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OVERVIEW OF THE GEM PROGRAM DOCUMENT (Abridged Version)

This brief version of the GEM (Gulf Ecosystem Monitoring and Research) Program Document contains only the programmatic components (Chapters 1-5 in Table O 1 below) of the complete GEM Program Document The complete document, which contains all of the chapters described in Table O 1, is available on the Trustee Council's web site at www oilspill state ak us

Chapters 1 through 5 explain the basic motivations for the program, conceptual foundation, tools and strategies for achieving program goals, and program implementation and management Chapters 6 through 9 present the factual basis for the program including the scientific background behind the development of essential program elements (Chapter 7) and detailed descriptions of two important components of the program modeling (Chapter 8) and data management and information transfer (Chapter 9) Table O 1 identifies the question addressed by each chapter and the products provided

Table O 1 Contents of the GEM Program Document

Chapter	Title Question Addressed	Products
Included in this abridged version		
1	Vision *Why do this and what do we hope to achieve?*	Mission and goals Geographic scope funding and governance
2	Conceptual Foundation *How do we think the ecosystem works?*	Central hypothesis Habitat types and time-space scales
3	Tools and Strategies *What information do we need and how do we get it?*	Tools Gap Analysis Synthesis Research Monitoring Modeling, and Data Management Strategies Community Involvement and Traditional Knowledge and Resource Management Applicability
4	Program Implementation *Where are we going to start and how will we proceed? (This chapter is expected to change over time)*	Potential questions by habitat type Program implementation and partnering
5	Program Management *What are the processes and policies for monitoring and research?*	Program administration Roles and responsibilities of the GEM components

Table O 1 Contents of the GEM Program Document

Chapter	Title Question Addressed	Products
Available on the web at www oilspill state ak us		
6	Introduction to the Scientific Background *What are the theories and principles on which the conceptual foundation is based?*	Leading hypotheses in marine ecosystems Principal ecological concepts and theories
7	Scientific Background Physics Biology Human Uses and Economics *Comprehensive review of the current state of scientific knowledge of Gulf of Alaska ecosystems*	Overview of physical chemical and biological characteristics of the Gulf of Alaska Status of non-human populations predators and prey Status of hum an activities and socio-economics in the Gulf of Alaska
8	Modeling *What is the role of modeling in GEM?*	Modeling definitions and options for program implementation
9	Data Management and Information Transfer *What are the roles of data management and information transfer in GEM implementation?*	Data management and information transfer options for program implementation
A	Acronyms and Web links	
B	Recovery Status of Injured Resources	
C	*Exxon Valdez* Oil Spill Tribal and Community Involvement	
D	GEM Database	
E	Glossary of Existing Agency Programs and Projects	
F	North Pacific Models of the Alaska Fisheries Science Center and Other Selected Organizations	
G	Fish And Invertebrate Species From 1996 NMFS Trawl Survey Of The Gulf Of Alaska	
H	Collected Research Questions	

CONTENTS

Figures

Tables

EXECUTIVE SUMMARY

On March 24, 1989, the *T/V Exxon Valdez* ran aground on Bligh Reef in Prince William Sound, spilling almost eleven million gallons of North Slope crude oil The event was the largest tanker spill in U S history, contaminating approximately 1,500 miles of Alaska's coastline, killing birds, mammals and fish, and disrupting the ecosystem in the path of the spreading oil In 1991, the Exxon Corporation agreed to pay the United States and the State of Alaska $900 million over ten years to restore, replace, enhance, or acquire the equivalent of natural resources injured by the spill, and the reduced or lost human services they provide (United States of America and State of Alaska 1991) Under the court-approved terms of the settlement, the *Exxon Valdez* Oil Spill Trustee Council (Trustee Council) was formed to administer the restoration funds, and in 1994 the *Exxon Valdez* Oil Spill Restoration Plan was adopted to guide the development and implementation of a comprehensive, interdisciplinary recovery and rehabilitation program

The knowledge and experience gained during years of biological and physical studies in the aftermath of the *Exxon Valdez* oil spill confirmed that understanding the sources of changes in marine resources and ecosystems requires putting those changes into an historical context Toward this end, in March 1999 the Trustee Council dedicated approximately $120 million for long-term monitoring and ecosystem-based research within the area affected by the 1989 oil spill, which is generally the northern Gulf of Alaska, including Prince William Sound, Cook Inlet, Kodiak Island, and the Alaska Peninsula This new program is called the GEM (the Gulf of Alaska Ecosystem Monitoring and Research) Program, and its mission is 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 Trustee Council identified five major goals necessary to accomplish this mission

