimately useful marine science. Among other activities, studies have focused on understanding of the effects of low-frequency sound on marine mammals, issues of biological diversity in marine systems, and the use of analytical chemistry for applications in chemical oceanography.

The Board faces many challenges as it attempts to serve the U.S. marine science community as well as the agencies that support them. Some of the federal agencies and Congress, in the midst of budget limitations, are discussing a shift of their support away from fundamental research to more short-term "applied" goals, and on to technology addressing immediate societal problems. The challenge to both the scientific community and the Federal government is to find an appropriate balance which meets near-term societal needs without undermining the investment in knowledge which will be necessary for the practical decisions of future generations. Finding and sustaining this balance will undoubtedly be the central effort of the Ocean Studies Board and the government agencies for the indefinite future. It will not be a easy task.

Carl Wunsch
Chairman

Background

The Ocean Studies Board (OSB), created in July 1985, serves as an independent advisor to the federal government on matters of ocean science and policy. It is a unit of the Commission on Geosciences, Environment, and Resources of the National Research Council (NRC). Jointly administered by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine, the NRC applies the intellectual resources of the scientific and engineering communities to national problems through its volunteer advisory committees.

The goals of the OSB are:

- To promote the advancement of scientific understanding of the ocean by overseeing the health of ocean sciences and stimulating their progress;
- To encourage the wise use of the ocean and its resources through the application of scientific knowledge;
- To lead in the formulation of national and international marine policy and to clarify scientific issues that affect this policy; and
- To promote international cooperation in oceanographic research and to improve scientific and technical

assistance to developing countries.

The OSB is a multidisciplinary body with representation from the fields of marine biology and biological oceanography, chemical oceanography, physical oceanography, marine geology and geophysics, engineering, and marine policy. Its twenty members serve staggered three-year terms. The OSB carries out much of its work through its committees and panels.

Members of the OSB and its subgroups are chosen from academic institutions, national laboratories, and industry on the basis of outstanding professional qualifications. They serve as individuals rather than as representatives of organizations. Approximately 100 distinguished persons served on the OSB and its subgroups in 1993. In addition, several hundred other individuals participated in OSB-sponsored symposia, workshops, and regional meetings in 1993.

On its own initiative or at the request of Congress or federal agency sponsors, the OSB examines ocean science and policy issues of national and international importance. The board meets three times annually to review existing projects and develop new ones, to discuss federal ocean research programs, and to help formulate U.S. positions on international ocean science issues. OSB members identify issues for study, assess study plans and

background documents, review draft reports, serve on committees, nominate new committee and board members, and organize special sessions at professional meetings.

OSB activities are supported primarily by federal agencies, including the National Oceanic and Atmospheric Administration (NOAA), the National Science Foundation (NSF), the Office of Naval Research (ONR), the Office of the Oceanographer of the Navy, the National Aeronautics and Space (NASA) Administration, the Department of Energy (DOE), the Environmental Protection Agency (EPA), the Department of State (DOS), the U.S. Geological Survey, the Federal Emergency Management Agency (FEMA), and the Minerals Management Service (MMS). Support is occasionally obtained from foundations, such as the Arthur W. Mellon Foundation and the David and Lucille Packard Foundation.

OSB activities fall into three broad categories: promoting the health of ocean sciences in the United States, encouraging the protection and wise use of the ocean and its resources, and applying ocean science to improve national security. In each area, the OSB focuses on basic science and, if appropriate, on how science relates to policy. A brief description of 1993 OSB activities, along with activities planned in 1994 and beyond, is presented herein.

Health of Ocean Sciences

The United States is a world leader in oceanographic research. Continued excellence in oceanography is essential to our national interests and requires constant improvement to both physical and human resources at oceanographic institutions. Ocean sciences must retain a healthy infrastructure to enable them to contribute to the understanding and possible solution of ocean-related problems. Thus, the Ocean Studies Board's first goal is to monitor and promote the health of ocean sciences.

In part, the OSB accomplishes this by functioning as a liaison between academic marine scientists and the federal government. The board also aids the discipline by carrying out other tasks, such as assessing the research infrastructure and identifying deficiencies, identifying promising new research areas, advising agencies, promoting science education at all levels, and promoting international cooperation in marine science.

The OSB serves as the U.S. National Committee to the Scientific Committee on Oceanic Research (SCOR), a component committee of the International Council of Scientific Unions. OSB member Brian Rothschild was elected Secretary of the SCOR Executive Committee in September of 1992 and the OSB receives regular updates on SCOR activities and discusses SCOR projects proposed by U.S. scientists.

The OSB thereby encourages participation of the U.S. ocean research community in SCOR meetings and associated international research. In addition, the OSB seeks to promote international cooperation through its committees.

The board completed in 1993 a disciplinary review on the topic of chemical oceanographic measurement technologies as well as reports on Navy-relevant research opportunities (see Navy Committee section). In 1994, reports are expected for the fields of molecular marine biology, low-frequency sound and marine mammals, and marine fisheries science and management. In addition, sub-groups of the OSB will review the ocean science programs of federal agencies, such as National Oceanic and Atmospheric Administration (Coastal Ocean Program and National Sea Grant College Program) and the Office of Naval Research.

Oceanography in the Next Decade: Building New Partnerships (Completed Activity)

Oceanography has matured and changed dramatically in the past twenty years. The Ocean Studies Board completed a study in 1992 that reviewed the state of marine sciences in the United States. The report addressed (1) the current status of oceanography and its infrastructure, (2) future scientific directions in ocean sciences, and (3) opportunities for

new partnerships between the federal government and academic oceanographers.

