22 03.04

The Gulf Ecosystem Monitoring Program: First Steps Toward A Long-term Research and Monitoring Plan

INTERIM REPORT

February 2001

Committee to Review the Gulf of Alaska Ecosystem Monitoring Program
Polar Research Board
Board on Environmental Studies and Toxicology
The National Research Council

NATIONAL ACADEMY PRESS
Washington, D C

NATIONAL ACADEMY PRESS 2101 Constitution Avenue, N W Washington, D C 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 study was supported by Contract/Grant No CMRC/WASC/NOAA 50ABNF-0-00013 (BAA00360) between the National Academy of Sciences and Exxon Valdez Oil Spill Trustee Council Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the organizations or agencies that provided support for the project

Copies of this report are available from
Polar Research Board
2101 Constitution Avenue NW
Washington, D C 20418
202 334 3479

or

National Academy Press
2101 Constitution Avenue, N W
Lockbox 285
Washington, D C 20055
800-624-6242
202-334-3313 (in the Washington metropolitan area)
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 to Review the Gulf of Alaska Ecosystem Monitoring Program

MICHAEL ROMAN, *Chair*, University of Maryland, Cambridge, MD
DON BOWEN, Fisheries and Oceans Canada, Nova Scotia
ADRIA A ELSKUS, University of Kentucky, Lexington
JOHN J GOERING, University of Alaska, Fairbanks
GEORGE HUNT, University of California, Irvine
SETH MACINKO, University of Connecticut, Groton
DONAL MANAHAN, University of Southern California, Los Angeles
BRENDA NORCROSS, University of Alaska, Fairbanks
STEVEN PICOU, University of South Alabama, Mobile
THOMAS C ROYER, Old Dominion University, Norfolk
JENNIFER RUESINK, University of Washington, Seattle
KARL TUREKIAN, Yale University, New Haven

Staff

CHRIS ELFRING, Director, Polar Research Board
DAVID POLICANSKY, Associate Director, Board on Environmental Studies and Toxicology
ANN CARLISLE, Senior Project Assistant
ROB GREENWAY, Project Assistant[1]

[1] Until November 2000

Polar Research Board

Board on Environmental Studies and Toxicology

Acknowledgments

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 NRC's Report Review Committee The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its 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 review of this report

Joanna Burger, Rutgers, The State University of New Jersey
Eileen Hofman, Old Dominion University, Virginia
Ed Houde, University of Maryland, Chesapeake Biological Laboratory
Mahlon C Kennicutt, Texas A&M University
Terrie Klinger, University of Washington
Bruce Menge, Oregon State University
Jim Schumacher, Consultant, New Mexico
Judith Vergun, Oregon State University

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations nor did they see the final draft of the report before its release The review of this report was overseen by Robert Paine, University of Washington Appointed by the National Research Council, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered Responsibility for the final content of this report rests entirely with the authoring committee and the institution

Contents

Executive Summary

After the *Exxon Valdez* oil spill (EVOS) in 1989, a civil settlement required Exxon Corporation to pay $900 million over 10 years to restore resources injured by the spill and compensate for reduced or lost services the resources provide A trustee council of three federal and three state members was established to administer the funds As part of its mission, the EVOS Trustee Council has disbursed research funds, first for damage assessment and then for monitoring and research It also set aside some of the funds to create a permanent trust to support continued, long-term research and monitoring in the region At this point, the *Exxon Valdez* Oil Spill Trustee Council is developing a plan to guide this new research program, to be known as the Gulf Ecosystem Monitoring (GEM) program

To ensure that the GEM program is based on a science plan that is robust, far-reaching, and scientifically sound, the Trustee Council asked the National Academies to serve as an independent advisor The Academies appointed a special committee and charged it to review the scope and content of the program as it evolves This interim report focuses on the conceptual foundation of the GEM science program, as presented in the document *Gulf Ecosystem Monitoring A Sentinel Monitoring Program for the Conservation of the Natural Resources of the Northern Gulf of Alaska*, Review Draft April 21, 2000 (sometimes called GEM 2000 and cited in this report as EVOSTC, 2000a, the Executive Summary of this document is reproduced in Appendix B) The committee will prepare a separate report reviewing the more detailed research and monitoring science plan when that document becomes available in mid-2001

MISSION

The EVOSTC showed great foresight in setting aside funds over the years to create the trust fund that will now provide long-term funding to the GEM program, and the initial descriptions of the intent and scope of the program are to be commended As envisioned, the GEM program will offer an unparalleled opportunity to increase understanding of how large marine ecosystems in general, and Prince William Sound in particular, function and change over time The committee believes that it stands to be a significant program of importance to Alaska, the nation, and the scientific community With our underlying support for GEM stated, the committee would like to point out areas where we believe the program could be improved We do not wish to be taken as overly critical, we remind readers that the committee was charged to provide advice and we offer our thoughts as constructive additions to the planning debate This report follows the general structure used in EVOSTC 2000a, beginning with discussion of the mission statement

GEM's mission, as stated in EVOSTC, 2000a, is broad and ambitious ' to sustain a healthy and biologically diverse marine ecosystem in the northern Gulf of Alaska and the human use of the marine resources in that ecosystem through greater understanding of how its productivity is influenced by natural changes and human activities " The purpose of any mission statement is to serve as a general guiding principle and statement of underlying philosophy and approach, and this mission statement accomplishes this purpose However, putting this statement into practice is likely to prove difficult

First, it is not clear that the objective of sustaining a healthy, diverse ecosystem can be met by understanding how natural and human influences affect the ecosystem's productivity In fact, it is not even clear whether research efforts will be able to distinguish natural from human influences Furthermore, the term *healthy ecosystem* itself has no clear definition, in part because there are no generally accepted, clearly defined measures for assessing ecosystem health (NRC, 2000) Still, the committee recognizes that GEM must work under the mission assigned to it and thus move past this definition problem It might be useful for GEM to develop a practical, working definition of ecosystem health that relates to a particular aspect or aspects of the Gulf of Alaska's ecosystem structure (the biotic community), or functioning (ecological processes such as productivity), or both Having a working definition of ecosystem health would allow GEM to use its funds more effectively and avoid the risk of trying to monitor and study more than the program can successfully handle

Although the mission statement gives equal weight to natural and human changes, the GEM program document (EVOSTC, 2000a) is primarily focused on large-scale climate changes, particularly the Pacific Decadal Oscillation Despite some language about the importance of human activities (such as fishing, tourism, and other human uses), there is little in the proposed research program that actually explores those activities As the research program becomes operational, the complexities and ambiguities presented by the mission statement will become more apparent and problematic

According to an early EVOSTC document, Restoration Update Winter 2000 (EVOSTC, 2000b) (see Appendix A), GEM was conceived to have three main components

1 long-term ecosystem monitoring (decades in duration),
2 short-term focused research (one to several years in length), and
3 ongoing community involvement, including use of traditional knowledge and local stewardship

The committee views these three components as a sound foundation upon which to build We recognize that this particular publication is a newsletter written for a general audience but believe the explanatory text does a good job of summarizing the original intent of the program

GOALS

The GEM program document outlines five program goals detect, understand, predict, inform, and solve While the general intent of these goals is understandable, in terms of guiding the design of the program, the committee sees them as extremely diverse and far-reaching This may be a problem caused by writing the goals with the primary purpose of informing the public rather than for steering the science program While the GEM mission provides a good general statement of intent, it is unrealistic to believe that the program can address all five stated goals equally Certainly, some effort can go toward each of the goals, but the program should focus on the goals most related to long-term monitoring detection of change and understanding the causes of change Together, these will facilitate progress in learning to predict future changes, although the Trustee Council should be cautious about having too high expectations of predictability from such a program The goal of informing the public can be built around this core structure The goal of solving problems for resource managers and regulators also can be addressed in parallel to some extent, but should not drive the conceptual foundation of the program

The committee's concern is that addressing all five goals will present the risk that the research and monitoring program will be spread too thin to be effective In this report, the committee suggests some approaches to focusing the program goals, emphasizing the importance of having a sound, underlying scientific foundation to guide the program over its intended long time horizon

THE IMPORTANCE OF A SOUND CONCEPTUAL FOUNDATION

The GEM program offers an unparalleled opportunity to increase understanding of how large marine ecosystems in general, and Prince William Sound in particular, function To fulfill its promise, the program needs a sound scientific conceptual foundation This basic conceptual underpinning is key because it will guide program planners to develop a core set of measurements that can be taken indefinitely The conceptual foundation needs to provide both intellectual stability, to help keep the program focused and effective, and also flexibility so the program can evolve as knowledge grows and needs change

The committee recommends that the conceptual foundation for GEM be built around a simple but clear ecosystem model such as the example shown in Chapter 2, Figure 2-1 The foundation should be developed without preconceived notions of what species or processes are important to monitor, as those specifics will evolve out of this underlying framework In other words, program planners should look at the important elements depicted in the chosen model and ask "what variables or questions need to be measured or asked to understand this element and its relationship to the others?"

The GEM program to date seems to be unwise in using the still-untested Pacific Decadal Oscillation (PDO) as its conceptual foundation (However, it is expected that the GEM program will ultimately generate data that will help researchers evaluate the PDO hypothesis) Other conceptual models, such as the inshore/offshore production model, are also too narrow to provide the right kind of conceptual foundation, although such models will provide useful input to GEM Similarly, assuming that top predators serve to integrate environmental factors or drive the ecosystem is an assumption still to be tested, and again is not a sound conceptual foundation The choice of conceptual foundation is, of course, critical, as this will drive the choice of species and parameters to monitor, as described in Chapter 2, Box 2-1

A broad conceptual foundation with a sound scientific basis will provide a strong scientific justification for the program and will help to defend the program from criticism and political pressures over time It will also provide an intellectual structure that guides modification of the program, if and when that becomes necessary One might ask if this approach is too academic for a program that includes practical, management goals, and whether it would preclude the study of issues identified by managers or the public The opposite is true If the GEM program has a broad scientific foundation, then short-term issues of public concern can be addressed as elements within this broad construct Even more important, a sound scientific framework would make it much more likely that the GEM program will collect the most useful and important ecological information However urgent an environmental issue might be, understanding and managing it almost always depends on scientific understanding Thus, a soundly designed program based on a scientific conceptual foundation should not be seen as an alternative to reflecting public interests and concerns Instead, it should be recognized as the only way to do that effectively and over the long term The committee offers the following recommendations to achieve this broad goal

- The GEM program cannot address all its five stated goals equally The program's main focus should be on the goals most related to long-term monitoring detecting and understanding the causes of changes

- The science plan should be strongly based on a broad conceptual foundation that is ecosystem-based It should include natural and human-induced changes and it should be flexible and able to accommodate changing needs without compromising the core long-term measurements

- The GEM program should articulate two or three fundamental questions about the ecosystem that then are used to guide the selection for monitoring of particular species and other physical, biological, and human aspects of the ecosystem

- Although it is properly intended to be a long-term program, GEM should include some short-term projects with clear management implications

- GEM's organizational structure should be enhanced to incorporate mechanisms for independent program planning, proposal review, and community involvement

- For the GEM program to be durable over time, the organizational structure should incorporate meaningful involvement of local communities This involvement should occur at all stages, from planning and development to oversight and review

- Although the total domain of GEM is large, the core long-term monitoring program should focus on tractable areas where critical environmental data are needed The primary geographic focus for monitoring should begin with Prince William Sound

- GEM should plan a series of small, focused workshops that will provide detailed guidance needed to implement the science plan

- GEM needs a major administrative commitment to data management, including mechanisms and procedures to ensure data quality and good archiving over time and to make data available to the public and to researchers

1

Introduction

In 1989, the T/V *Exxon Valdez* spilled 11 million gallons of crude oil into Prince William Sound in Alaska, setting off a cascade of effects that still have repercussions more than a decade later (Figure 1-1) One result of the spill was that in 1991, the U S District Court approved a civil settlement that required Exxon Corporation to pay the United States and the State of Alaska $900 million over 10 years to restore the resources injured by the spill and compensate for the reduced or lost services (human uses) the resources provided Under the court-approved terms of the settlement, a Trustee Council of three federal and three state members was formed to administer these funds The mission of the *Exxon Valdez* Oil Spill Trustee Council has been to return the environment to a "healthy, productive, world-renowned ecosystem" by restoring, replacing, enhancing, or acquiring the equivalent of natural resources injured by the spill and the services provided by those resources

As part of its mission, the *Exxon Valdez* Oil Spill Trustee Council (EVOSTC) has disbursed research funds for almost 10 years, at first for damage assessment activities and then for monitoring and research to better understand the ecosystem and to understand impacts of the oil spill on identified important "resource clusters," or communities/resources (e g , salmon, herring, marine mammals, subsistence resources) Extensive research has been conducted over the decade, making this the most studied cold water marine oil spill in history At the same time, a portion of each payment has been set aside to create a permanent trust fund for future activities, and it is the use of this trust fund that is now being planned