- **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,
- **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,

- **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, and

- **Predict** Develop the capacity to predict the status and trends of natural resources for use by resource managers and consumers

Given the size and complexity of the northern Gulf of Alaska ecosystem and the available funding, the GEM Program alone can not meet these goals For that reason, the Trustee Council adopted a set of additional goals for implementing the program These call for the GEM Program to

- **Lead** the way in integrating, synthesizing, and interpreting monitoring and research results to form and convey a "big picture" of the status of and trends in the Gulf of Alaska ecosystem,

- **Track** work of other entities relevant to understanding biological production in the Gulf of Alaska and **coordinate** GEM with those efforts,

- **Leverage** funds to augment ongoing monitoring work funded by other entities,

- **Involve** other government agencies, non-governmental organizations, stakeholders, policy makers, and the general public in a collaborative process to achieve the mission and goals of GEM,

- **Increase** community involvement and local and traditional knowledge in order to enhance long-term stewardship of living marine resources, and

- **Facilitate** application of GEM research and monitoring results to benefit conservation and management of marine resources

To fully achieve its mission, GEM must provide information that enables resource-dependent people, such as subsistence users, recreation users, and commercial fishers, to better cope with changes in marine resources The data and information produced by GEM during its first decade may not totally solve problems for the public, commercial interests, resource managers, and policy makers faced with environmental change Nonetheless, as information accumulates, the ability for GEM to provide problem-solving information and tools can and must increase

The GEM Program is based on the current state of knowledge about the natural factors and ecological impacts of human activities that cause change in the Gulf of Alaska Within the northern Gulf of Alaska, 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 Gulf of Alaska 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

Populations of important marine resources in the northern Gulf of Alaska 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 overwintering 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 Gulf of Alaska have declined since about 1977, whereas species and populations having access to offshore gulf habitats have generally increased

The Gulf of Alaska and its watersheds are part of a larger oceanic ecosystem in which natural physical forces such as currents, upwelling, downwelling, precipitation and runoff, play important roles in determining basic biological productivity Natural physical forces are shaped by the surface topography of the Gulf of Alaska and the submarine topography of the continental shelf and respond primarily to seasonal shifts in the weather, and in particular to long-term changes in the intensity and location of the Aleutian Low Pressure system Increased upwelling offshore appears to increase inputs of nutrients to surface waters, which in turn increases productivity of plankton, the basis of the food chain and the primary food source for all marine life Increased winds appear to increase the transport of zooplankton shoreward toward and past the continental shelf-break How often and how much offshore zooplankton sources contribute to coastal food webs depends on natural physical and biological forces such as predation, migration, currents, fronts, and eddies, degree and extent of turbulence, and responses of plankton to short and long-term changes in temperature and salinity

The ecological impacts of a wide range of human uses and activities interact with these natural forces to change the productivity and community structure in the Gulf of Alaska. More than 70,000 people live within the area directly affected by the oil spill, and two to three times that number use the area seasonally for work and recreation When combined with the population of the nearby centers of Anchorage and Wasilla, plus nearly a million tourists who visit the state each year, it becomes clear that the natural resources of the Gulf of Alaska cannot be immune to the pressures associated with human uses and activities

Human activities have the most direct and obvious impacts at those sites in watersheds and intertidal areas where human populations are high Crude oil and fuel tanker traffic, increasing tourism and recreational use, expanded road building, and growing commercial and sport fishing pressure could have increasing effects on marine resources and ecosystems Some human activities affect populations of birds, fish, shellfish, and mammals even far offshore, and also have impacts far from the sites of the actions Large scale fishing that occurs in international waters impacts Alaska resources 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

In short, human activities and natural forces act together over local and global scales to drive and shape marine and terrestrial life in the Gulf of Alaska and its tributary watersheds This conceptual foundation is summarized into a central hypothesis that will guide the GEM Program

> ***Natural forces and human activities working over global to local scales bring about short term and long lasting changes in the biological communities that support birds, fish, shellfish and mammals Natural forces and human activities bring about change by altering relationships among defining characteristics of habitats and ecosystems such as heat and salt distribution, insolation, biological energy flow, freshwater flow, biogeochemical cycles, food web structure, fishery impacts, and pollutant levels***