The OSB recommended a broader range of partnerships between the government and academia and concluded that many of the science goals of oceanography will be achieved only with formation of stronger partnerships and efficient division of labor and responsibilities, and with sharing of human, physical, and fiscal resources among academic institutions, private research institutions, and national laboratories. The science goals at stake are not only those of basic science to fulfill intellectual curiosity, but also the applied science missions of several federal agencies.

The board will continue to promote the implementation of the report recommendations. OSB members plan to use the report as a basis for discussions as they meet with individual federal agencies to develop plans to apply oceanographic science to issues relevant to the agencies' programs and encourage agencies to support basic science that is ultimately necessary to fulfill their missions. It is significant that the Board of Governors of the Joint Oceanographic Institutions, Inc. issued a resolution stating that they would use *Oceanography in the Next Decade* as a "blueprint" for their attempts to encourage greater cooperation between academic oceanography programs and federal agencies.

Committee on Molecular Marine Biology (Ongoing Activity)

The Committee on Molecular Marine Biology was formed in 1991 to evaluate the use of molecular biology tools to answer ocean science questions. The committee has focused on 1) the basic research needs of the ocean science community, 2) how molecular techniques could help answer fundamental questions about the biology of marine organisms and enhance our understanding of oceanographic processes, and 3) the potential benefits to society that may result from such advances. Potential benefits include enhanced understanding of the ocean's role in regulating global processes, information necessary for improved management of ecologically and economically important fish populations, and aid in environmental quality evaluation and assessment of the impact of global change on marine ecosystems. The committee will complete a report entitled *Molecular Biology in Marine Science: Scientific Questions, Technological Approaches, and Practical Implications* in 1994.

In the next two years, a new committee will begin a study entitled *Molecular Marine Biology and Marine Biotechnology: Research Opportunities and Policy Issues*. This is a joint committee between the NRC Board on Biology and the Ocean Studies Board. The new committee will 1) evaluate the potential of applying molecular biological "tools" to problems in marine biology and

biological oceanography, 2) examine the importance of marine biotechnology and research as they relate to policy issues, and 3) assess the present status of basic research on marine organisms and their future as models for biomedical, environmental, and agricultural research.

Review of the National Sea Grant College Program (Planned Activity)

In November 1993, the Undersecretary for Oceans and Atmosphere of the Department of Commerce requested that the Ocean Studies Board review the National Sea Grant College Program by June 1, 1994.

The purpose of the review will be to "provide the basis for any needed changes in the program and to provide the basis for NOAA working with the Congress on Sea Grant's Reauthorization." A review committee of approximately ten members will be formed. The committee will include expertise on basic and applied marine science, as well as engineering, policy, and education.

Panel on the NOAA Coastal Ocean Program (Ongoing Activity)

The NOAA Coastal Ocean Program (COP) coordinates new coastal research programs across NOAA's

five line offices and awards research funding to both NOAA and academic scientists. COP elements address several of the pressing marine problems facing the coastal environment including environmental quality, coastal hazards, and fisheries ecosystems. An OSB panel was formed in 1989 to advise COP on program priority setting and management; scientific planning; procedures for proposal solicitation, review, and peer review; information dissemination; and relationships with the scientific communities outside NOAA. The panel issued a report in 1991, *A Review of the NOAA Coastal Ocean Program*, that commended the progress of COP and recommended improvements to the program.

In late 1993, the panel began a new review that is expected to be completed by April 1, 1994. This review will evaluate COP's accomplishments and plans for the future.

Ocean Environment and Resources

The ocean plays a role in regulating Earth's climate, sustains a large portion of Earth's biodiversity, and is used for a variety of sometimes conflicting purposes. Populations have increased and marine ecosystems, in particular coastal ecosystems, are increasingly affected by human activities, including pollution and depletion of important

resources. There is a sense of urgency about reducing human impacts on the ocean and a need to understand the potential effects of oceanic changes on society.

Ocean environment and resource issues are in acute need of new science-based policy. Thus, the Ocean Studies Board's second area of interest is the application of scientific knowledge for the protection and wise use of the ocean and its resources, as well as to understand the ocean's role in global change.

Committee on Low-Frequency Sound and Marine Mammals (Ongoing Activity)

Marine scientists are increasing their use of acoustic methods to conduct oceanographic research. Low-frequency sound, because of its physical properties, is particularly useful for studying ocean circulation, the structure and processes of ocean sediments and crust, and global climate change. There are many sources of low-frequency sound in the ocean including natural sources such as wave action, ice cracking and seismic activity, and human-made sources such as ships and oil and gas drilling.

Low-frequency sound is of special interest as it relates to marine mammals, because they are known to vocalize, and presumably hear, in these frequencies and because they are protected by one or more laws—

the Marine Mammal Protection Act (MMPA), the Endangered Species Act (ESA), and the Fur Seal Act. Consequently, in order to provide effective protection, it is necessary to determine the effects of low-frequency sound on marine mammals and to assess accurately the impact and contributions of the various human activities producing such sounds.

The Committee on Low-Frequency Sound and Marine Mammals was established in 1992 to review the current state of knowledge and ongoing research of the effects of low-frequency sound (1-1000 Hz) on marine mammals; advise the sponsors about effects on marine mammals while considering the trade-offs between possibly harmful effects and the benefits of underwater sound as a research tool; and recommend research needed to improve our basic understanding of the effects of low-frequency sound on marine mammals.