In keeping with its mandate and after extensive public input, the Trustee Council decided to use the trust fund to support continued research and monitoring in the region into the future As conceived, this program—the Gulf Ecosystem Monitoring (GEM) program—has a unique opportunity to monitor the system in depth and over time in ways that bring both practical management lessons and deeper understanding of the causes and effects of ecosystem change

THE COMMITTEE'S CHARGE

To ensure that its plan for long-term research and monitoring in the Gulf of Alaska Ecosystem is the best possible, the Trustee Council asked the National Academies for assistance and a specially appointed committee was formed to review the scope, content, and structure of the draft Science Program and draft Research and Monitoring Plan (Box 1-1) The committee agreed to prepare this interim report commenting on the adequacy of the conceptual foundation of the GEM Program (as described in the document *Gulf Ecosystem Monitoring A Sentinel Monitoring Program for the Conservation of the Natural Resources of the Northern Gulf of Alaska*, Review Draft, April 21, 2000, cited in this report as EVOSTC, 2000a) Later, the committee will prepare a final report reviewing the Research and Monitoring Science Plan, when it becomes available in mid-2001

This interim report is divided into sections that roughly parallel the structure of the Trustee Council's 2000a document, first covering the GEM program mission and goals, then the structure and approach, and finally the scientific framework in some detail The report includes insights drawn from other long-term science plans regarding issues such as governance structures and data management Finally, the committee summarizes its conclusions about the conceptual foundation of the GEM program and provides recommendations to help guide development of the Research and Monitoring Science Plan

BOX 1-1
THE COMMITTEE'S CHARGE

The Committee to Review the Gulf of Alaska Ecosystem Monitoring Program is charged to provide independent scientific guidance to the *Exxon Valdez* Oil Spill Trustee Council, research community and public as the Trustee Council develops a comprehensive plan for a long-term interdisciplinary research and monitoring program in the northern Gulf of Alaska Specifically, the committee will

- Gain through briefings and literature review familiarity with the relevant body of scientific knowledge including but not limited to that developed by the research and monitoring activities sponsored by the Trustee Council in the past
- Convene one or more information-gathering meetings in Alaska where researchers, the public and other interested people can convey their perspectives on what the research and monitoring plan should accomplish
- Review the general strategy proposed in the draft Science Program (which includes information on the social and political context mission approach and scientific background) and make suggestions for improvement
- Review -- once it is available -- the draft Research and Monitoring Plan, including the scope structure and quality of the approach proposed for a long-term research and monitoring program in the northern Gulf of Alaska This will include whether the conceptual foundation provides an adequate basis for long-term research and monitoring and whether the research and monitoring plan adequately addresses gaps in the knowledge base and existing uncertainties The committee will also address broader issues related to overall effectiveness of the Trustee Council s program and plan for guiding continued efforts to understand biological change in the Gulf of Alaska

2

PLANNING THE GEM PROGRAM
ESTABLISHING THE UNDERLYING FOUNDATION

The GEM program offers an unparalleled opportunity to increase our understanding of how large marine ecosystems (in general) and Prince William Sound (in particular) function No other research and monitoring plan has a century-long time horizon This kind of long-time-series measurement is a crucial tool for understanding ecosystem function Thus, along with this opportunity comes an obligation to craft a research and monitoring plan that can withstand the test of time This requires a core set of measurements that can be taken consistently and indefinitely, as well as flexibility to alter both conceptual understanding and research interests

The first step for this or any research and monitoring plan is development of a conceptual foundation This foundation needs to be broad, precisely because of the long time scale of GEM No one can know what theories, taxa, or processes will emerge as critical to the public or managers, or relevant to ecosystem functioning, in future decades The choice of conceptual foundation is, of course, critical, as this will drive the choice of species and parameters to monitor Conceptual foundations that rest on a few indicator species, specific hypotheses about marine ecosystems (e g , Pacific Decadal Oscillation), or current human impacts (e g , fishing) are likely to be too narrow and inflexible to support the GEM mission (Box 2-1) Instead, the GEM conceptual foundation needs to incorporate the sense that marine ecosystems (processes and taxa) change in response to physical and biological changes and human impacts, as is clearly expressed within the GEM mission statement Figure 2-1 presents one example of the kind of conceptual model that might be valuable to the program planners Even if the same endpoints for monitoring could be reached by choosing variables to measure in the absence of a broad conceptual foundation (NRC 1995), it would be difficult to justify them without a conceptual foundation that provides the broad context and helps illustrate relationships

A solid conceptual foundation will also buffer GEM against inevitable shifts in public concerns, such as current concerns with Steller sea lions Indeed, GEM is clearly aware of the difficulty of pursuing long-term monitoring in the face of short-term interests There are provisions for multi-decade measurements and for shorter research programs targeting specific issues or hypotheses, so that GEM can respond to current concerns without sacrificing long-term data sets that will prove increasingly useful as they accumulate A well designed and broadly based program will provide the best possible scientific basis for dealing with short-term ecological issues of public concern Indeed, a strongly designed program will provide a sound basis for additional attention to be paid to matters of urgency or immediate public concern, even if they are not central to the program itself However, GEM will have to be carefully constructed to avoid being excessively distracted by real or perceived ecological crises

GEM as conceived is meant to be a long-term monitoring program, and long time series are essential to detecting change on intermediate and long time scales However, it is absolutely vital to recognize that long-term monitoring *per se* will not necessarily lead to a better scientific understanding of the ecosystem The value and utility of monitoring critically depends on the variables measured, the spatial and temporal extent of sampling, the spatial and temporal intensity of sampling, and the methods employed Without clear vision at the outset, it is very difficult to establish monitoring programs that will provide useful data for a range of post-hoc tests This is why the monitoring program must have a strong conceptual foundation and be hypothesis-driven

Rendering the conceptual foundation into specific research activities implies the generation of questions These questions can come from members of the scientific community They can also come from members of the local native communities, fishing communities, state and federal resource managers, and any of the wide range of stakeholders of interest The benefits of incorporating local communities in a meaningful fashion are twofold local knowledge and participation can enrich the scientific program and, reciprocally, provide a broader basis of support and understanding for the central mission of the program Indeed, while it is appropriate and probably necessary that a scientific conceptual foundation be developed primarily by scientists, the ability of local communities to inform and provide knowledge of the ecosystem must be emphasized

Finally, the conceptual foundation must be compatible with the fundamental mission of GEM This mission, as stated in the program, is broad and somewhat indefinite Despite its breadth, however, the mission does focus attention on the reciprocal interactions between humans and the marine environment humans derive goods, services, and pleasure from the ocean, and marine systems are in turn affected by human activities All of this occurs within a context of regional climatic and oceanic change, changes that will inevitably (but perhaps unpredictably) occur during the time scale of GEM

BOX 2-1
THE IMPORTANCE OF SELECTING A RANGE OF INDICATOR SPECIES

With a broad conceptual foundation in mind it will be necessary to select a number of physical and biological parameters to monitor The selection of these items—including species or groups of species—must be based on implicit or explicit hypotheses about ecosystem functioning and what is important to monitor to gain knowledge of that system (NRC, 2000) These hypotheses can be broad, such as that the system is most strongly affected by climate-driven physical processes that affect production (called bottom-up control") or by predators, including fishers which structure marine communities and affect energy flow (called 'top-down control) Additionally species may be selected because they are of great human interest or of particular commercial value

However with respect to the selection of species or species groups that are likely to have large effects on the food webs of the Gulf of Alaska and Prince William Sound information from these and other similar systems elsewhere should be used to identify the most important species or species groups to monitor This will be critical in developing the monitoring program because the ability to detect changes in the system in a timely fashion will depend on the choice of subjects to monitor New groups or species that may play pivotal roles in the food web should be monitored as well as taxa that have been monitored previously Species such as sand lance (*Ammodytes hexapterus*) capelin (*Mallotus villosus*), and juveniles of pollock (*Theragra chalcogramma*) and herring (*Clupea harengus pallasi*) may be important in the transfer of energy from the zooplankton to larger predators such as whales, pinnipeds marine birds, and species of commercially harvested fish Likewise, large predatory fish such as pollock, Pacific cod (*Gadus macrocephalus*) and arrowtooth flounder (*Aresthes stomias*) may play an important role in top-down control of juveniles of commercially important fish species Monitoring of jellyfish populations is often overlooked, yet these can have large impacts on marine ecosystems and commercial fisheries (Brodeur et al , 1999)

It is important to identify species that may be important in shaping food webs and the fisheries dependent upon them For example Bailey (2000) hypothesized that variation in pollock recruitment has shifted from being controlled by environmental factors that determine the survival of very young fish to control by predation by large fish Similarly paying attention to hypotheses about the control of other ecosystems leads to the conclusion that some uncommon species that are presently not monitored should be monitored For example in the Bering Sea, Merrick (1997) suggested that there has been a trophic cascade following the removal of whales and other planktivores that previously helped suppress species such as pollock He argued that the removal of the whales paved the way for increases in pollock and other piscivorous groundfish Large baleen whales are apparently increasing in the Bering Sea (Baretta and Hunt 1994 Tynan 1998, 1999) and possibly in the Gulf of Alaska We do not know what effect they will have on the ecosystems as they are presently structured but if we fail to monitor them now because they are scarce, we will never know whether they exert a top-down control if they become more numerous Selecting what is to be monitored is a crucial decision that will determine the success or failure of the GEM program Hypothesis-driven choices will help to ensure that to the best of present knowledge, the most critical determinants of ecosystem functioning will be monitored

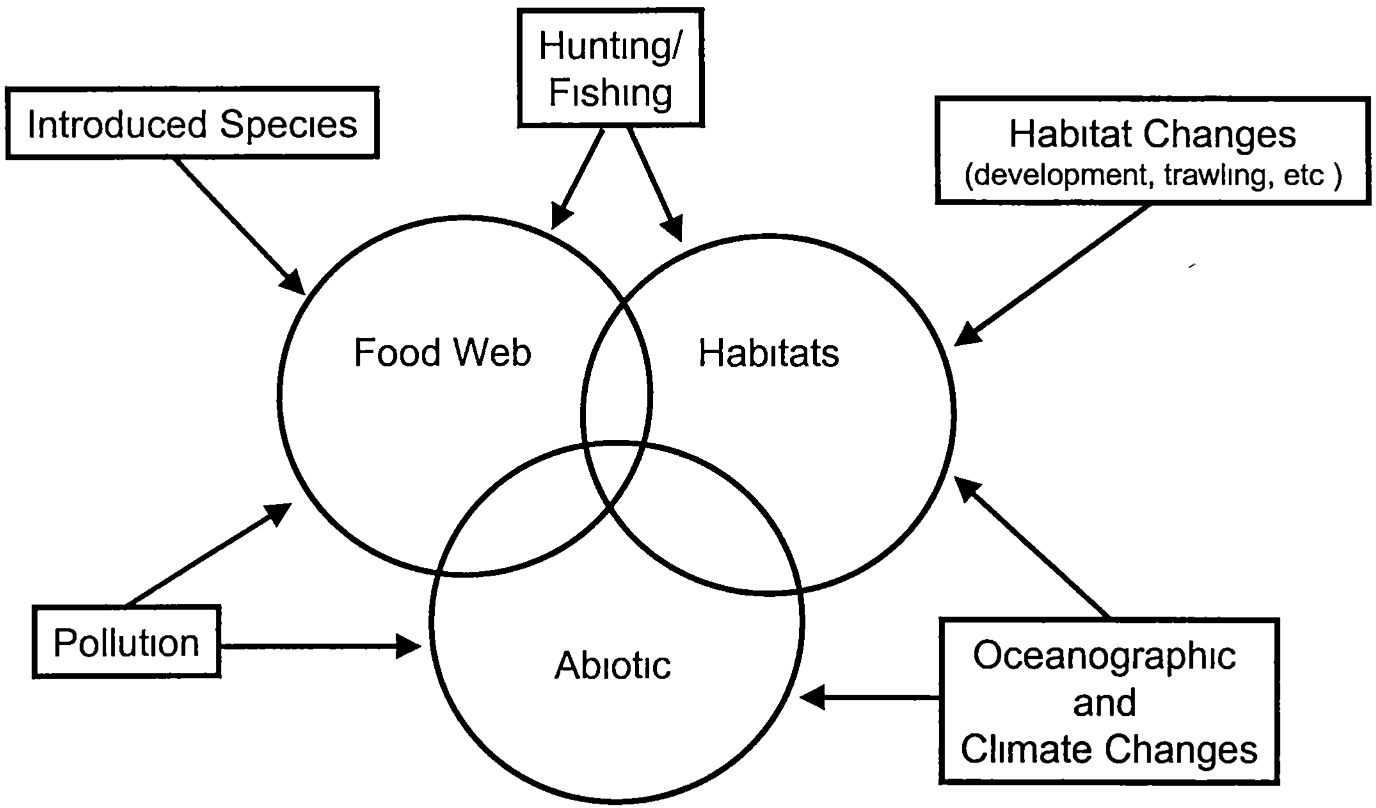

FIGURE 2-1 The conceptual foundation of the GEM program must reflect the understanding that ecosystems change in response to physical and biological changes and human influences Modified from Salomon et al , in press