This broad, interdisciplinary hypothesis states what is thought to be known in general, prepares the way for questions that test the validity of this knowledge and serves as a flexible framework for determining the type of monitoring and research activities that will be undertaken in implementing the GEM Program

Since the gulf ecosystem under consideration is extremely complex and consists 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 Gulf of Alaska. Four habitat types, representative of the GEM region, have been identified as themes around which the interdisciplinary monitoring and research activities that address GEM's central hypothesis will be organized These habitat types are watersheds, the intertidal and subtidal areas, the Alaska Coastal Current, and the offshore areas (the continental shelf break and the Alaska Gyre) The habitats are composed of identifiable, although not rigid, collections of characteristic microhabitats, resident and migratory species, and physical features The decision to use habitats as a mechanism for stratifying funds and allocating resources will require the GEM

Program to ensure that such cross-habitat processes and linkages as freshwater flow and cross-shelf nutrient transport are not forgotten or ignored

The GEM central hypothesis can be translated into a hypothesis for each of these habitat types However, before they can be used to guide research, they need to be further refined into questions which can then be used to identify a core set of measurements for long-term monitoring The GEM Program will use the tools of gap analysis, synthesis, and modeling to develop a series of initial research questions and to continually refine and implement GEM's long-term core monitoring program The "flagship" of GEM will be a long-term monitoring program that will be maintained even if funding levels vary The monitoring component 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

To further develop the program, the Trustee Council will use two major strategies incorporating community involvement and traditional knowledge and focusing on resource management applications Communities and stakeholders must be involved at all levels of the program The Trustee Council believes that encouraging local awareness and participation in research and monitoring enhances long-term stewardship of living marine resources In addition, traditional and local ecological knowledge can provide important observations and insights about changes in these resources In order to enhance the information managers and stakeholders use to cope with these changes, the GEM Program will seek to acquire data with significant potential for use in resource management applications

The hypotheses, research questions, tools and strategies will all be used to develop a Science Plan for GEM The goal of the Science Plan is to implement a long-term monitoring program to detect and understand change over time within the northern Gulf of Alaska ecosystem The Science Plan will develop over time and include an implementation schedule, partners doing related monitoring or research, models to synthesize results and transfer information to users, core monitoring variables, and core monitoring activities

The GEM Program will be administered by the Trustee Council's core professional staff, based in Anchorage, Alaska Funds will be provided by the Trustee Council's investment fund, managed as an endowment, with the annual program funded by investment earnings after inflation-proofing The Trustee Council's executive director will oversee the financial, program management and administrative, scientific, and public involvement aspects of the program The Trustee Council and staff will actively solicit advice on science and policy matters, including review of monitoring and research activities, from experts, including a Scientific and Technical Advisory Committee, and from the public, including the Trustee Council's Public Advisory Committee

The Science and Technical Advisory Committee will play a key role in guiding the GEM Program and ensuring a high degree of scientific credibility is maintained Subcommittees composed of scientists, resource managers, stakeholders, and other experts and community members will be established to assist the Science and Technical Advisory Committee The Science and Technical Advisory Committee and subcommittees will work with resource managers, stakeholders, the scientific community and the public to refine a common set of priorities for research and monitoring in the northern gulf

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 documented, 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 Gulf of Alaska ecosystem One approach is through the use of periodic "State of the Gulf" and "State of the North Pacific" workshops and reports Another is use of the GEM web site The Trustee Council is committed to public input and outreach as vital components of the long-term GEM Program

Data management and information transfer policies are an integral part of GEM Program management Clear and effective approaches to gathering information and making it widely available in understandable formats are essential to the successful operation of the GEM Program Because the program is a regional program with goals of cooperation, coordination, and integration with existing marine science programs, data policies are to be compatible with, and similar to, existing norms for state, federal, and nongovernmental marine science programs