As part of its deliberations, the committee was briefed about marine mammal research sponsored by the Office of Naval Research, the NOAA National Marine Fisheries Service, and the Minerals Management Service. In addition, a representative from NOAA's Office of Protected Resources explained the federal marine mammal protection and management programs and the legal and regulatory aspects of conducting scientific research in accordance with the MMPA and ESA, and the applicability of these laws and regulations to oceanographic research.

Committee members and outside experts summarized scientific knowledge from their areas of expertise, for example, effects of low-frequency sound and noise on marine mammals, marine mammal auditory physiology, underwater low-frequency sound propagation, ambient noise, and marine mammal behavior and communication.

The committee's findings are expected to be published in early 1994. The committee report will review what is known about the effects of low-frequency sound on marine mammals, making recommendations for improving the regulatory process governing scientific research under the MMPA, and making recommendations for future research to improve our understanding of the effects of low-frequency sound on marine mammals.

Committee on Fisheries (Ongoing Activity)

More attention is being focused on the management of our living marine resources, in part because these economically valuable resources are increasing in demand, and decreasing in supply. Under such conditions, effective management based on the best scientific information is key to maintaining sustainable populations while maximizing available catch and profit. Ineffective management results in waste and lost profits and furthermore, may not maintain sustainable populations.

The OSB formed a Committee on Fisheries in 1992 to review alternative fisheries management approaches and to identify and analyze strategic-level priority issues concerned with a) science, b) criteria for public-sector performance in fishery management and conservation, c) fishery policy, and d) policy implementation.

The committee has gathered information about critical fisheries issues from panels of interest groups including federal agency representatives, congressional staff, fisheries managers, fishing industry representatives, and environmental organizations in the Mid-Atlantic and the Gulf of Mexico regions.

In 1993, the committee focused on fisheries issues relevant to the reauthorization of the Magnuson Fishery Conservation and Management Act (MFCMA) and plans to complete a report on this topic in 1994 for consideration during the reauthorization of the MFCMA by Congress. At the end of 1993, Dr. John Magnuson (University of Wisconsin) assumed the responsibilities of the committee chairmanship. The committee will endeavor to maintain a close liaison with other NRC committees focused on fisheries topics.

Committee on the Coastal Ocean (Ongoing Activity)

The Committee on the Coastal Ocean was established in 1989 to provide guidance and oversight for the

science of the coastal ocean and its application to societal needs. The committee serves as a focal point within the National Research Council for discussion of coastal science issues. The committee has responded to requests from federal agencies for advice and review of their programs, has promoted greater international participation in coastal ocean science by the U.S. scientific community, and launched an effort to improve the linkage between coastal ocean science and environmental policy development.

Committee activities are focused in five areas that are important for enhancing coastal ocean science in the United States:

- Assist in the development of a coherent U.S. coastal ocean science program.

The committee will continue to articulate a broad vision of the needs, purposes, and foci for U.S. coastal ocean science and will assist, if requested, any interagency coastal ocean science initiative that develops.

- Improve the linkage between coastal ocean science and policy.

Coastal science and coastal zone management often proceed independently, with little opportunity for mutually beneficial interactions. In November 1992 the committee convened a symposium on improved interactions between coastal science and policy. The symposium focused

on California and was designed to bring together regional scientific, natural resource management, and political communities to discuss how scientific knowledge can be used more effectively in the policy process and how needs for scientific information can be better communicated from managers to scientists. An additional symposium, focused on the Gulf of Mexico regions, is being planned for June 1994. A proceedings report will be issued after each symposium. A third symposium focused on the Gulf of Maine may be planned at a later date.

- Respond to agency and congressional requests for review and advice.

The committee is prepared to provide timely reviews to federal agencies regarding the direction of their coastal ocean science programs.

- Cooperate and coordinate with other NRC committees on issues relevant to coastal ocean science.

Priority will be placed on effective cooperation with other NRC panels and committees, not only under the OSB, but also under other boards that are addressing issues relevant to coastal ocean science.

- Improve the linkage between U.S. and international coastal science efforts.

The committee will encourage the development of means to use the U.S.

educational system for international human resource development for coastal ocean science.

Committee on Biological Diversity in Marine Systems (Planned Activity)

This committee will be a cooperative activity with the NRC Board on Biology to plan and convene a workshop on biological diversity in marine systems. Little is known about marine biodiversity, the evolution and extinction of marine species, and factors controlling species distributions. This is an important topic as marine species are experiencing increasing pressure from habitat degradation and loss, invasion by non-indigenous species, and changes in environmental parameters due to climate change, pollution, and other natural and human-induced factors. The planned workshop, to be held in mid-1994, will be the first phase of the project. Phase II will consist of a study based on the workshop findings and the expertise of committee members to develop a phased plan for priority research on biological diversity in marine systems.

Committee on Oceanic Carbon (Ongoing activity)

The Ocean Studies Board formed a Committee on Oceanic Carbon in 1992 to focus on three issues: 1) chemical measurement technologies for ocean science, 2) oceanic CO₂

measurements, calibration, and data; and 3) carbon exchange across the air-sea and sediment-water interfaces, and its relation to the global carbon cycle.

As the committee discussed means of improving knowledge of the global carbon cycle, it became obvious that new measurement techniques and instruments would be required for carbon and other biologically-important elements. In particular, in situ remote sensors are needed for long-term measurements of specific elements and molecules. The committee issued a report, *Applications of Analytical Chemistry to Oceanic Carbon Cycle Studies*, in late 1993. The report identifies state-of-the-art measurement technologies of promise for use in ocean science and discusses technical hurdles, opportunities, and the role that government and academia can play in overcoming the non-technical barriers to successful research, development, and transfer of these technologies to the ocean science community. The committee recommended new techniques for measuring carbon dioxide, nutrients, trace metals, and other biologically important elements and compounds.