THE SCIENTIFIC BASIS FOR GEM

The world's oceans have long been viewed as producing an inexhaustible supply of protein and other goods and services for human use But evidence of the adverse effects of human activities on marine ecosystems is increasing and reminding us that the ocean's resources are not inexhaustible (NRC, 1999a) Furthermore, it is increasingly clear that the structure and functioning of marine ecosystems is profoundly linked to variability and changes in ocean climate and that those changes can occur rapidly Thus, one of the greatest challenges facing society, and particularly managers of marine living resources in the Gulf of Alaska and elsewhere, is to understand the relative effects of human activities and natural changes in ocean climate on the goods and services supplied by marine ecosystems (NRC, 1996)

Why is this so difficult? One reason is that marine ecosystems are large, complex, interactive systems in which organisms, habitats, and external influences act together to regulate both the abundance and distribution of species (NRC, 1999a) Species interactions and the effects of variability in ocean climate on those interactions occur at spatial scales ranging from centimeters to hundreds of kilometers and on temporal scales ranging from minutes to decades Human activities also act at various scales and may act selectively on certain components of an ecosystem (e g , higher trophic levels), although such activities can have cascading effects throughout marine ecosystems (Carpenter et al , 1985, NRC, 1996) These disparate spatial and temporal scales make it difficult to measure the processes affecting marine ecosystems and to monitor ecosystem structure and functioning Finally, perturbations to marine ecosystems often appear to act in subtle, nonlinear ways making it difficult to understand the consequences on ecosystem components that may be of particular interest to society, such as birds, mammals, and fishes

Given the complexity of marine ecosystems and the failure of single-species management to produce sustainable fisheries in many parts of the world (NRC, 1999a), it is not surprising that both scientists and managers have increasingly promoted the concepts of multispecies or ecosystem-based management However, it is clear that not enough is known about most large marine ecosystems, including the Gulf of Alaska, to implement a useful whole-system approach to management So it is reasonable to consider what benefits could be provided from an ecosystem-based approach to management that cannot be gained from a single-species approach The NRC (1999a) considered two benefits One is the ability to broaden the policy framework to include a wide range of ecosystem goods and services, and acknowledge the critical role of ecosystem processes in providing those goods and services The other benefit is an explicit recognition that segments of society may have different goals and values with respect to a marine ecosystem and that those goals and values may conflict

It is within this context that the GEM program offers an unparalleled opportunity to increase our understanding of how large marine ecosystems in general, and the Gulf of Alaska in particular, function To do this effectively, the GEM program must take a longer (interdecadal) view at appropriate spatial scales

GEM'S MISSION

The stated mission of the Gulf Ecosystem Monitoring (GEM) program is broad and ambitious 'to sustain a healthy and biologically diverse marine ecosystem in the northern Gulf of Alaska (GOA) and the human use of the marine resources in that ecosystem through greater understanding of how its productivity is influenced by natural changes and human activities ' (EVOSTC, 2000a) While the mission statement is fine as a general statement and for conveying the basic intent to a general audience it creates difficulties for those tasked to design and implement a long-term science plan According to this mission, GEM has a dual purpose to sustain a healthy ecosystem *and* ensure sustainable human uses of the marine resources Of course, humans are part of the ecosystem and in the largest view sustainable human use is inherently dependent on the health of the underlying ecosystem But still, sometimes the purposes of sustaining ecosystem health and sustaining human use of marine resources run counter to each other, which will complicate planning For example, management options designed to maximize benefits to humans would not necessarily be the same as options to maximize species diversity or some other measure of ecosystem "health " The second part of the mission statement assumes that ability to meet these objectives will be accomplished by understanding how both natural changes and human activities influence ecosystem productivity Implicit in this rationale is that it is possible to separate the causes of natural changes from human-induced changes It also assumes that a successful monitoring program has to take into account both climate change *and* changing patterns of human exploitation (e g , fishing practices), which could call for attention to a very complex array of variables

Another concern is that the term "healthy ecosystem" has no clear definition, in part because we lack clearly defined measures for assessing ecosystem health (NRC, 2000) For instance, if ecosystem health is judged on the system's ability to support top predators, then research might focus on marine mammals and birds If ecosystem health is judged to be productivity of valuable fish species, then fisheries research would be key If healthy ecosystems are judged to be those that provide sustained esthetic and subsistence benefits to humans, then research has to be directed at understanding natural variation in exploited resources and crisis events such as red tides GEM could usefully develop a practical, working definition of ecosystem health that relates to particular aspects of the Gulf These aspects could be related to ecosystem structure (the biotic community), or functioning (ecological processes such as productivity), or both Using such a working definition of ecosystem health would allow GEM to use its finite funds effectively and avoid the risk of trying to monitor and study more than the program can successfully handle

The mission statement gives equal weight to the role of natural changes and human activities as potential forces on pattern and process in the marine ecosystem Yet the GEM program document primarily emphasizes scientific understandings of large-scale (climate, Pacific Decadal Oscillation) changes It is unclear if this inconsistency occurs because smaller-scale human-induced changes are less well-known, less important, or too local and context-specific to be included in a plan for the entire Gulf of Alaska In fact, the GEM draft in general articulates a marked turn away from local/community concerns toward a large-scale research program focused on questions defined by the physical and natural scientific community This shift is not "wrong' but it is pronounced and there is a conceptual disconnect between the references in the narrative to community involvement and use of Traditional Ecological Knowledge (TEK), and the actual outline of the proposed research and the accompanying conceptual foundation Changing fishing quotas, the role of hatcheries, the potential of areas protected from fishing—all ways to think about the effects of human activities—receive little attention in the GEM document A program that addresses the objectives of the mission statement would need to strive to integrate studies of human uses of marine resources with studies of natural changes in the ecosystem

Furthermore, while the separation of "natural ' from "human" impacts may be a laudable goal, the program description does not seem to develop its intent on the anthropogenic impacts side of this equation The GEM plan needs clearly defined measures of human induced changes in the Gulf of Alaska and Prince William Sound ecosystems

The effects of the complexity of the mission statement will be most apparent as the program becomes operational (i e , as the science plan is developed in more detail and as decision makers decide what to support) GEM program resources are expected to provide about $5-10 million annually at least for the next few years When making financial commitments, program decision-makers will need to strike a balance among (1) long-term monitoring, (2) targeted research, (3) data management, and (4) community involvement It is not possible for the GEM program to be all things to all people

GOALS

The GEM program is intended to have five major programmatic goals
- to detect (change in the ecosystem),
- to understand (the ecosystem),
- to predict (future changes in the ecosystem),
- to inform (the public, decision makers, and managers), and
- to solve (environmental problems)

The committee understands the need for stating such a broad and diverse set of objectives at the outset of planning, given the public's concerns and the political realities under which the Trustee Council operates At first reading these goals seem laudable, appropriate, and logical However, as the committee discussed the goals in depth, it became apparent that they are too far reaching, to the point of being unrealistic and setting the program up to be disappointing to those whose favored goals cannot be obtained (Box 2-2) The committee contends that the ability to detect change and to understand the causes of change are prerequisites to prediction, and thus are more attainable goals in the medium term Prediction can be considered a long-term goal, but it should not be a driving force in the program's first decade (and possibly longer)

Although the GEM program might grow—its funding could double in 20 years if the principal is invested wisely and economic conditions continue to prosper—there seems to be no realistic chance of achieving all five goals within the foreseeable future Yet the program's size is not the only or even the biggest difficulty A much larger one is the difficulty of designing an effective program that has multiple, complex goals A strategy for providing focus is essential The unique opportunity of GEM, as its title reflects, is to establish a truly long-term monitoring program It would thus seem advisable to focus the program around that goal and base the science plan on it There could be smaller components to support specific, albeit related, elements of the other goals

BOX 2-2

ARE THE GEM GOALS ATTAINABLE?

Detection of change is a reasonable and attainable goal and should be one of the core purposes of GEM Detection of change should not be assumed to be easy the climatic regime shift that occurred in the Gulf of Alaska in the late 1970s was not detected until 15 years after it occurred because picking up the signals is challenging Detection hinges on measuring appropriate variables consistent interpretation of data, and having a priori expectations of what changes will occur and why

Understanding change and the causes of changes is a valid goal for the GEM program, and movement toward understanding is attainable Understanding emerges from two types of studies smaller process-oriented studies that test particular hypotheses and broad synthesis-type studies based on models that can be tested with independent data (that is data that were not used to build the model) To develop understanding of the issues most important to managers and citizens they must be included in the process of choosing research questions

Prediction is a difficult goal that is inherently long-term and difficult to achieve Both scientists and managers have a fairly poor track record of foreseeing environmental change For example, the El Nino-Southern Oscillation (ENSO) illustrates the challenge of striving to predict change Scientists have carried out intensive observation of ENSO phenomena for several decades, in addition to records of casual observations that go back more than 100 years Yet it took about two decades of repeated observations before an understanding of ENSO was developed And predictions of ENSO are now attempted but with limited success In comparisons with the Gulf of Alaska ecosystem, ENSO has a large signal with global responses It is a physical system that should actually have a more predictable response than a complex physical-biological system with anthropogenic influences, as is the case in the Gulf ENSO also has a much shorter periodicity (3-7 years) than the Gulf of Alaska (20-50 years), so that 20 years of ENSO observations have more degrees of freedom than 100 years of sampling in the Gulf of Alaska Thus the goal of predicting change in the Gulf of Alaska in the next 100 years is highly problematic

Informing managers and the general public of research results is both possible and necessary, given the GEM program mission But this element would seem to be an output of earlier goals, and not a goal in its own right

Solving environmental problems is, like prediction, an ambitious and long-term goal Solving problems, per se, is not a logical purpose for a research program but rather is what should happen as managers put scientific information to use

Why is it risky to propose multiple complex goals? If the plan allows research on every question or issue, GEM may fail to provide insight into the system as a whole Perhaps worse, GEM could be co-opted to answer questions (e g , on fishery catch quotas or contaminants) that are clearly the responsibility of others The risk of a plan that encompasses everything and anything can be alleviated by improving the focus of GEM during this planning phase Although committee members agree on the need for focus, all acknowledge that there are several viable options of how to focus (Box 2-3) These range from plans that concentrate on oceanographic measurements to test hypotheses about climate regime shifts to plans that emphasize modeling and synthesis using data sets already in existence

In general, for a long-term monitoring program, species and sampling locations should be selected based on the ability of the information to help answer questions about ecosystem functioning In terms of focus, the GEM program would be most effective if it focused on monitoring and identifying and addressing important data gaps A monitoring program could consist of regular biological surveys of community structure including diversity at multiple locations sited in Prince William Sound and on the neighboring inner shelf of the Gulf, quantification of the recruitment dynamics and ecology of a set of key species at selected locations, and measurements of physical oceanographic parameters and climatological conditions in the Sound and on the inner shelf of the Gulf Short-term projects might focus on dynamics of key species and their interactions, on mechanisms underlying production, growth, larval supply, larval transport, food availability, and similar processes

The committee agrees that it is appropriate to identify a number of short-term objectives (attainable in 2-3 years) and long-term objectives (5+ years) that might have tangible benefits for policy makers, resource managers, and the public An example of a short-term goal would be to identify trends or relationships by modeling historic fisheries data in relation to climate data and contaminant levels in biota A long-term goal might be to measure and ultimately model climate variability in Gulf of Alaska as it relates to near- and off-shore fishery production While the GEM program can take advantage of opportunities to leverage funds by coordinating and forming partnerships with other research programs underway in the Gulf of Alaska, it should be careful that doing so does not overwhelm or distract its small administrative staff or dilute the program's impact

BOX 2-3
PROVIDING FOCUS BY SELECTING KEY RESEARCH QUESTIONS

GEM is a unique opportunity to establish a realistic long-term monitoring program Thus one logical approach would be to focus the program around long-term monitoring as the core activity with smaller elements added to meet other goals, and base the science plan around this two-prong structure To make success more likely, program planners would need to select a few key questions to guide the work and these questions in turn, should be based on some clear conceptual model (e g , NRC 1995 2000) One way to begin is to ask what parameters are most able to provide insight into the desired questions if there is a long time-series of data available Another approach is to identify the questions for their own sake and let them suggest the parameters to be monitored

The questions listed in Appendix C 2 of EVOSTC, 2000a are a good start The quality and relevance of the questions suggested by members of various communities that made presentations in Anchorage on October 6 2000 were excellent For example the question about the degree to which ocean conditions (productivity) affect the growth and survival of juvenile salmon and hence the degree to which science can help predict the probable percentage of returns from hatchery releases is very relevant To answer this question requires information on physical chemical and biological features of the ocean, including information about salmon Long time-series of information on such factors would not only help answer the specific question, but would also be of great use for understanding related questions, such as insights into fluctuations in the populations of other important ecosystem components including marine mammals crabs marine birds and herring