The GEM Program cannot be the sole solution to problems facing the northern Gulf of Alaska ecosystem However, a permanent fund, dedicated to monitoring the long-term health of a marine ecosystem, is totally unique and provides an unparalleled opportunity to increase our understanding of the functioning of this system The Trustee Council views the GEM Program as a permanent legacy of its efforts to restore the northern Gulf of Alaska from the effects of the 1989 *Exxon Valdez* oil spill And for that reason, the Trustee Council believes that the program must be justified on what it can teach policy makers, resource managers, and the public about options for directing human behavior to achieve the GEM mission "to sustain a healthy and biologically diverse marine ecosystem and the human use of the marine resources in that ecosystem "

1. VISION

In This Chapter

- Origin of the GEM Program
- Mission and Goals Identified for the Program
- Geographic Scope, Funding and Governance
- Building on Lessons of the Past

1.1 Introduction

On March 24, 1989, the *T/V Exxon Valdez* ran aground on Bligh Reef in Prince William Sound, spilling almost eleven million gallons of North Slope crude oil The event was the largest tanker spill in U S history, contaminating approximately 1,500 miles of Alaska's coastline, killing birds, mammals and fish, and disrupting the ecosystem in the path of the spreading oil In 1991, the Exxon Corporation agreed to pay the United States and the State of Alaska $900 million over ten years to restore, replace, enhance, or acquire the equivalent of natural resources injured by the spill, and the reduced or lost human services they provide (United States of America and State of Alaska 1991) Under the court-approved terms of the settlement, the *Exxon Valdez* Oil Spill Trustee Council (Trustee Council) was formed to administer the restoration funds, and in 1994 the *Exxon Valdez* Oil Spill Restoration Plan was adopted to guide the development and implementation of a comprehensive, interdisciplinary recovery and rehabilitation program

Thirteen years after the spill, total recovery has still not been achieved Current information regarding the recovery status of resources injured by the spill is available on the web at www oilspill state ak us or by contacting the Trustee Council Office There are still two main concerns about lingering effects of the spill The first is the potential effect of pockets of residual oil in the environment The second concern is the ability of a population to fully recover by overcoming changes in the population dynamics resulting from the initial oil-related mortalities and the interaction of these effects with other kinds of changes and disturbances in the marine ecosystem

The knowledge and experience gained during years of biological and physical studies in the aftermath of the *Exxon Valdez* oil spill confirmed that a solid historical context is essential to understand the sources of changes in valued natural resources Toward this end, in March 1999 the Trustee Council dedicated approximately $120 million for long-term monitoring and ecosystem-based research in the northern Gulf of Alaska This new program is called the GEM (Gulf of Alaska Ecosystem Monitoring and Research) Program Funding for the GEM Program comes from an endowment, with an annual program funded through investment earnings, after allowing for inflation-proofing and modest growth of the corpus

A program rooted in the science of a large-scale ecological disaster is uniquely suited to form the foundation for ecosystem-based management In making the decision to allocate these funds for a long-term program of monitoring and research, the Trustee Council explicitly recognized that complete recovery from the oil spill may not occur for decades, and that full restoration of these resources will most likely be achieved through long-term observation and, as needed, restoration actions The Trustee Council further recognized that conservation and improved management of these resources and services would require substantial ongoing investment to improve understanding of the marine and coastal ecosystems that support the resources, as well as the people, of the spill region Improving the quality of information available to resource managers should result in improved resource management In addition, prudent use of the natural resources of the spill area without compromising their health and recovery requires increased knowledge of critical ecological information about the northern Gulf of Alaska. This knowledge can only be provided through a long-term monitoring and research program that will span decades, if not centuries

Prudent use of the natural resources of the spill area requires increased knowledge of critical ecological information about the northern Gulf of Alaska

1.2 Mission

The original mission of the Trustee Council's Restoration Program, adopted in 1993, was to "efficiently restore the environment injured by the *Exxon Valdez* oil spill to a healthy, productive, world-renowned ecosystem, while taking into account the importance of the quality of life and the need for viable opportunities to establish and sustain a reasonable standard of living"

Consistent with this mission and with the ecosystem approach to restoration adopted by the Trustee Council in the 1994 *Exxon Valdez* Oil Spill Restoration Plan, the mission of the GEM Program is 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

In pursuit of this mission, the GEM Program will accomplish the following

- Sustain the necessary institutional infrastructure to provide scientific leadership in identifying research and monitoring gaps and priorities,
- Sponsor monitoring, research, and other projects that respond to these identified needs,