Measurements of components of the seawater carbon system are now a part of several global research programs, including the World Ocean Circulation Experiment and the Joint Global Ocean Flux Study. There is still much debate about measurement techniques for some forms of carbon. CO₂ measurements are made by a

variety of methods, and standards are in the initial stages of development for some carbon system components. There is a need to provide guidance to the federal agencies on standardization of procedures and preparation of reference materials for ocean carbon system components. The committee plans to issue a letter report in 1994 to the agencies that fund carbon research and measurements. This report will highlight the need for development of new reference materials for carbon system measurements.

Fluxes of carbon among the ocean, atmosphere, and sea floor are poorly understood, limiting our ability to model the role of various forms of carbon in the global carbon cycle, important for understanding global climate change. Knowledge of the role of air-sea and sediment-water fluxes of carbon is crucial for building models that will predict future atmospheric carbon dioxide concentrations accurately. The committee is working on a report that documents what is known about carbon fluxes and suggests areas of research that should be pursued to achieve a better understanding of carbon flux processes due to riverine inputs, coastal ocean processes, air-sea interactions, oceanic primary production, and sediment-water fluxes.

The Ocean's Role in Global Change (Ongoing activity)

The Ocean Studies Board has had a long-standing interest in the role of the ocean in global climate change, climate prediction, and other global processes. Although that role is not fully understood, there is general agreement that it is significant. Present and proposed research and observation programs aim to increase our knowledge of ocean processes and ultimately to provide an understanding of these processes sufficient to enable us to predict the long-term interaction of the ocean and climate systems. The OSB has coordinated its activities on global change with related activities of the NRC Board on Global Change through an OSB member (Dr. William Merrell, Texas A&M University) being appointed as a liaison to the Board on Global Change. The chair of that board, Dr. Edward Frieman (Scripps Institution of Oceanography), was also a member of the OSB.

A number of large, multi-disciplinary research programs have been planned and initiated over the past decade to study various aspects of the ocean's role in global cycles. The OSB will issue a report in 1994 that documents information about the major ocean-related research programs that contribute to the understanding the ocean's role in the global cycles, including the plans, accomplishments, and the significance of the accomplishments of these programs. The purpose of this report is to serve as an educational document and

reference work that should be of interest to decision makers and policy makers in universities, federal agencies, and Congress.

The OSB will continue to work with the Board on Global Change and other relevant NRC boards to develop appropriate studies related to the ocean's role in global change.

National Security

Information about the ocean and its range of effects on ships is crucial for the operations of Navy aircraft, ships, and submarines. The Navy recognized the importance of stimulating oceanographic research and became the first major supporter of the field on oceanography soon after World War II. The dramatic political changes that have occurred around the globe in recent years have not diminished the need for ocean science research and improved understanding of the ocean. In fact, as the likelihood of coastal warfare has increased, coastal oceanography has become even more important. The complexity of the processes that occur in coastal environments has increased the need for improved models and predictive capabilities of coastal ocean conditions.

The Ocean Studies Board conducts a range of activities to help the Navy identify the areas of science that area both important to a basic understanding of the ocean and relevant to the Navy mission. At the request of the Chief of Naval

Research and the Oceanographer of the Navy, the OSB has provided advice on Navy marine science programs and on potential oceanographic contributions to national security. The advice to the Navy is given through the OSB Navy Committee.

Navy Committee (Ongoing activity)

The Navy Committee was formed in 1985 to help the Navy develop long-range plans for ocean science research and development, to identify Navy research priorities, to review documents describing Navy programs, and to provide other guidance as requested.

In 1993, ONR requested that the committee report on future research opportunities in the areas of marine meteorology, coastal sciences, oceanic chemistry, and marine geology and geophysics. The opportunities presented were to emphasize naval relevance. The Navy Committee responded to this request by forming study panels for each topic. Panels appointed by the NRC and composed of experts in the relevant fields were selected by the committee and the board. Reports were prepared and published in 1993, identifying opportunities for new research initiatives.

ONR has requested that the Navy Committee offer advice on promising research opportunities for each of its

core programs. To complete the review of the core programs, the Navy Committee plans to consider the last three programs—Arctic sciences, ocean optics, and small-scale physical oceanography—in 1994.

Symposium on Tactical Oceanography (Planned activity)

The OSB initiated a series of classified symposia on tactical oceanography in 1990, with subsequent symposia held in 1991 and 1993.

The symposia are organized by the Navy Committee and supported by the Office of the Oceanographer of the Navy and the Office of Naval Research. The purpose of the symposia is to provide an opportunity for discussion and an exchange of ideas between academic scientists and Navy users of their research. Academic participants discussed the potential contributions that science and technology could offer for support of naval warfare. Approximately 125 individuals participated in each of the first two symposia, half from the academic community and half from the military community. An unclassified summary of the first symposium was published in 1991. The second symposium was on the topic of Naval Warfare and Coastal Oceanography and an unclassified summary was published in late 1992.

The third symposium was held on 2-5 August 1993 with a focus on coastal oceanography and littoral warfare.