Several approaches could help impose greater focus on GEM during implementation, even given its broad mission and goals The committee is not recommending these as the right' tasks but as illustrations of the range of thinking that is possible

- Develop a whole-ecosystem fishery model as a guide to think about what needs to be monitored Such a model would use current and historical data to relate yields to climate data and contaminant levels and might stress biological and physical endpoints (zooplankton/phytoplankton blooms macrofauna populations) and climate and physical oceanography endpoints in conjunction with modeling

- Identify indicator taxa for monitoring Species should be selected based on the ability of monitoring information to provide information on ecosystem functioning, not solely to reflect economic value or political importance This takes smart choices so the indicator species reflect a wide set of variables for measurement and serve as sentinels to provide clear and early warning of change

- Conduct or take advantage of large-scale adaptive management studies that others implement The Trustee Council does not have the authority to impose management changes but it could for example follow population trajectories in areas with and without fishery closures or record biogeochemical variables in bays before and after aquaculture operations are instituted

ADMINISTRATION

The EVOSTC has administered its research program to date using a combination of a small paid staff (responsible for most aspects of program planning and implementation), paid peer reviewers (responsible for judging quality of proposals), and scientists (through participation in an annual workshop devoted to presentation of research results and discussions of needed future directions) This approach has increased in effectiveness over the years With the new GEM program, with its large mission and long time horizon, the Trustee Council consciously sought to evaluate its approach and make adjustments as needed to ensure the program's long-term success and scientific credibility How best to administer the new GEM program over time again emphasizes the importance of being clear about the program's focus – who sets it and how it is implemented

One of the most important administrative questions concerns the role of Trustee Council staff in the program plan Is GEM to act like a science funding agency, where scientific questions emerge from outside the Trustee Council and are filtered and ranked by independent advisory groups and implemented by staff (a bottom-up approach), or more like a foundation, where questions and projects are identified by the leadership and staff and then proposals in those areas are sought (a top-down approach)? Most long-term science plans run on the former model, and the committee believes this would be best for GEM as well We recognize, however, that the program will always have some elements of both approaches, given its origins and the strong role of agency leaders on the Trustee Council itself Furthermore, detecting change will require that a core set of variables be measured over a long time period, which is most likely to occur if the Trustee Council makes those studies a priority

Implementation of the GEM science plan will raise many questions requiring input from scientists The committee believes there will be a long-term need for an independent scientific advisory committee, peer review of proposals by individuals outside Trustee Council agencies, and periodic reassessment of monitored variables We had significant discussions about the degree to which the administrative structure facilitates managing and sharing data Information gathered in GEM should be accessible to the general public, managers, and other scientists in a coherent and understandable form within several years of its collection Such data management requires in-house expertise, recognized as expensive but necessary

ORGANIZATION AND GOVERNANCE

Other large, long-term research programs have struggled with how best to organize and make decisions (NRC, 1999b) and GEM planning staff should establish strong ties with other ongoing ecological programs such as the Northeast Pacific Global Ocean Ecosystem Dynamics Program, the NSF-funded Long-Term Ecological Research Network, and NOAA-funded programs in the Gulf of Alaska and the Bering Sea The committee reviewed a number of these programs to draw lessons about how other programs handled common issues, such as how long the programs took to develop (Box 2-4), how strategic guidance and peer review were obtained, and how the programs balanced the need for stable commitment to a long-term vision and flexibility to take on newly identified issues

BOX 2 4
THE EVOLUTION OF MAJOR SCIENCE PLANS TAKES TIME

The creation of all long-term science plans takes time because the process of developing the plan is as important as the details included in the plan For example the U S portion of Joint Global Ocean Flux Study (JGOFS) had its beginnings in 1984 with the international component starting about three years later (NRC, 1999b) The formation of this effort was not simple

Initially the U S Global Ocean Flux Study (GOFS) was an outgrowth of three separate projects that were active in the early 1980s the National Academies Ocean Studies Board was investigating the feasibility of a program that would conduct long-term studies of the biological and chemical dynamics of the ocean on basin-wide and global scales, the NSF Advisory Committee for the Ocean Science Program was developing a long-range plan, and a separate National Academies committee had identified initial priorities for the International Geosphere-Biosphere Programme As the relationships among these activities became clear, and with support from NSF, NASA ONR, and NOAA, a group of scientists met in 1984 at Woods Hole under the auspices of the National Academies This generated the basic scientific underpinnings that defined the proposed mission for GOFS and led to the GOFS Scientific Steering Committee, which was formed in 1985 Then, after continued discussion and planning in 1987 an overview document was published that more fully outlined the program Between 1986 and 1990, the science community produced nine reports that summarized the recommendations of workshops designed to expand on the general plans covering topics such as water column processes, benthic processes, continental margins, data management, and modeling Finally, in 1990 the JGOFS Long Range Science Plan was published based in part on the recommendations of the workshops It was 1995 when JGOFS released an Implementation Plan which gave the status of the JGOFS research and future directions

One strength of a major research program is the ability to draw and direct a significant amount of talent and scientific interest toward a large and often high profile scientific challenge But to realize that opportunity requires significant advance planning and coordination, and one key element is taking the time necessary to allow wide participation in the program's definition and evolution

Source NRC 1999b

Overall, the structure currently in use by EVOSTC has worked well to date, but will need to evolve to handle GEM's broad, long-term, more scientifically complex goals Based on its review and deliberation, the committee believes that the GEM program requires a more fully developed organizational structure to provide guidance over the long-term To fulfill the potential of GEM, execute the scientific objectives, address the expressed interest in community involvement, and attain the best quality science, the management of the proposed GEM program is likely to need an enhanced administrative structure, perhaps similar to that used in other large research programs Such a structure would likely include an Executive Director / Chief Scientist, a Program Advisory Committee (PAC), a Science Advisory Committee (SAC), a Community Advisory Committee (CAC) and, a Principal Investigator Coordinating Committee (PICC) (Figure 2-2) While the precise form, lines of authority, and responsibilities remain to be defined, the general roles of the important components would be as follows

- *Executive Director /Chief Scientist* The role of the Executive Director would be to interact with the Trustees, the public and scientists in the GEM program The Chief Scientist's role would be to make certain the quality of science is maintained and properly executed Whether this is one person or two is less important than being sure the person or persons are capable of both administrative and scientific communication and organization

- *Program Advisory Committee* The Program Advisory Committee (PAC) would be a rotating committee of scientists and community representatives external to the main scientific programs of GEM The PAC would report to the Executive Director/Chief Scientist and the Trustees The PAC would evaluate the selection of members for the Science Advisory Committee, and the Community Advisory Committee The PAC would periodically review the GEM program and advise the Executive Director/Chief Scientist and Trustees on the progress, scientific accomplishments and the future course of development of the GEM program

- *Science Advisory Committee* The Science Advisory Committee (SAC) would be responsible for obtaining proposal reviews and ranking proposals It would also address questions of scientific balance and how proposals relate to the goals of the GEM program The SAC would be composed of scientists (academic, government, and/or agency) who have no direct stake in GEM The composition and size of the SAC should be sufficient to bridge the range of scientific disciplines that are part of GEM The suggested package of acceptable proposals would then be communicated to the Executive Director/Chief Scientist, who would clear the final proposal selection with the PAC The SAC and CAC (described below) should have periodic joint meetings

- *Community Advisory Committee* The Community Advisory Committee (CAC) would comprise representatives from various communities interested in and affected by the Gulf of Alaska ecosystem The CAC would provide input to the Executive Director and Trustees on issues of community importance in development of the GEM program and would work closely with the SAC This committee would have a significant advice-giving role, with active involvement in setting priorities and defining questions The committee could have a direct role in selecting community-based project proposals, if this approach is incorporated into GEM in the future The CAC could also be helpful in suggesting ways to disseminate information to communities

- *Principal Investigators Coordinating Committee* The Principal Investigators Coordinating Committee (PICC) would be composed of the principal investigators and GEM Data Manager The PICCs function would be to ensure coordination, where appropriate, plus certification of the quality of the data The reports of the PICC would be vetted through the PAC who would advise the Executive Director/Chief Scientist of the status of the GEM program

The tradition of having all program participants meet periodically (i e , the annual Restoration Workshop) is likely to remain important, as this provides valuable opportunties to share data, form partnerships, and plan new activities, however, it is possible that the timing and design of the meetings will need to change to accommodate any new administrative structures and the needs of GEM as it takes shape

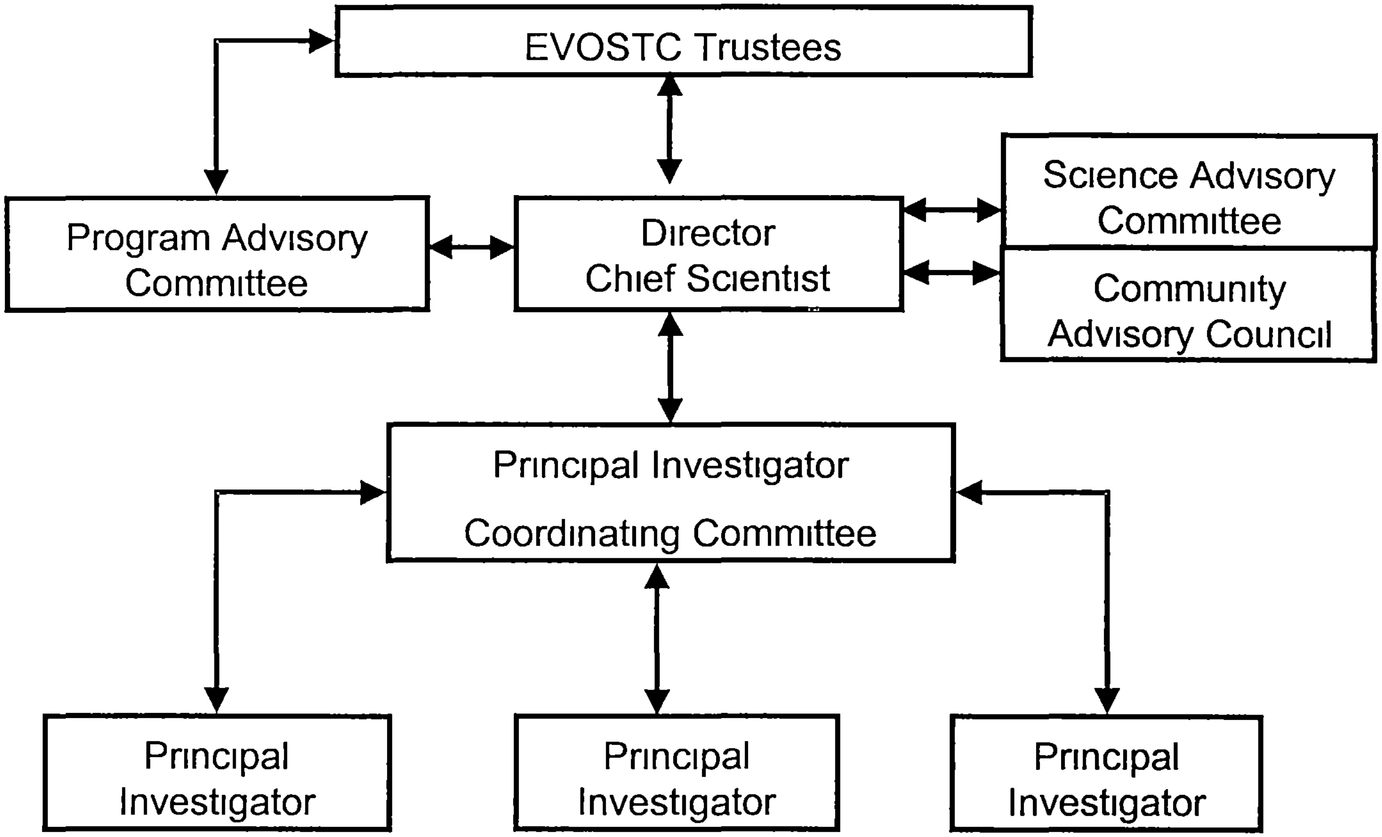

FIGURE 2-2 Possible organizational structure for the GEM program

GEOGRAPHIC SCALE

The geographic scale currently proposed in the GEM document covers the entire northern Gulf of Alaska ecosystem, and this is appropriate given the current mission and goals However, it is likely that such a large area will be a challenge given GEM's available resources at this point in time A more feasible scenario for long-term monitoring over multi-decadal time-scales is to study a smaller area in depth Selection of a tractable, well-delineated geographic 'core' area will allow GEM to maintain funding for the type of high density sampling, on both temporal and spatial scales (multi-station/multi-depth/multi-species, infaunal, epifaunal, pelagic) unprecedented in marine monitoring programs It is critical that this geographic core remain unchanged for the life of the GEM program