- Encourage efficiency in and integration of Gulf of Alaska monitoring and research activities through leveraging of funds and interagency coordination and partnerships, and
- Promote local stewardship by involving stakeholders and having them help plan, guide, and carry out parts of the GEM Program

In adopting this mission, the Trustee Council acknowledges that, at times, sustaining a healthy ecosystem and ensuring sustainable human uses of the marine resources may be in conflict In those instances, the goal of achieving a healthy ecosystem will be paramount The Trustee Council also acknowledges that, at this time, clearly defined measures for assessing "ecosystem health" are lacking (NRC 2000) These measures will be incorporated into the program as they are developed

1.3 Goals

Five major goals have been identified as necessary to accomplish the GEM mission Attaining all five, however, will require several decades Two of these goals may be attainable within the early decades of operating the GEM Program, given sufficient funding and collaboration with other partners

1 **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, and

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

Two other goals provide an essential piece of the foundation for a long-term program Although these goals are likely to be fully realized only after the first decade of operating the GEM Program, shorter-term accomplishments should be achieved sooner

3 **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

4 **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 fifth goal is inherently long-term and difficult to achieve, but of considerable potential value to resource users and managers It serves more as a long-range beacon to guide the design of monitoring activities, than as a goal to be attained within the near term

5 **Predict** Develop the capacity to predict the status and trends of natural resources for use by resource managers and consumers

During the process of learning how to detect and understand change in the northern Gulf of Alaska, resource managers and the concerned public should collect incremental dividends on their investment in GEM. Ultimately, however, the benefits will be maximized over the long run. To fully achieve its mission, GEM must provide information that enables resource-dependent people, such as subsistence users, recreationalists, and commercial fishers, to better understand and therefore hopefully cope with changes in marine resources. The data and information produced by GEM during its first decade may not totally solve problems for the public, commercial interests, resource managers, and policy makers faced with environmental change. Nonetheless, as information accumulates, the ability for GEM to provide problem-solving information and tools can and must increase.

Given the size and complexity of the northern Gulf of Alaska ecosystem and the available funding, it will not be possible to meet these goals with only the data collected by GEM. Addressing the program goals will require achieving the following implementation goals:

- **Lead** the way in integrating, synthesizing, and interpreting monitoring and research results to form and convey a "big picture" of the status of and trends in the Gulf of Alaska ecosystem,
- **Track** work of other entities relevant to understanding biological production in the Gulf of Alaska and **coordinate** GEM with those efforts,
- **Leverage** funds to augment ongoing monitoring work funded by other entities,
- **Involve** other government agencies, non-governmental organizations, stakeholders, policy makers, and the general public in a collaborative process to achieve the mission and goals of GEM,
- **Increase** community involvement and local and traditional knowledge in order to enhance long-term stewardship of living marine resources, and
- **Facilitate** application of GEM research and monitoring results to benefit conservation and management of marine resources.

The substantial experience of the *Exxon Valdez* Oil Spill Restoration Program indicates that these six implementation goals are reasonable, necessary, and attainable.

1.4 Geographic Scope

Consistent with the Restoration Plan, GEM Program activities will occur within the area affected by the 1989 oil spill, which is generally the northern Gulf of Alaska, including Prince William Sound, Cook Inlet, Kodiak Island, and the Alaska Peninsula (Figure 1.1). Recognizing that the marine ecosystems affected by the oil spill do not have discrete boundaries, some monitoring and research activities may extend into adjacent areas of the northern Gulf of Alaska.