The symposium brought together 125 individuals from the operational Navy, the Navy oceanography research development and acquisition community, and academia, with the goals of:

1. Addressing timely operational problems, fleet mission needs, and other requirements where research and development assistance and inputs are sought by naval leaders and program managers.
2. Enhancing communications and understanding among basic and applied research communities, and between these communities and naval forces.
3. Enabling an extended group of researchers to become familiar with challenging naval issues unique or strongly applicable to the littoral regime.

The classified symposium opened with a littoral warfare wargame that was designed to emphasize the impact of decisions forced on warfare commanders by rapidly changing environmental conditions, such as experienced in the Persian Gulf War. The remainder of the symposium was devoted to plenary sessions and working groups. Working group discussions focused on four areas: harbors and approaches, straits and archipelagos, the surf zone, and continental shelves.

A report will be published in 1994 providing summaries of the working group deliberations intended to

document current status and "where to go now"—the direction for specific areas.

ONR will follow-up on the research issues identified and attempt to capture the new ideas within current research and development programs supporting mine warfare, special warfare, and shallow antisubmarine warfare against the diesel submarine threat.

APPENDIX I
OCEAN STUDIES BOARD
MEMBERSHIPS

Committee on Biological Diversity in Marine Systems

Cheryl Ann Butman, Woods Hole Oceanographic Institution, *Co-Chair*
James T. Carlton, Williams College, *Co-Chair*
George W. Boehlert, NOAA/National Marine Fisheries Service
Susan H. Brawley, University of Maine
Edward F. DeLong, University of California at Santa Barbara
J. Frederick Grassle, Rutgers University
Jeremy B. C. Jackson, Smithsonian Tropical Research Institute
Simon A. Levin, Princeton University
Arthur R.M. Nowell, University of Washington
Robert T. Paine, NAS, University of Washington
Stephen R. Palumbi, University of Hawaii
Geerat J. Vermeij, University of California at Davis
Les Watling, University of Maine

Committee on Fisheries

John J. Magnuson, University of Wisconsin, *Chair* (Oct. 1993-present)
Brian Rothschild, University of Maryland, *Chair* (Jan.-Sept. 1993)
Dayton Lee Alverson, National Resource Consultants, Inc.
Charles Black, Sr., NAE, Mardela Corporation
Gardner M. Brown, Jr., University of Washington
William Burke, University of Washington
Paul Dayton, Scripps Institution of Oceanography
Jake Dykstra, Industry Representative, RI
James Joseph, International Atlantic Tropical Tuna Commission
Charles Meacham, Alaska Department of Fish and Game
William J. Merrell, Jr., Texas A&M University
Donald Olson, University of Miami
Terrance J. Quinn II, University of Alaska

Committee on Low-Frequency Sound and Marine Mammals

David M. Green, NAS, University of Florida, *Chair*
Harry A. DeFerrari, University of Miami
Dennis McFadden, University of Texas
John Pearse, University of California at Santa Cruz
Arthur N. Popper, University of Maryland
W. John Richardson, LGL, Ltd., Canada
Samuel H. Ridgway, Naval Ocean Systems Center at San Diego
Peter L. Tyack, Woods Hole Oceanographic Institution

Committee on Molecular Marine Biology

Dennis Powers, Stanford University, *Chair*
Barbara Block, University of Chicago
Peter Brewer, Monterey Bay Aquarium Research Institute
Sallie Chisholm, Massachusetts Institute of Technology
Eric Davidson, NAS, California Institute of Technology
William Fenical, Scripps Institution of Oceanography
Michael Hadfield, University of Hawaii
Robert Haselkorn, NAS, University of Chicago
Daniel Morse, University of California, Santa Barbara
Mary Jane Perry, University of Washington
George Somero, NAS, Oregon State University
A. Aristides Yayanos, Scripps Institution of Oceanography

Committee on the Coastal Ocean

Donald F. Boesch, University of Maryland, *Chair*
David G. Aubrey, Woods Hole Oceanographic Institution
Kenneth Brink, Woods Hole Oceanographic Institution
Biliana Cicin-Sain, University of Delaware
John R. Costlow, Jr., Duke University (ret.)
Michael Dagg, Louisiana Universities Marine Consortium
John Farrington, University of Massachusetts
Judith Grassle, Rutgers University
Richard Hildreth, University of Oregon
Charles Nittrouer, State University of New York
Scott W. Nixon, University of Rhode Island
James E. Overland, NOAA/PMEL
Roger Pielke, Colorado State University
Thomas M. Powell, University of California, Davis

Jerry Schubel, State University of New York
Deborah Swackhamer, University of Minnesota
Karl. K. Turekian, NAS, Yale University
Clinton Winant, Scripps Institution of Oceanography

Panel on the NOAA Coastal Ocean Program

Robert C. Beardsley, Woods Hole Oceanographic Institution, *Chair*
Thomas Church, University of Delaware
Michael Freilich, Oregon State University
Carl Friehe, University of California, Irvine
Anne Giblin, Marine Biological Laboratory, Woods Hole
Kenneth Haddad, Florida Marine Research Institute
Dale B. Haidvogel, Rutgers University
Edward Houde, University of Maryland
Michael N. Josselyn, San Francisco State University
James Kitchell, University of Wisconsin
Judith McDowell, Woods Hole Oceanographic Institution
John B. Mooney, Jr., Harbor Branch Oceanographic Institute