The committee recommends that the primary geographic focus of the GEM monitoring program begin with Prince William Sound (PWS) The PWS ecosystem received the greatest amount of oiling from the spill and might be expected to be among the last areas to recover As such, PWS could be a useful indicator of wide-scale recovery of the area In addition, since PWS will continue to receive some degree of anthropogenic impact (e g , heavy commercial shipping traffic, fishing, harbor runoff, recreational boating), comparison of data on the PWS ecosystem with that collected at relatively non-impacted sites would allow separation of anthropogenically induced changes from natural changes Importantly, data on the PWS ecosystem would be immediately useful to managers and of interest to local fishers, including PWS subsistence communities, increasing the likelihood of strong community support for long-term monitoring of this area as a starting point

A focus on the Prince William Sound coastal ecosystem, defined according to physical and ecological boundaries, is logical The coastal zone is the marine area most heavily affected by human activities and is typically the most productive marine habitat It is critical with respect to issues of larval transport, recruitment, and growth for species living in, or passing through, the nearshore ecosystem The nearshore region is believed to be the most critical habitat for salmon and serves as an avenue for marine mammal migrations The marine ecosystem of the Sound is forced by offshore and along-shore influences, having responses that can be traced offshore to the central Gulf of Alaska and along-shore to the equatorial Pacific It is not well defined according to depth since water depths of more than 200 meters are found throughout this coastal system Other programs and agencies have as their mission research on fisheries and oceanography in the more offshore waters of the Gulf Although this research is probably not as well integrated or synchronized as would be desirable, it would seem that use of GEM funding to carry out such research would be duplicative and less appropriate than focusing on the coastal ecosystem

As monitoring programs progress, there is a tendency to continually expand ecosystem boundaries Such boundaries must be rationally established based on resource limitations Selection criteria for these boundaries should include not only contaminant status (oiled or non-oiled), but also the existence of data for these areas, and consideration of the physical (fronts and currents), chemical (sources and fluxes) and biological (populations) properties that delineate ecosystems

It is imperative that the PWS ecosystem be seen in the context of the larger Gulf of Alaska and North Pacific ecosystems because it is hypothesized that these systems are strongly linked The sound is influenced by oceanographic conditions on the Gulf continental shelf, which are, in turn, linked to even more distant oceanic and climate conditions Clearly, GEM does not have the resources to make measurements on ocean basin or global scales

Fortunately, the importance of most shelf- and basin-based influences on the PWS ecosystem diminishes with distance from Prince William Sound Also, such data are available from other programs For example some hypotheses suggest that El Niño-Southern Oscillation processes in the tropical Pacific might influence marine and climate conditions in PWS GEM will be able to use data collected by NOAA's climate programs to explore some of those questions While an understanding of the oceanographic conditions on the shelf will be essential to an understanding of the seasonal and decadal changes in Prince William Sound, other oceanographic sampling programs such as OCSEAP, GLOBEC and ARGO[1] Global Ocean Observing System have been or will be carrying out some of the critical measurements GEM must integrate its observations with these efforts and should base some of its geographic site selections on these programs and their existing time series data

Since no single person has the broad knowledge and background needed to select the boundaries for this program, it is recommended that an interdisciplinary workshop be held to discuss these boundaries It should include participation from all disciplines and from similar ecosystem monitoring programs elsewhere (e g , fisheries studies in eastern and western Canada)

High density, long-time scale data are essential to building well-parameterized dynamic ecosystem models The strength of such models is determined by the quality and quantity of data available to build them For the Gulf of Alaska, only GEM has the potential to maintain a core, geographic monitoring area for which such uninterrupted, long-term data could be generated

DATA MANAGEMENT

As planning for GEM proceeds, it will soon need to deal with essential practical issues One such critical issue is data management The success of GEM will be critically dependent on a Data Management System (DMS) The DMS would be composed of a data manager and the necessary infrastructure to organize, disseminate and archive the data The data manager would participate in the planning of the sampling program, organizing the data, assuring data quality, archiving the data and providing data to the PIs and public The data manager must coordinate with researchers (e g , serve on the PICC) and provide the "big picture ' on variables being monitored (e g , periodically report to the PAC) These groups would develop a GEM data policy which promotes the exchange of data between GEM investigators, makes the data available to the public in a timely manner, and insures that the GEM data are properly archived To achieve the goals of the GEM program, a strong commitment to data management is required of the participating scientists In accepting support from the GEM program, each investigator would be obligated to follow the data management requirements as an integral aspect of their participation in the GEM program

The data sets would be organized in a manner that will be useable to both GEM scientists and the public via the Web or future global communication networks Examples of these types of data management activities and policies can be found for other U S oceanographic programs (JGOFS = http //usjgofs whoi edu, GLOBEC = http //cbl umces edu/fogarty/usglobec, CoOP = http //starbuck SKIO Peachnet coop) There would be several levels of data archiving and data management ranging from international archives to PI websites The GEM data would also be submitted to the National Oceanographic Data Center (NODC) where it will be permanently archived

There would be working data archives within the GEM program that contain the program data plus other data sets or Web links to data sets that will be necessary for the analysis of the GEM data Examples of pertinent ancillary data sets are those from EVOS funded studies, NOAA's TAO (ENSO) data, PDO estimates, the Gulf of Alaska GLOBEC program, and historical regional oceanographic and climate data Another example is the PICES TCODE

[1] OCSEAP is the Outer Continental Shelf Environmental Assessment Program GLOBEC is the GLOBal Ecosystems dynamics program ARGO is an array of temperature/salinity profiling floats and is part of the Global Climate Observing System

(Technical Committee on Data Exchange) Web page that contains links to long-term, interdisciplinary data sets for the North Pacific

Access to the data archives and software display will be an important component to the public outreach of the GEM program There would be multiple levels of complexity to the data access ranging from users with limited backgrounds with these data, to use by the investigators who gathered the data The data archives will be essential to ecosystem modeling and synthesis of the GEM program

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

The GEM program document (EVOSTC, 2000a) indicates a clear desire to incorporate community involvement and traditional ecological knowledge (TEK) into the overall GEM program This is also seen in an earlier document (Appendix A, EVOSTC 2000b), a special edition of the regular newsletter that is distributed to keep people abreast of GEM, which provides even greater clarity as to the fundamental components envisioned for the GEM program This newsletter summarized the GEM program by explaining that "GEM will have three main components

1 long-term ecosystem monitoring (decades in duration),
2 short-term focused research (one to several years in length), and
3 ongoing community involvement, including traditional knowledge and local stewardship "

Although the rationale for the third component is never clearly stated in the GEM program document, the committee concludes that involvement of local Native, fishing, and other communities is an appropriate and necessary component of the GEM program Questions about the relationships between local people and scientific researchers pervade the literature on TEK (e g , Baines and Williams, 1993, Rose, 1993) and on local participation (e g , Chambers, 1997, Holland and Blackburn, 1998) The close correspondence between issues present in the GEM program planning context and themes in the general literature suggests that the GEM program is not unique in terms of the challenges it faces with TEK and community involvement issues (see Box 2-5) Because the GEM program has an extraordinarily long time frame and strong ties to local communities, these challenges are likely to be exacerbated—not ameliorated—if left unanswered over time

BOX 2-5

TRADITIONAL ECOLOGICAL KNOWLEDGE

As the pace of ecological change increases so too does the need for baseline information with which to direct conservation and restoration activities There are complementary sources of knowledge about local ecosystems held by people whose lives are interwoven in complex ways with particular lands and waters Rich local knowledge accumulated over generations, embedding observations and corresponding cultural adaptations provides valuable information within a context of long-term ecological change The language of Traditional Ecological Knowledge is not the language of scientific discourse Mutual understanding requires mutual respect an investment of time and willingness on the part of Western scientists to accept that TEK is grounded in moral, ethical and spiritual worldviews that are not out of touch with reality (Martinez 2000)

The challenge then is not whether community involvement is warranted, but rather how to build such involvement in a meaningful way With respect to the first two of the three components identified above, the committee has stressed the need to provide the GEM program with a foundation that is simple, robust, and adaptable Community involvement needs a similar foundation that permits the local issues to be addressed in a meaningful way from the very beginning of the program

To provide a foundation for community involvement, there are three possible arrangements to consider First, every project sponsored under the GEM program could be required to feature community involvement But this first approach is fatally flawed because such formulaic insistence on community involvement in every project will do little more than encourage tokenism Second, the GEM program could include a separate, distinct "community GEM program" that would operate with autonomy However, this approach is vulnerable to the inevitable difficulties of allocating between communities, and would limit opportunities for exchange between scientific and local communities

The committee therefore suggests an approach based on shared power and shared opportunity between the scientific and local communities (Box 2-6) As envisioned in Figure 2-2, the committee sees creation of a Community Advisory Council (CAC) that is parallel in function to the Science Advisory Council (SAC) The goal of real shared power requires community representation at the highest organizational level below the chief scientist For community-originated studies to be effective, these structural provisions of power to communities must be accompanied by opportunities to gain funding Also, to ensure genuine incorporation of community interests and local knowledge and experience, the program should avoid the temptation to fund only those proposals in the standard format and phrasing of the scientific establishment to the exclusion of projects that reflect local interests and knowledge This approach to community involvement would have to be regarded as a work in progress because building the necessary relationships and developing a process that works will take time

In many respects, the GEM program will be breaking new ground in terms of integrating community involvement into a long-term science plan However, some principles apply throughout the structure envisioned in Figure 2-2 The goal for the selection of all projects (whether through the SAC or the CAC) is to have a process that is open, fair, and accepted by all The necessity to rotate membership on advisory groups applies throughout the structure

In summary, the committee recommends that community involvement be designed into the GEM program from the start in a manner that promotes meaningful involvement and provides for flexibility into the future as the GEM program evolves

BOX 2-6
AN EXAMPLE OF COMMUNITY INVOLVEMENT
THE FISHERMAN AND SCIENTIST RESEARCH SOCIETY

Community involvement in scientific research aimed at gaining a better understanding of marine ecosystems can bring benefits However for community involvement to succeed over the long term it must be meaningful That is, communities must have a role in helping to define what will be done and how it will be done They must also be actively involved in conducting the research analyzing data and disseminating the results to members of the community and other stakeholders

One example of this approach to community involvement, and how long it can take to develop, is underway among coastal fishermen and fisheries biologists from the Canadian Department of Fisheries and Oceans (DFO) in Nova Scotia, Canada The Fisherman and Scientist Research Society was formed in the early 1990s to help develop a common understanding of the status of commercially harvested fishes and invertebrates on the continental shelf off Nova Scotia Officers of the Society are fishermen elected by the membership The Executive is advised by Directors at Large, drawn from the membership and participating member scientists a Communications Committee and a Scientific Program Committee More than 300 members from fishing communities across the province meet annually to discuss the results of research undertaken in the previous year and to plan new major initiatives The first several years represented a difficult and uncertain period for the Society It takes time, hard work, and a commitment to succeed to overcome existing biases and to build new relationships based on mutual respect

Over the past 8 years however the Society has made tremendous strides It has undertaken collaborative research with the DFO on a range of topics including inshore fish abundance surveys fish tagging studies on fish diets and physical condition, lobster recruitment and coastal ocean temperature The impetus behind most of these studies has come from questions posed by the membership with their direct involvement at the community level As the Society matures the range and scope of the research conducted continues to grow providing fisheries scientists and oceanographers with an opportunity to address questions that would be difficult to address otherwise

3

Conclusions and Recommendations

The committee offers the following recommendations as guidance to steer future development of the GEM program

MISSION & GOALS

- While the GEM mission provides a good general statement of intent, it is unrealistic to believe that the program can address all five stated goals equally Certainly, some effort can go toward each of the goals, but the program should focus on the goals most related to long-term monitoring detection of change and understanding the causes of change Together, these will facilitate progress in learning to predict future changes, although the Trustee Council should be cautious about having too high expectations of predictability from such a program The goal of informing the public can be built around this core structure The goal of solving problems for resource managers and regulators also can be addressed in parallel to some extent, but should not drive the conceptual foundation of the program

STRUCTURE & APPROACH

- The science plan should be strongly based on a broad conceptual foundation to make sure it is soundly developed, has long-term viability, and that it is defensible and justifiable over time The conceptual foundation should be ecosystem-based It should include natural and human-induced changes and reciprocal interactions between humans and the marine environment It should be flexible so it can accommodate changing needs without compromising the core long-term measurements

- There are two ways to design a research program projects can be selected to investigate particular questions (hypotheses) or they can be selected to monitor specific variables identified as important to the goals The committee believes that the most useful approach for understanding the dynamics of an ecosystem will be hypothesis-driven, but we recognize that a combination of these approaches may work best for GEM because of its need to respond to public needs That is, we believe that GEM – based on a conceptual framework – should articulate two or three fundamental questions about the ecosystem that then guide the selection of species and other physical and biological parameters to be monitored