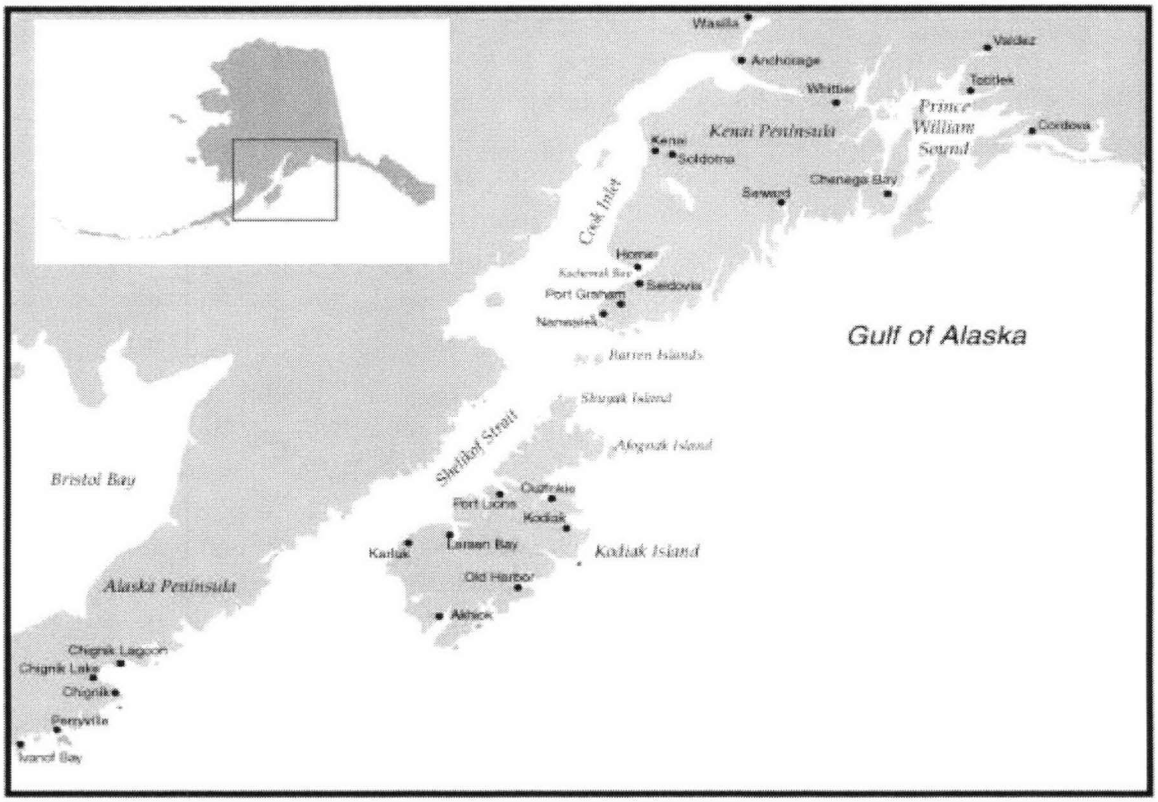

Figure 1.1 Map of the spill area showing the location of communities.

The primary geographic focus of GEM will be the four habitat types that contain the ecosystems of the northern Gulf of Alaska. These habitats are the watersheds, intertidal and subtidal, Alaska Coastal Current, and offshore (the continental shelf break and the Alaska Gyre).

Although GEM has a regional outlook, the waters of the Gulf of Alaska are connected to adjacent waters. Waters from the shelf and basin of the Gulf of Alaska eventually enter the Bering Sea and the Arctic Ocean through the Bering Strait. Waters from the west coast states (California, Oregon, and Washington), Canada and southern Alaska also feed into the northern Gulf of Alaska. Consequently, the program will be of vital importance in understanding the downstream Bering Sea and Arctic Ocean ecosystems, as well as the upstream southern Gulf of Alaska. In addition to the linkages provided by the movements of ocean waters, the Gulf of Alaska is linked to other regions by the many species of birds, fish, and mammals that move through these regions It is also becoming increasingly clear that environmental conditions in the Gulf of Alaska, such as levels of persistent organic pollutants, as well as the temperature of Gulf of Alaska waters, can originate many thousands of miles away

The Trustee Council is aware of the trade-offs between the size of the area to be studied and the frequency and intensity of the monitoring and research that can be conducted there In selecting core variables for long-term research and monitoring, the GEM Program will need to ensure that measurements are conducted at the spatial and temporal scales necessary to achieve the desired goals of the program For this reason, much thought must be given to the selection of the variables and the identification of the subset of the northern Gulf of Alaska that can reasonably be monitored by a program the size of GEM It is anticipated that partnering with other agencies and programs will help extend the GEM research area beyond that which GEM could fund on its own However, because of its critical importance to meeting the program's goals and objectives, core monitoring based on a set of core variables will be fully supported by the GEM Program

1.5 Funding and Governance

The Trustee Council will fund the GEM Program beginning in October 2002 with funds allocated for long-term monitoring and research, estimated to be approximately $120 million The Trustee Council will manage these funds as an endowment, with the annual program funded by investment earnings after inflation-proofing, thus providing for a stable program through time The Trustee Council may choose to fund a smaller program in the early years to allow the corpus of the fund to build The Trustee Council's long-term goal is to allow for additional deposits and donations to the fund from other sources to increase the corpus Achieving this goal might require changes in state or federal laws and possibly a change in the court-approved settlement and will be pursued at a later time