Committee on Oceanic Carbon

Taro Takahashi, Lamont-Doherty Earth Observatory, *Chair*
Robert Berner, NAS, Yale University
Andrew G. Dickson, Scripps Institution of Oceanography
Ellen R. Druffel, University of California at Irvine
Hugh Ducklow, Woods Hole Oceanographic Institution
John I. Hedges, University of Washington
William Jenkins, Woods Hole Oceanographic Institution
Paul D. Quay, University of Washington
Jorge Sarmiento, Princeton University
Eric Sundquist, U.S. Geological Survey, Woods Hole
Pieter Tans, National Oceanic and Atmospheric Administration, Boulder, Colorado
Ray F. Weiss, Scripps Institution of Oceanography
James Yoder, University of Rhode Island

Navy Committee

Kenneth Brink, Woods Hole Oceanographic Institution, *Chair*
Robert Cannon, Jr., NAE, Stanford University
Robert Detrick, Woods Hole Oceanographic Institution
Eileen Hofmann, Old Dominion University
William Kuperman, Naval Research Laboratory
Arthur R.M. Nowell, University of Washington

Coastal Sciences Study Panel

Robert Beardsley, Woods Hole Oceanographic Institution, *Chair*
John Allen, Oregon State University
Anthony Bowen, Dalhousie University
Kenneth Brink, Woods Hole Oceanographic Institution
Robert Cannon, Jr., NAE, Stanford University
Richard Garvine, University of Delaware
Robert Guza, Scripps Institution of Oceanography
Adriana Huyer, Oregon State University

Marine Chemistry Study Panel

Robert Duce, Texas A&M University, *Chair*
Edward Boyle, Massachusetts Institute of Technology
Edward Goldberg, NAS, Scripps Institution of Oceanography
Susan Heinrichs, University of Alaska at Fairbanks
Kenneth S. Johnson, Moss Landing Marine Laboratories
George Luther III, University of Delaware

Marine Geology and Geophysics Study Panel

John Orcutt, Scripps Institution of Oceanography, *Chair*
William Curry, Woods Hole Oceanographic Institution
John Delaney, University of Washington
Paul J. Fox, University of Rhode Island
Marcia McNutt, Massachusetts Institute of Technology
Richard Sternberg, University of Washington
Paul Stoffa, University of Texas

Marine Meteorology Study Panel

Stephen Cox, Colorado State University, *Chair*
Bruce Albrecht, Pennsylvania State University
Kenneth Brink, Woods Hole Oceanographic Institution
Russell Elsberry, Naval Postgraduate School

Carl Friehe, University of California at Irvine
Kristina Katsaros, University of Washington
James Overland, Pacific Marine Environmental Laboratory/NOAA

APPENDIX II
OCEAN STUDIES BOARD
1993 MEETINGS

January 6-8	Ocean Studies Board, Washington, DC
February 2-4	Committee on Oceanic Carbon, Irvine, CA
March 7-10	Committee on Fisheries, New Orleans, LA
March 25-26	Committee on the Coastal Ocean, Washington, DC
May 4	Steering Committee for Symposium Series on Improving Interactions Between Coastal Science and Policy, Washington, DC
May 4-5	Committee on Fisheries, Washington, DC
May 4-5	Marine Chemistry Study Panel
May 11-12	Marine Geology and Geophysics Study Panel
May 15-17	Committee on Low-Frequency Sound and Marine Mammals, Ottawa, Canada
May 18-19	Executive Committee, Washington, DC
May 24-25	Coastal Sciences Study Panel
May 25	Planning meeting for activities of the Panel on the NOAA Coastal Ocean Program, Washington, DC
June 1-2	Marine Meteorology Study Panel
July 22	Regional Steering Committee for Gulf of Mexico Symposium on Improving Interactions Between Coastal Science and Policy, New Orleans, LA
August 2-5	Tactical Oceanography Symposium III, San Diego, CA
August 6	Navy Committee, San Diego, CA

August 12-13	Committee on Fisheries, Seattle, WA
September 13	Planning meeting for activities of the Panel on the NOAA Coastal Ocean Program, Washington, DC
September 24	Steering Committee for Symposium Series on Improving Interactions Between Coastal Science and Policy, Washington, DC
October 5-7	Ocean Studies Board, Washington, DC
October 11-12	Committee on the Coastal Ocean, Washington, DC
October 14-15	Committee on Oceanic Carbon, Washington, DC
October 21	OSB NSIA Meeting, Washington, DC
November 1-2	Panel on the NOAA Coastal Ocean Program, Washington, DC
November 11	Steering Committee on Improving Interactions Between Coastal Science and Policy
December 17	OSB Executive Committee, Washington, DC

APPENDIX III
OCEAN STUDIES BOARD
PUBLICATIONS

1987

- Greenland Sea Project
- The Mid-Oceanic Ridge: A Dynamic Global System--Proceedings of a Workshop
- Physical Oceanography for the Year 2000
- Recruitment Processes and Ecosystem Structure of the Sea

1988

- Oceanography and the Navy--Future Directions
- Ocean Studies Board Annual Report 1987 and Future Plans
- Background Papers for the Workshop on Continental Margins: Evolution of Passive Continental Margins and Active Marginal Processes

1989

- Ocean Studies Board Annual Report 1988 and Future Plans
- Symposium Commemorating the 25th Anniversary of the Demonstration of the Feasibility of Deep Ocean Drilling
- Margins: A Research Initiative for Interdisciplinary Studies of Processes Attending Lithospheric Extensions and Convergence
- The Navy's Role in Global Change Research

1990

- Ocean Studies Board Annual Report 1989 and Future Plans
- The Ocean's Role in Global Change: The Contemporary System--An Overview of Major Research Programs

1991

- Ocean Studies Board Annual Report 1990
- Symposium on Tactical Oceanography
- A Review of the NOAA Coastal Ocean Program
- Review of the Department of Energy Report: *Dynamics of Continental Margins*