- Although it is properly intended to be a long-term program, it is wise for GEM to include some short-term projects with clear management implications The science plan needs to be flexible and able to accommodate changing needs without compromising the core long-term measurements

ORGANIZATION AND GOVERNANCE

- All major science programs, especially those of the scope, duration, and complexity of GEM, use a governance structure with layers of both staff and stakeholder input to provide direction, set priorities, and ensure that the program continues to meet its goals over time The GEM organizational structure should be enhanced along the lines of Figure 2-2 (flow chart), incorporating mechanisms for independent program planning, proposal review, and community involvement This general approach incorporates many of the main features of most other successful large science programs and seeks to ensure quality, longevity, independence, and openness

- Gem should be prepared to plan a series of small, focused workshops (held over time) that will provide the detailed guidance needed to implement the science plan For example, workshops will be needed to determine the boundaries of the core monitoring area, plan integrative modeling of GEM systems to reveal nodal species and critical measurements, plan data management, and determine what sampling tools will be appropriate for the monitoring program

GEOGRAPHIC SCALE

- Although the total domain to be covered by GEM is legitimately large, the long-term GEM monitoring studies that form the core part of the program should focus on tractable areas where critical environmental data is needed

- The primary geographic focus for monitoring should begin with Prince William Sound, because this ecosystem received the greatest amount of oil and might be expected to be among the last areas to recover, thus serving as a useful indicator of wide-scale recovery At some point, GEM will need to define more clearly the ecosystem they are monitoring, perhaps through a workshop that addresses what scale best supports the GEM core program

DATA MANAGEMENT

- GEM needs to have a major administrative commitment to data management This includes mechanisms and procedures to ensure data quality, provide data archiving, and take steps that data are available into the future as platforms and languages change over time There should be mechanisms to make data available to the public and among researchers

COMMUNITY INVOLVEMENT

- For the GEM program to be durable over time, the organizational structure needs to incorporate meaningful community involvement This involvement should occur at all stages, from planning (e g , selecting the questions to be addressed and variables to be monitored) to oversight and review

FINAL THOUGHTS

This committee was charged to provide feedback on the EVOSTC 2000a document But as the committee held its meetings, the GEM program has been evolving and we have been kept abreast of those changes as much as possible We focused this report on the written EVOSTC 2000a document because that document is, so far the most authoritative, written description of the program and because it is difficult to provide advice on orally presented ideas that are still in the process of evolving However, the committee wants to acknowledge that the plan for the GEM program has changed much since the EVOSTC 2000a document was distributed Thus the following is based solely on our interpretation of where it "sounds" like the GEM plan is headed

The committee wishes to express concern that the GEM program may be moving toward a piece-meal, small-scale, project-driven approach GEM appears to be evolving from being oriented toward ideas and hypotheses, as expressed in the April GEM document, to being oriented toward specific tasks, as emphasized in subsequent discussions and draft materials It seems to be losing sight of its ecosystem focus as it selects individual species for attention We understand that the creation of a complex new program can be a messy process, thus we remain optimistic that the core mission of GEM is still to provide broad, ecosystem-based, long-term monitoring and research that will lead to an integrated understanding of the Gulf of Alaska ecosystem

REFERENCES

Bailey, K M 2000 Shifting control of recruitment of walleye pollock *Theragra chalcogramma* after a major climatic and ecosystem change *Marine Ecology Progress Series* 198 215-224

Baines, G , and N Williams 1993 Partnerships in Tradition and Science " Pp 1-12 in Williams, N and G Baines (eds), *Traditional Ecological Knowledge Wisdom for Sustainable Development* Canberra Centre for Resource and Environmental Studies, Australian National University

Baretta, L and Hunt, G L , Jr 1994 Changes in the numbers of cetaceans near the Pribilof Islands, Bering Sea, between 1975-78 and 1987-89 *Arctic* 47 321-326

Brodeur, R D , B Frost, S R Hare, R C Francis, and W J Ingraham, Jr 1996 Interannual variations in zooplankton biomass in the Gulf of Alaska and covariations with the California current zooplankton biomass *CalCOFI Report* 37 80-99

Brodeur, R D , C E Mills, J E Overland, G E Walters, and J D Schumacher 1999 Substantial increase in gelatinous zooplankton in the Bering Sea, with possible links to climate change *Fisheries Oceanography* 8 296-306

Carpenter, S R , J F Kitchell, and J R Hodgson 1985 Cascading trophic interactions and lake productivity *BioScience* 35 634-639

Chambers, R 1997 *Whose Reality Counts Putting the First Last* London Intermediate Technology Publications

Duggins, D O , C A Simenstad, and J A Estes 1989 Magnification of secondary production by kelp detritus in coastal marine ecosystems *Science* 245 170-173

Exxon *Valdez* Oil Spill Trustee Council (EVOSTC) 2000a Gulf Ecosystem Monitoring A Sentinal Monitoring Program for the Conservation of the Natural Resources of the Northern Gulf of Alaska GEM Science Program NRC Review Draft April 21, 2000

Exxon *Valdez* Oil Spill Trustee Council (EVOSTC) 2000b Can we predict the ways of the sea? *Restoration Update* 7(1) 2, 10-11

Holland, J , and J Blackburn (eds) 1998 *Whose Voice Participatory research and policy change* London Intermediate Technology Publications

Martinez, D 2000 Traditional Ecological Knowledge, Ecosystem Science, and Environmental Management, Invited Feature *Ecological Applications* 10(5) 1249

Merrick, R L 1997 Current and historical roles of apex predators in the Bering Sea ecosystem *Journal of Northwest Atlantic Fisheries Science* 22 343-355

National Research Council (NRC) 1995 *Review of EPA s Environmental Monitoring and Assessment Program Overall Evaluation* Washington D C National Academy Press

National Research Council (NRC) 1996 *The Bering Sea Ecosystem* Washington, D C National Academy Press

National Research Council (NRC) 1999a *Sustaining Marine Fisheries* Washington D C National Academy Press

National Research Council (NRC) 1999b *Global Ocean Science Toward An Integrated Approach* Washington D C National Academy Press

National Research Council (NRC) 2000 *Ecological Indicators for the Nation* Washington D C National Academy Press

Paine, R T and J L Ruesink, A Sun, E L Soulanille, M J Wonham, C D G Harley, D R Brumbaugh, and D L Secord 1996 Trouble on Oiled Waters Lessons frm the *Exxon Valdez* Oil Spill *Annual Review of Ecological Systems* 27 197-235

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 1710-1716

Reeburgh, W S , and G W Kipphut 1986 Chemical distributions and signals in the Gulf of Alaska, its coastal margins and estuaries Pp 77-91 in D W Hoot and S T Zimmerman (eds), *The Gulf of Alaska, Physical Environment and Biological Resources* MMS/NOAA Alaska Office, Anchorage, OCAS Study MMS 86-0095

Rose, D 1993 Reflections on Ecologies for the Twenty-first Century Pp 115-118 in Williams, N and G Baines (eds) *Traditional Ecological Knowledge Wisdom for Sustainable Development* Canberra Centre for Resource and Environmental Studies, Australian National University

Simenstad, C A , J A Estes, and K W Kenyon 1978 Aleuts, sea otters and alternate stable state communities *Science* 200 403-411

Salomon, A K , J L Ruesink, B X Semmens, and R T Paine In press Incorporating human and ecological communities in marine conservation An alternative to Zacharias and Roff *Conservation Biology*

Tynan, C T 1998 Coherence between whale distributions, chlorophyll concentration, and oceanographic conditions on the southeast Bering Sea shelf during a coccolithophore bloom, July-August, 1997 *EOS Transatlantic American Geophysical Union* 79 127

Tynan, C T 1999 Redistributions of cetaceans in the southeast Bering Sea relative to anomalous oceanographic conditions during the 1997 El Niño *PICES Science Report* 10 115-117

Wooster, W S 1992 King crab dethroned Pp 15-30 in M H Glanz (ed), *Climate Variability Climate Change and Fisheries* Cambridge Cambridge University Press

A

EVOSTC Restoration Update, Winter 2000, Volume 7, Number 1
Elements of GEM

GEM will have three main components

- long-term ecosystem monitoring (decades in duration),
- short-term focused research (one to several years in length), and
- ongoing community involvement, including traditional knowledge and local stewardship

In addition, GEM will require a strong science management effort and a concerted public information and data management program

LONG-TERM ECOSYSTEM MONITORING

GEM will contribute to a core of strategic measurements taken over decades by many agencies in order to track changes in the outer shelf and coastal regions of the northern Gulf of Alaska Monitoring goals are to understand the factors involved in productivity of fish, birds, and marine life, improve our ability to distinguish between natural and human-caused changes, and accurately model and predict ecological change This information will be available to organizations, agencies, universities, and individual stakeholders for the use, management, and conservation of marine resources

GEM will take advantage of existing projects being carried out by agencies and other institutions Funds will be used to obtain measurements that are essential to taking the pulse of the Gulf of Alaska and that are not being obtained reliably through other programs

SHORT-TERM RESEARCH

Strategically chosen research projects with relatively short-term goals will be funded as needed Research will

- Follow up on issues related to any lingering effects of the *Exxon Valdez* oil spill This research is expected to diminish over time as impacts from the spill become more and more difficult to distinguish

- Explore questions or concerns that arise out of the monitoring data Research would focus more on individual species to understand how they are being impacted by changes in the ecosystem A sudden rise or decline in a species population is one way to trigger such research
- Provide key information and tools for management and conservation purposes This would include, for example, improved scientific techniques and better technologies for stock assessments of fisheries Research can also identify sensitive habitats in the marine environment so that this information can be considered in management strategies

TRADITIONAL KNOWLEDGE, COMMUNITY INVOLVEMENT, AND LOCAL STEWARDSHIP

The last 10 years of oil spill research has proven that community involvement can provide important observations and insights about changes in the status and health of marine resources Encouraging local awareness and participation in research and monitoring enhances long-term stewardship of living marine resources

Local monitoring, documentation, and stewardship projects must be linked under GEM wherever possible with other monitoring, research, and conservation projects to promote sharing of information and ideas Scientific steering committees, composed of academic, agency and local representatives, can identify and oversee opportunities for productive collaboration

The actual mechanisms for achieving this goal are not fully developed Several approaches have been tried in the current restoration program and elsewhere in Alaska, and GEM will draw on these experiences to design processes for involving communities and their expertise One approach, the Youth Area Watch, has proven to be an effective and popular means of involving and educating young people and their home communities about oil spill research Similar projects may be developed as part of GEM in coastal communities throughout the oil-spill area

SCIENCE MANAGEMENT

It's expected that GEM will be governed by the Trustee Council until impacts from the oil spill are no longer discernible It would be administered by the current Restoration Office, made considerably smaller to reflect the scope of the program

A senior staff scientist will work with the executive director, Trustee Council, scientific community, resource managers, and stakeholders to implement and evaluate GEM The program will be administered consistent with the Restoration Plan, adopted by the Trustee Council in 1994

Public participation and independent peer review will be an essential part of the process An independent panel of scientists will fine tune the GEM program every five years

PUBLIC INFORMATION, DATA MANAGEMENT, AND INTEGRATION OF RESULTS

Gathering data is one thing Managing and maintaining that data is a consistent form that can be utilized easily by researchers is another It is essential that a strong data management strategy be in place before long-term monitoring projects are initiated

The data will be analyzed and integrated into predictive ecosystem models Results will be available to the public through periodic "State of the Gulf" workshops and reports and this will be made accessible on the internet Workshops and other forums will bring together a variety of participants in the various aspects of GEM to stimulate discussions and spark new ideas

The Trustee Council is committed to public input and public outreach as vital components of the long-term GEM program Public meetings, newsletters, annual reports, informational web sites, and the 17-member Public Advisory Group are some of the ways the public is currently informed about restoration activities

It's envisioned that this effort would continue, but to a lesser degree to reflect the smaller GEM program The Trustee Council will likely develop a series of alternatives on continuing public advice in the next two years and then go out for public comment before taking any final action

B

"Gulf Ecosystem Monitoring A Sentinel Monitoring Program for the Conservation of the Natural Resources of the Northern Gulf of Alaska"

GEM Science Program NRC Review Draft (April 21, 2000)

Executive Summary

This document provides the foundation for the Gulf Ecosystem Monitoring (GEM) program, a long-term research and monitoring effort in the northern Gulf of Alaska The *Exxon Valdez* Oil Spill Trustee Council (Trustee Council) has endowed this program as a final legacy of its mission to restore the fish and wildlife resources injured by the 1989 *Exxon Valdez* oil spill

This document is composed of four main sections plus supporting materials
• Section I describes the Gulf of Alaska (GOA) region and the Trustee Council's program needs at this scale,
• Section II contains the Trustee Council's vision for meeting these regional needs,
• Section III is the framework of an institution and process for realizing that vision, • Section IV presents and organizes the scientific information available to guide the

Trustee Council as it develops and implements the GEM program Accordingly, Section IV attempts to be inclusive of all the biological and physical components of the GOA ecosystem

The GEM document is not itself a research and monitoring plan Rather, this document provides the overall framework for a program that includes a three-year process of developing, reviewing and adopting a research and monitoring plan Implementation of the future plan is expected to begin in October 2002

Within the northern GOA (including Prince William Sound, Cook Inlet, Kodiak Island and the Alaska Peninsula), offshore and nearshore marine, estuarine, freshwater and terrestrial environments interact with geologic, climatic, oceanographic, and biologic processes to produce highly valued natural bounty and exceptional beauty The GOA provides habitat for diverse and abundant populations of fish and shellfish, marine mammals and seabirds It is a major source of seafood for the entire nation, as well as for Alaska Natives, who rely on it for subsistence and cultural purposes It is also a source of beauty and inspiration for those who love nature and part of the ' lungs ' of the planet for recycling of oxygen and carbon to and from the atmosphere As a result of both human influences and natural processes, these important attributes are continually changing

More than half of the state's 621,000 permanent residents live within the geographic area of the northern GOA and the nearby population center of the greater Anchorage area Most of the more than one-million tourists that travel to the state each year visit this region The private-sector economy of Alaska depends heavily on extraction of natural resources from this region, including petroleum, fish and shellfish, minerals, and timber Crude oil and fuel tanker traffic, increasing tourism and recreational use, expanded road building, and growing commercial and sport fishing pressure are all human activities that could affect the marine resources and ecosystem of the northern GOA In addition, recent evidence of persistent organic pollutants and heavy metals in fish and wildlife tissues in the gulf indicate that this region is not immune from worldwide concerns about potential effects of contaminants on marine organisms and on human consumers, particularly Alaska Native subsistence users

Populations of important marine resources in the northern GOA have undergone major changes, especially since the late 1970s Salmon catches of all species, and especially of sockeye, have remained near record levels for two decades, with annual catches significantly greater than those in the three decades ending in 1979 Shrimp and red king crab have fallen to extremely low levels in the gulf since 1980, in sharp contrast to the very high levels in the two prior decades Kodiak's red king crab fishery, once among the world's richest, has been completely closed since 1984 As shrimp and crab declined, cod, pollock and flatfish, such as arrowtooth flounder, have rapidly increased Some marine mammals associated with the gulf, such as sea lions, harbor seals and over-wintering fur seals, have steadily declined since 1980 Other species, such as sea otters and elephant seals, have been on the rise for more than a decade Colonies of seabirds, such as black-legged kittiwakes, common murres and cormorants, have shown declines since about 1980 in some coastal localities, such as Prince William Sound and central Cook Inlet, but not in others Overall, many species and populations associated with nearshore habitats in the GOA have declined since about 1977, whereas species and populations having access to offshore gulf habitats have generally increased

Understanding the sources of these changes, whether natural or influenced by human activities, requires a solid historical context This certainly has been the lesson of the 1989 *Exxon Valdez* oil spill, a large-scale ecological disaster, resulting in hundreds of millions of dollars invested in studies and restoration projects in the past decade Based on the knowledge and experience gained through this program, the Trustee Council has dedicated approximately $120 million to complete work on lingering oil-spill injury and to endow long-term monitoring and research in the world-renowned ecosystem of the northern GOA

For planning purposes, the program is referred to as the Gulf Ecosystem Monitoring (GEM) program The mission of the program is "to sustain a healthy and biologically diverse marine ecosystem in the northern GOA and the human use of the marine resources in that ecosystem through greater understanding of how its productivity is influenced by natural changes and human activities "

GEM has five major programmatic goals These are to

DETECT Serve as a sentinel (early warning) system by detecting annual and long-term changes in the marine ecosystem, from coastal watersheds to the central gulf,

UNDERSTAND Identify causes of change in the marine ecosystem, including natural variation, human influences, and their interaction,

PREDICT Develop the capacity to predict the status and trends of natural resources for use by resource managers and consumers,

INFORM Provide integrated and synthesized information to the public, resource managers, industry and policy makers in order for them to respond to changes in natural resources and

SOLVE Develop tools, technologies, and information that can help resource managers and regulators improve management of marine resources and address problems that may arise from human activities

The annual earnings from a $120 million endowment will not be able to fund all that needs to be done to achieve the above goals Instead, the Trustee Council will focus alarge part of its efforts on providing leadership in identifying monitoring and research gaps and priorities, encouraging efficiency and integration through leveraging of funds, coordination, and partnerships, and involving stakeholders in local stewardship by having them help guide and carry out parts of the program

Recognizing that the gulf ecosystem under consideration is extremely complex, consisting of thousands of species, it also will not be possible for GEM to answer all, or even most, of the questions that could be posed about the GOA GEM instead will be focused, to a large extent, on key species and ecological processes in the system These will be selected on the basis of ecological importance, human relevance, and their ability to indicate ecosystem disturbance, as well as their importance for understanding the physical and biological bases for productivity In the end, GEM must be justified on what it can teach policy makers, resource managers and the public about options for directing human behavior toward achieving sustainable resource management goals

The GEM program will continue to work with resource managers, stakeholders, the scientific community and the public to refine a common set of priorities for research, monitoring and protection in the northern gulf In order to do that, we must share an understanding of which marine resources of the northern gulf are valued and what stressors or potential threats could affect their overall health The GEM program will build a matrix of who is monitoring what, where, and when and identify gaps in monitoring those things that are important to us GEM will work towards filling in the important gaps

The long-term monitoring element of GEM will be complemented by strategically chosen research projects These projects will follow up on lingering effects of the *Exxon Valdez* oil spill, explore questions and concerns that arise out of interpretation of the monitoring data, especially in trying to understand the causes of change, and provide key information and tools for management and conservation

The Trustee Council believes that encouraging local awareness and participation in research and monitoring enhances long-term stewardship of living marine resources Traditional and local knowledge can provide important observations and insights about changes in the status and health of marine resources and should be incorporated into GEM Citizen monitoring efforts are already underway in several communities in the GEM region and should be looked to for future collaboration

Independent peer review of the GEM program is essential for a high-caliber scientific program Participation in research and monitoring is expected to be completely open to competition All data must be archived, maintained, and readily accessible to other scientific users and the public In order for GEM to be successful, it will be necessary to integrate, synthesize, and interpret monitoring and research results to form and present a "big picture" of the status of and trends in the northern GOA ecosystem Some possible approaches include the use of models, periodic "State of the Gulf" and "State of the North Pacific ' workshops and reports, and a GEM website The Trustee Council is committed to public input and outreach as vital components of the long-term GEM program

C

Committee Comments on the Scientific Elements Supporting GEM 2000 Program

In general, the committee attempted to focus its comments on the broad issues for GEM However, in our deliberations we did at times comment quite specifically on the GEM document, and especially on the scientific framework described in Sections IV C, D, and Appendix C Feedback on the scientific framework was requested specifically by the program staff This appendix provides these more detailed comments and is likely most useful to program staff

Based on our reading, it appears that GEM program planners see the Pacific Decadal Oscillation (PDO) as the core of the scientific framework, or conceptual foundation, underpinning GEM This choice is based on recent evidence that the PDO is an important indicator of ecosystem change in the Gulf of Alaska

However, the committee is concerned that the program's reliance on the PDO concept will prove controversial over time This emphasis might constrain research and prevent exploration of alternative hypotheses There also appears to be a disconnection between what appears to be a strong offshore focus and the GEM's broader mission The mission emphasizes reciprocal links between humans and the marine environment, many of which occur close to shore If the PDO is maintained as the centerpiece of the plan, GEM should commit to coordinating sampling of biophysical conditions throughout the Northeast Pacific and particularly at offshore fronts because of their proposed importance in transferring production among regions

The inshore-offshore inverse production regime and linkage to the PDO is not firmly established, and therefore it is not wise to base an entire research program on it Not only may the hypothesis be incorrect, but it would constrain all research to be centered on a single over-arching hypothesis that was not generated by researchers, limiting scientific creativity Additionally, it is not logical to base the entire GEM program on a hypothesis that centers on offshore fronts To address the hypothesis that is detailed here, a very large, long-term (50 years at least) offshore monitoring program would be necessary Not only would the cost of such an immense investigation be beyond the financial capabilities of GEM, but also GEM is a nearshore-based program That fact conflicts with the ability to address the hypothesis

In the following sections, we comment first on the explanation of the PDO provided in the GEM document We then turn to other scientific issues raised in sections IV C, D and Appendix C The eventual conceptual framework developed for GEM will undoubtedly need to be able to incorporate both the PDO and other factors leading to ecosystem change

THE PDO AS FACT OR HYPOTHESIS?

The background section (IV C) and framework section (IV D) of EVOSTC (2000a) imply a stronger consensus or evidence about the PDO than actually exists Many marine scientists agree that the positive PDO (strong low pressure cell over the GOA) is associated with increased algal and zooplankton production in the central Gulf, and this positive PDO has also been correlated with higher salmon production, and possibly lower forage fish production (inshore taxa) However, there is not yet consensus or evidence to explain why production increases offshore, nor if there is an inverse relation with forage fish production onshore (as stated on p 73, para 3, line 2) There is some evidence that decreased mixed layer thickness can cause an increase in primary production through the alleviation of light-limitation of algae (e g , Polovina et al 1995) The GEM document suggests that increased production is mainly due to offshore transport of nutrients because of increased precipitation over land -- essentially, the document hypothesizes that more rain leads to greater runoff, more nutrients, and higher fish production This hypothesis would require that the circulation of the offshore North Pacific would be enhanced with the increase in the runoff and that additional onshore flow of subsurface waters would accompany the increase in offshore flows at the surface However, this has not been shown to be the case in this system With respect to salmon stocks, the model requires that increased primary production result in more zooplankton (which Brodeur et al 1996 suggest is the case) and that this zooplankton abundance is what regulates salmon production Unfortunately, data are limited and ideas on these issues are still evolving Also, Brodeur et al (1996) only address zooplankton in central (offshelf) Gulf of Alaska Certainly, there is evidence of higher salmonid escapement during the positive PDO (and higher zooplankton abundance) phases, but the difference in fish production is not necessarily due to having more food This is a logical and possible scenario, but it could as easily be related to changes in predator abundance as the salmon pass through the nearshore region (if the inverse off-nearshore fish production oscillation is true), changes in survival because of altered salinities, temperatures, or other factors

The background section links GOA productivity to the shelf-break and oceanographic fronts, but fails to focus on these areas for research and monitoring The importance of shelf-break areas is suggested on p 60 (line 33), 64 (line 32), 69 (line 33), 70 (line 19) and 74 (line 40) However, a plan that focuses on the nearshore—as GEM probably will—will not be able to answer many potentially important questions about observed patterns in the GOA A comprehensive oceanographic program for the Northeast Pacific would be very useful, but this is not GEM's role New technologies might permit a broad sampling scheme (e g , remote sensing) and a few well placed moorings might be used The cross-shelf versus alongshore flux of heat, salt and nutrients needs to be investigated, and process experiments on seasonal time scales with some interdisciplinary modeling might shed light on these questions The PDO and associated large-scale changes in productivity represent hypotheses, therefore they must be explicitly tested Within the GEM document, data collection at fronts only appear as a priority in the Appendix of scientific questions

Section IV D of the GEM document develops a set of specific interrelated physical and biological changes expected to follow from the PDO These interrelated changes come across as fact, yet the statements on pages 70-73 are mostly hypotheses, which have not been proven

For instance, regarding the items listed on page 70-71

Item 1 There is a very strong seasonal change in the wind stress, but a similar acceleration has not been observed in the Alaska Current or gyre
Item 2 The increased wind stress should increase mid-gyre upwelling but not necessarily upwelling to the ocean surface, only into the upper layers
Item 3 The interdependence of the Alaska and California Currents has yet to be proven, though satellite altimeter data should provide the evidence if it is true
Item 6 suggests an increase in runoff and organic carbon and anthropogenic inputs, which have not been proven or even studied Prior evidence suggests that runoff here is nutrient limited (Reeburgh and Kipphut 1986)

Item 10 Where is the evidence for the deepening of the Alaska Coastal Current nearshore? An increase in the ACC transport could be accomplished by increased speed and/or width

Regarding the items listed on pages 71-73, the committee provides the following comments

Item 1 The mixed layer depth could be shallower This shoaling of the mixed layer depth could be caused by increased upwelling rather than warming Also, changes in salinity of the upper layer salinity can also affect the stratification Once again, this section gives the impression that much more is known about the physical and biological processes in the Gulf of Alaska than is actually the case These hypotheses are reasonable but unproven
Item 5 Organic matter does not originate in the Gulf but rather is transported there by global thermohaline circulation, where it might be upwelled into the upper layers It is uncertain whether the nutrient-rich water is advected across the shelf in the upper layers or deep layers or whether it downwells more strongly before it reaches the coast
Item 6 The idea that organic matter downwells on the outer shelf and slope to supply benthic communities is an interesting idea but is unproven
Item 7 The connection between biooceanographic variables and the abundance and distribution of species on the shelf and slope remains a hypothesis, requiring field study and measurements to prove or disprove it The plans presented later in the GEM document do not call for such measurements in this region of the gulf

Finally, the questions in Appendix C, sections c, d, and e appear to be specific to the PDO foundation and therefore may inhibit scientific creativity and progress

PROBLEMS RELATED TO REPRESENTATION OF THE LITERATURE

As noted earlier, Trustee Council staff said that the committee could be of help both by providing broad, general guidance and by identifying specific problems or errors In reading the GEM document, the committee identified a number of statements that were insufficiently or incorrectly cited, or that appeared to lack a scientific basis The following is a list of these issues

- p 63, bottom Concepts attributed to Hollowed and Wooster (1992) and Brodeur et al (1996) are unlikely to have been stated as interpreted
- p 64, first sentence Zheng and Kruse is a study of crabs, but the document makes statements about groundfish eggs and larvae
- P 61, paragraph 1 and Figure 8 Brodeur's work did not refer to the PDO His figures show zooplankton, not plankton in general
- P 71, paragraph 3 the waters of the Alaska Coastal Current are not known to be nutrient limited
- Page 61 Line 47 There are insufficient nutrient data to conclude that Gull Island seabird food chains might be supported by "nutrient supply from deep water enabled by exceptionally strong, topographically focused, tidal-induced mixing in lower Cook Inlet
- Page 62 line 3 The "continuing increase of average surface-water temperatures in the North Pacific" is not supported by references and may not be valid

Page 63 line 4 What is the evidence of movement of the ACC away from the coast?