1992

- Ocean Studies Board Annual Report 1991
- A Review of the Ocean Drilling Program Long Range Plan
- Oceanography in the Next Decade: Building New Partnerships
- Symposium on Naval Warfare and Coastal Oceanography
- Background papers for the California Symposium on Interactions Between Coastal Science and Policy

1993

- Ocean Studies Board Annual Report 1992
- Applications of Analytical Chemistry to Oceanic Carbon Cycle Studies
- Research Opportunities in Ocean Acoustics
- Research Opportunities in Mesoscale and Large-Scale Physical Oceanography
- Research Opportunities in Remote Sensing
- Research Opportunities in Oceanic Biology
- Research Opportunities in Marine Geology and Geophysics for ONR Programs
- Research Opportunities in Oceanic Chemistry for ONR Programs
- Research Opportunities in Coastal Sciences for ONR Programs
- Research Opportunities in Marine Meteorology for ONR Programs

1994 (Expected)

- Ocean Studies Board Annual Report 1993
- A Review of the Accomplishments and Plans of the NOAA Coastal Ocean Program (1994)
- A Review of the National Sea Grant College Program
- Improving the Management of U.S. Marine Fisheries
- Low-Frequency Sound and Marine Mammals: Current Knowledge and Research Needs
- Proceedings of a Workshop on Biological Diversity in Marine Systems
- Proceedings of the California Symposium on Improving Interactions Between Coastal Science and Policy

- The Ocean's Role in Global Change: Progress of Major Research Programs
- Proceedings of the Symposium on Coastal Oceanography and Littoral Warfare
- Review of the Scientific Basis of Management for Atlantic Bluefin Tuna

APPENDIX IV

OCEAN STUDIES BOARD

MEMBERS

Carl Wunsch, Chairman of the Ocean Studies Board since July 1991, is the Cecil and Ida Green Professor of Physical Oceanography at Massachusetts Institute of Technology. Dr. Wunsch was elected a member of the National Academy of Sciences in 1978. He has most recently been involved in planning for several international activities important to physical oceanography, including the World Ocean Circulation Experiment and the TOPEX/Poseidon satellite development. Dr. Wunsch received an S.B. in Mathematics in June 1961 and a Ph.D. in Geophysics in 1966, both from M.I.T.

Donald Boesch is a Professor of Marine Sciences and President of the Center for Environmental and Estuarine Studies of the University of Maryland System. His expertise is in the areas of biological oceanography, estuarine studies and environmental science and management. Dr. Boesch has been a member of the Ocean Studies Board since 1989. He also serves as chairman of the OSB Committee on the Coastal Ocean and as a member of the OSB Panel on the NOAA Coastal Ocean Program. He received a B.S. in Biology from Tulane University in 1967 and a Ph.D. in Marine Science from the College of William and Mary in 1971.

Peter Brewer is President and Chief Executive Officer of the Monterey Bay Aquarium Research Institute. Dr. Brewer served as Senior Scientist at Woods Hole Oceanographic Institution from 1978-1991. Dr. Brewer has served on the OSB since 1987 and presently serves on the OSB Committee on Oceanic Carbon and Committee on Molecular Marine Biology. His research interests are in the areas of chemical oceanography and new measurement technologies. He received a B.S. in 1962 and a Ph.D. in 1967 from Liverpool University, England.

Kenneth Brink is an Associate Scientist at Woods Hole Oceanographic Institution where he has worked since 1980. Dr. Brink has been a member of the OSB since 1991 and will assume the chairperson position of the OSB Navy Committee in 1993. His research interests include shelf dynamics, coastal upwelling and subtidal frequency fluctuations over the continental shelf and slope. Dr. Brink is leading the multidisciplinary Coastal Ocean Processes research initiative. Dr. Brink received a Ph.D. in Geology and Geophysics from Yale University in 1977.

Robert Cannon is chairman and Charles Lee Powell Professor of Aeronautics and Astronautics at Stanford University. Dr. Cannon has been a member of the National Academy of Engineering since 1973. He began his membership on the OSB in 1991. His research interests include dynamics and automatic control, inertial guidance and automatic flight control of the air, water and spacecraft, hydrofoil boats, and wave actuated pumps. Dr. Cannon received an Sc.D. in mechanical engineering from M.I.T. in 1950.

Sallie Chisholm is a Professor of Civil and Environmental Engineering at MIT, and Director of the MIT/Woods Hole Joint Program in Oceanography. Dr. Chisholm has been an OSB member since 1990 and also serves on the Committee on Molecular Marine Biology. Her research area is biological oceanography, and her interests include the regulation of primary production in the sea, phytoplankton ecology and physiology. She is also involved in the Joint Global Ocean Flux Study. Dr. Chisholm received a B.A. in Biology/Chemistry in 1969 from Skidmore College and a Ph.D. in Biology from the State University of New York at Albany in 1974.

Biliana Cicin-Sain is a Professor of Marine Studies in the Graduate College of Marine Studies at the University of Delaware, where she holds joint appointments in the Department of Political Science and in the College of Urban Affairs and Public Policy. Professor Cicin-Sain also serves as Co-Director of the Center for the Study of Marine Policy at the University of Delaware. Dr. Cicin-Sain has been a member of the OSB since 1991 and also serves as a member of the OSB Committee on the Coastal Ocean. She has written extensively on a range of marine policy issues, including fisheries management, marine mammal management, offshore oil development, multiple use conflicts, and international marine policy. She received a B.A., M.A., and Ph.D. in political science from the University of California in Los Angeles.