BEYOND THE PDO COMMENTS ON OTHER PORTIONS OF THE SCIENTIFIC FRAMEWORK

The inshore/offshore inverse production model is too narrow to provide a conceptual foundation It could, however, be one hypothesis within a larger framework that seeks to understand spatial and temporal variability and forcing factors (natural/ anthropogenic, top-down/ bottom-up)

Top predators are assumed to act as integrators of environmental factors (especially productivity and stress) and, thus, to be good indicators of change But this assumption is not supported and leads to some faulty statements For example, p 67 states "the rates of recovery of these apex predators from heavy exploitation offer insights into many aspects of the trophic structure ' This is a general statement, but it has no meaning without follow up On p 67, third paragraph, the document states that "harbor seals should be considered candidates " However, not only does this concept not belong in that paragraph, there is no explanation to explain why harbor seals should be monitored

The framework focuses on oceanic and climatic phenomena This focus is not "wrong," but it ignores nearshore intertidal and subtidal areas that receive some of the most direct human impacts A tremendous amount of attention was paid to intertidal and shallow subtidal areas after EVOS because much of the oil washed up onshore Yet the section on benthos includes essentially none of this work Even if the specifics are too numerous to be included, there are some excellent conceptual foundations that could be employed to focus research In fact, many of the testable hypotheses about community processes (top-down/bottom-up control, keystone predation, supply side/post-recruitment control, facilitation in stressful environments) were first developed and explored in intertidal systems

Some impacts from human activity will interact with natural change at the scale of the entire Gulf (for instance, climate warming, persistent organic pollutants, some fisheries) Many, however, are likely to have impacts primarily on near-coastal areas (such as impacts from nutrient loading, aquaculture, forestry, erosion, subsistence harvest, and some fisheries Currently in the program, marine-terrestrial linkages refer almost exclusively to the transport of marine nutrients upstream by salmon Clearly there may be many other processes occurring at this ecotone

The North Pacific Marine Science Program (known as PICES) may provide a good research model for integrating the oceanographic and shoreline components of GEM (<http //pices ios bc ca/>), as may the Partnership for Interdisciplinary Studies of the Coastal Ocean (PISCO) For instance, it is essentially unknown whether recruitment and growth of intertidal and shallow subtidal organisms reflect offshore regime shifts It is even possible to imagine reciprocal linkages in which nearshore communities affect oceanographic conditions For instance, nearshore food webs have been shown to have a role in marine productivity In the Aleutians, the presence or absence of sea otters can alter energy sources and growth rates of intertidal filter feeders through an indirect trophic pathway—mussels consume greater quantities of plankton when otters are rare, and consume more kelp detritus when otters are abundant (Simenstad et al , 1978, Duggins et al , 1989)

In the scientific questions in Appendix C, part b includes specific nearshore locations that are absent from questions in other sections (although PWS, Cook Inlet, and Kodiak shelf must be implied locations for studies of seabirds, some mammals, benthic and intertidal communities) Many anthropogenic impacts disproportionately affect nearshore areas, and important impacts appear to be absent from Appendix C, section f This section currently includes questions about contaminants Other human impacts should be considered, including aquaculture, removal of top predators, introduced species and eutrophication

Finally, as a last variation on the theme of better incorporation of nearshore areas in the scientific framework, the questions on benthic and intertidal communities might be more usefully framed as

a) What are sources and rates of natural disturbance to these communities, and what are rates and patterns of recovery?

b) How variable is recruitment in space and time, and among planktonic species?
c) What is the relationship between recruitment rates and growth rates of filter feeders? Algae? Predators?
d) What are primary energy and nutrient sources of intertidal and benthic communities-in situ, upwelling, offshore, terrestrial runoff?
e) Under what conditions are populations limited by recruitment, food, space, natural disturbance, temperature, predators, competitors, disease?

The Trustee Council was impressively far-sighted in setting aside a portion of the settlement from the Exxon Valdez oil spill for long-term research and monitoring in the area affected by the spill One of the main scientific messages of the spill was that it is difficult to tell whether ecological change has or has not occurred when baseline data are spotty or unavailable (Paine et al 1996) Clearly, monitoring will improve the capacity to detect future trends and shifts, with the caveat that the changes most likely to be detected are strong ones superimposed on a baseline of low intrinsic or observer-based variability The deliberate approach to developing the GEM plan, which has included workshops, reports from consultants, and the initial Program development, seems entirely in keeping with the long time frame of the plan

The program begins to describe environmental science in the Gulf of Alaska in terms of both what is known and how it is being studied As the summaries of work performed in PWS over the past 10 years are developed, they will contribute to ecological knowledge Appendix Table 1, which summarizes information-gathering programs in the GOA, is a useful matrix of projects, data collections, and study areas, which can help investigators make connections among disciplines and locations It may also prove possible to provide links to the data sets that emerge from this variety of projects

D

Biographical Sketches of the Committee's Members

Michael Roman (chair) is Professor at Horn Point Environmental Laboratories at the University System of Maryland's Center for Environmental Sciences His research interests are biological oceanography, zooplankton ecology, food-web dynamics, estuarine and coastal interaction, and the carbon cycle in the ocean Dr Roman was chair of the Coastal Ocean Processes (CoOP) Steering Committee for the National Science Foundation and has experience leading a multidisciplinary activity He brings a broad ecological perspective to this setting

Don Bowen is a research scientist at the Marine Fish division of the Bedford Institute of Oceanography's Department of Fisheries and Oceans His research has focused on the population dynamics, foraging ecology, and ecological energetics of pinnipeds Objectives of these studies are twofold First, to understand the diversity of pinniped life histories and second, to understand the nature of competitive interactions between seals and commercial fisheries Since 1997, Dr Bowen has also conducted ecological research on the northern right whale with the aim to foster the recovery of the species

Adria A Elskus is Assistant Professor of Environmental Physiology at the T H Morgan School of Biological Sciences at the University of Kentucky Her scientific background includes work in endocrinology, geochemistry, biochemistry, and physiology, and she has worked as a consultant in industry (Energy Resources Company), as a toxicologist and chemist in government (US EPA/Narragansett lab), and in academia Her research interests include the fate and effects of contaminants in aquatic ecosystems, particularly effects on reproduction, adaptation to environmental contaminants, organic pollutant metabolism and the interplay of hormones and pollutants, and the biochemical mechanisms of pollutant effects

John J Goering is Professor Emeritus and former Associate Director of the Institute of Marine Science, University of Alaska Fairbanks He is well-known as one of the first to make significant discoveries in the areas of the marine nitrogen cycle, the silicon cycle, and silicon and nitrogen assimilation by phytoplankton He has served as Vice-President and later President of the Pacific Section of the American Society of Limnology and Oceanography, as chair of the Oil Spill Recovery Institute Science Advisory Committee, and as a member of the North Slope Borough Science Advisory Committee and the Coastal Marine Institute Technical Advisory Committee

George Hunt is Professor of Ocean Ecology and Marine Ornithology at the University of California, Irvine His research group focuses on the trophic transfer of energy within marine ecosystems, particularly as it pertains to the foraging and reproductive ecology of marine birds Marine birds provide useful models for investigation of the interactions of physical and biological processes in the ocean that result in concentrations of prey Colony-based studies of seabird reproductive ecology and food habits are also used as sources of information about the effects of climate change on the structure and functioning of marine ecosystems In this work, he emphasizes the importance of physical processes in determining the structure and function of marine ecosystems

Seth Macinko an Assistant Professor in the University of Connecticut's Department of Geography Previously he was a Social and Economic Policy Analyst at the Alaska Department of Fish and Game He also fished commercially off Alaska from 1979 to 1983 His research interests are broadly focused on the intersections between natural resource management (especially marine resources), environmental history, and political ecology He is particularly interested in the role of institutional arrangements and culture in resource management Current projects are focused on distributional issues involving access to marine resources property rights in marine fisheries, the role of place and community in property right reformations, and linkages between marine resources and community development

Donal T Manahan is an environmental physiologist from the University of Southern California where he is the Director of the Marine Biology Section in the Department of Biological Sciences He is active in many areas of science in the Antarctic, as well as in temperate regions and deep-sea hydrothermal vents His research includes physiological ecology of early stages (larvae) of animal development, animal/chemical interactions in the ocean, and the genetic bases of physiological processes In education, he is currently the director of an international training course (Ph D level) in Antarctica, "Integrative Biology and Adaptation of Antarctic Marine Organisms " Dr Manahan is the chair of the Polar Research Board and serves as the Board's liaison to this activity

Brenda Norcross is Associate Professor of Fisheries Oceanography at the Institute of Marine Science, University of Alaska, Fairbanks Her research focuses on fish and their habitats, including human induced effects on the environment She has studied flatfishes in Alaskan waters, including defining habitats and developing models for nursery areas of five species of flatfishes in Alaskan waters based on depth, sediment type, temperature and other environmental factors Dr Norcross also worked on the herring component of the multi-investigator Sound Ecosystem Assessment (SEA) project, which investigated the environment of Prince William Sound following the Exxon Valdez oil spill She has studied distribution of juvenile fishes and their availability to marine mammals, especially Steller sea lions, and seabirds

J Steven Picou is a professor of sociology in the Department of Sociology and Anthropology, University of South Alabama His research interests include technological disasters, community change, and applied sociology He directed an interdisciplinary team of researchers studying the economic, social, cultural, and psychological impacts of the Exxon Valdez oil spill

Thomas C Royer holds the Samuel and Fay Slover distinguished chair in Oceanography at Old Dominion University in Norfolk, VA, and is a leading authority on the oceanography of the Gulf of Alaska His research interests are in deep ocean and coastal hydrography and currents, long-time series measurements, and air-sea interactions He was at the University of Alaska for several decades, where he was one of the cornerposts of their academic and research programs and where his discovery of a significant coastal current along the coast of Alaska, driven by freshwater discharge, allowed a reasonable prediction of the trajectory of the oil released during the 1989 *Exxon Valdez* oil spill He represented the University of Alaska Fairbanks in UNOLS for many years and led the UAF ship program He has a very broad view of marine science, and he has seen extensive service on many panels, boards, and committees

Jennifer Ruesink is Assistant Professor of Zoology at the University of Washington Her areas of academic interest include community ecology, especially food web interactions, species invasions, the conservation of biological diversity, and ecosystem functioning She has studied the ecological impacts of the *Exxon Valdez* oil spill on the ecology of tidal communities in Prince William Sound, including work with NAS member Dr Robert Paine

Karl Turekian, a member of the National Academy of Sciences, is Silliman Professor of Geology and Geophysics at Yale University He also is the Director of the Institute of Biospheric Studies and the Director of the Center for the Study of Global Change His research areas include marine geochemistry, atmospheric geochemistry of cosmogenic, radon daughter and man-made radionuclides, surficial and groundwater geochemistry of radionuclides, planetary degassing, geochronology based on uranium decay chain and radiocarbon of the Pleistocene, osmium isotope geochemistry, meteorite origins in relation to planetary systems, oceanic upwelling, and climate change Dr Turekian serves as a member of the Ocean Studies Board and as a member of the Committee on Global Change Research of the National Research Council