William Curry is an Associate Scientist at Woods Hole Oceanographic Institution. Dr. Curry became an OSB member in 1992. His research area is marine geology and sedimentology and he presently serves as associate editor for the scientific journals *Paleoceanography* and *Reviews of Geophysics*. Dr. Curry received his B.S. from the University of Delaware in 1974 and his Ph.D. from Brown University in 1980.

Gordon Eaton is Director of the Lamont-Doherty Earth Observatory of Columbia University. Dr. Eaton became a member of the Ocean Studies Board in 1991. Dr. Eaton's previous appointments include President of Iowa State University and Dean of the College of Geosciences, and, later, Provost and Vice President for Academic Affairs at Texas A&M University. Prior to that, he was Associate Chief Geologist of the U. S. Geological Survey. His research interests lie in physical geology and regional geophysics. Dr. Eaton received a Ph.D. in geology and geophysics from the California Institute of Technology in 1957.

Rana Fine is chairperson of the Division of Marine and Atmospheric Chemistry, Rosentiel School of Marine and Atmospheric Sciences at the University of Miami. Dr. Fine became a member of the OSB in 1992 and serves on committees for the Board on Earth Sciences and Resources and the Board on Atmospheric Sciences and Climate. Dr. Fine received a B.S. from the University of New York in 1965 and both an M.S. and Ph.D. from the University of Miami in 1973 and 1975, respectively.

Michael Freilich is an Associate Professor in the College of Oceanography at Oregon State University. He became an OSB member in 1992. Dr. Freilich's previous positions include an eight-

year tenure as a project scientist on the NASA Scatterometer Project at the Jet Propulsion Laboratory. He received his B.S. from Haverford College in 1975 and Ph.D. from Scripps Institution of Oceanography in 1981.

Edward Frieman is Director of Scripps Institution of Oceanography and Vice Chancellor of Marine Sciences, at the University of California, San Diego. Dr. Frieman has been a member of the National Academy of Sciences since 1981 and he has been a member of the Ocean Studies Board since 1987. Dr. Frieman presently serves on numerous scientific boards and committees including the Vice President's Space Advisory Board and the Secretary of Energy Advisory Board. He received his Bachelor's degree in Engineering in 1946 from Columbia University, a Master's degree in Physics in 1948 and his Doctoral degree in Physics in 1952 from Polytechnic Institute of Brooklyn.

Arnold L. Gordon is a Professor of Oceanography at the Lamont-Doherty Earth Observatory of Columbia University. He has served as a member of the Ocean Studies Board since 1988. His research interests relate to the ocean's role in the global climate system with a special focus on physical oceanographic investigations in the Southern Hemisphere. He received a Ph.D. in oceanography from Columbia University in 1965.

Gordon Greve is Manager of Geophysics for World-Wide Operations at Amoco Production Company. He has been a member of the Ocean Studies Board since 1989. His research interests include improvement of seismic data quality through new and improved data acquisition techniques. Dr. Greve received his Ph.D. in 1962 from Stanford University.

William Merrell is Vice President for Research and Policy at Texas A&M University. He has been a member of the Ocean Studies Board since 1991, and also serves on the OSB Committee on Fisheries. Dr. Merrell's previous appointments include President of Texas A&M University at Galveston and President of the Texas Institute of Oceanography. His research interests include the dynamics of internal waves, descriptive physical oceanography, and marine resource management. He received a Ph.D. from Texas A&M University in 1971.

Arthur Nowell is a Professor and Director of the School of Oceanography, University of Washington. Dr. Nowell has been a member of the Ocean Studies Board since 1990. His research interests include biological sedimentary

dynamics, geophysical boundary layers, sediment transport, and oceanic particulate dynamics. Dr. Nowell received his B.S. in 1969 from Trinity College, Cambridge, England, and M.S. in 1971 and Ph.D. in 1975 from the University of British Columbia.

Dennis Powers is Director of Hopkins Marine Station and Harold A. Miller Professor of Biological Sciences, Stanford University. Dr. Powers has been an OSB member since 1987 and presently serves as chairman of the OSB Committee on Molecular Marine Biology. Dr. Power's research is focused in the field of molecular marine biology. He received a B.A. in Chemistry from Ottawa University in 1963 and a Ph.D. in Zoology/Protein Chemistry from the Argonne National Laboratory, Chicago and The University of Kansas in 1970.

Frank Richter is a professor at the University of Chicago. He became a member of the OSB in 1992. His research interests include fluid/rock interactions with a range of fluids from melts to porewater in deep-sea sediments. Dr. Richter received an engineering degree from the Colorado School of mines in 1965 and an M.S. and Ph.D. from the University of Chicago in 1971 and 1972 respectively.

Brian Rothschild is a Professor at the Center for Environment and Estuarine Studies, at the Chesapeake Biological Laboratory, University of Maryland. He has served on the OSB since 1991, and presently serves as Chairman of the OSB Committee on Fisheries. His research interests include ecology of fishes, marine ecology, biology and population dynamics, and resource policy. He received a Ph.D. in Zoology from Cornell University in 1962.

Paul Stoffa is a Carlton Centennial Professor in Geophysics, Department of Geological Sciences at the University of Texas at Austin. He became a member of the OSB in 1992. His research interests include marine geology and geophysics, applied seismology, and nonlinear optimization methods. He received a B.S. in physics from Rensselaer Polytechnic Institute in 1970 and Ph.D. in geophysics from Columbia University in 1974.