Under existing law and court orders, three state and three federal trustees have been designated by the Governor of Alaska and the President of the United States to administer the restoration fund, which includes funding for GEM, and to restore the resources and services injured by the oil spill The State of Alaska trustees are the Commissioner of the Alaska Department of Environmental Conservation, the Commissioner of the Alaska Department of Fish and Game, and the Attorney General The federal trustees are the Secretary of the Interior, the Secretary of Agriculture, and the Administrator of the National Oceanic and Atmospheric Administration, U S Department of Commerce

The trustees established the Trustee Council to administer the restoration fund The state trustees serve directly on the Trustee Council The federal trustees each have appointed a representative in Alaska to serve on the Trustee Council The representatives currently are the Senior Advisor to the Secretary for Alaskan

Affairs (Department of the Interior), the Alaska Director of the National Marine Fisheries Service (National Oceanic and Atmospheric Administration), and the Supervisor of the Chugach National Forest (U S Department of Agriculture) All decisions by the Trustee Council are required to be unanimous

It is expected that the current Trustee Council will make policy and funding decisions for the GEM Program It has been suggested that at some time in the future, a new board or oversight structure other than the Trustee Council be established to administer or guide the GEM fund It is also possible that an existing board, either under its current structure or with minor modifications, could take over management of the fund Use of a new governance structure, if justified, would require changes in law and the applicable court decrees Such changes would take considerable time and are not anticipated in the near future

1.6 Building on Lessons of the Past

The GEM Program is not the first attempt to look at large areas of Alaska's marine ecosystems from a broader perspective The *Exxon Valdez* Oil Spill Restoration Program, as well as a number of other programs, provides valuable guidance This section briefly describes some of these programs and their relevance to the development of GEM

1.6 1 Alaska Regional Marine Research Plan (1993)

The *Alaska Regional Marine Research Plan* (ARMRP) (1993) is a marine science planning document with a broad geographic scope that was prepared under the U S Regional Marine Research Act of 1991 ARMRP goals express the scientific needs of the Alaska region as of 1992 and are still relevant to the GEM effort

Goals of other major programs are relevant to the GEM effort

- Distinguish between natural and human-induced changes in marine ecosystems of the Alaska region,
- Distinguish between natural and human-induced changes in water quality of the Alaska region,
- Stimulate the development of a data gathering and sharing system that will serve scientists in the region from government, academia, and the private sector in dealing with water quality and ecosystem health issues, and
- Provide a forum for enhancing and maintaining broad discussion among the marine scientific community on the most direct and effective way to understand and address issues related to maintaining the health of the water quality and ecosystem health in the region

1 6 2 Bering Sea Ecosystem Research Plan (1998)

The Bering Sea has received considerable attention because of concern about long-term declines in populations of high-profile species such as king and tanner crab, Steller sea lions, spectacled eiders, Steller's eiders, common murres, thick-billed murres, and red-legged and black-legged kittiwakes (DOI et al 1998b) The GEM mission is consistent with the vision of the federal-state regulatory agencies for the *Bering Sea Ecosystem Research Plan* (DOI et al 1998a), which states "We envision a productive, ecologically diverse Bering Sea ecosystem that will provide long-term, sustained benefits to local communities and the nation " The basic concepts of the GEM Program are also consistent with the overarching hypotheses of the Bering Sea plan

1 6 3 GLOBEC (1991 to Present)

The Scientific Committee on Oceanic Research (SCOR) and the Intergovernmental Oceanographic Commission (IOC) established the Global Ocean Ecosystem Dynamics (GLOBEC) program in late 1991 GLOBEC is the core project of the International Geosphere-Biosphere Programme responsible for understanding how global change will affect abundance, diversity, and productivity of marine populations The program focuses on the regulatory control of zooplankton dynamics on the biomass of many fish and shellfish

The GLOBEC Science Plan (U S GLOBEC 1997) describes an approach that uses a combination of field observations and modeling to concentrate on the middle and upper trophic levels of the ecosystem The overarching concept is that marine and terrestrial ecosystems have close connections among energy flow, chemical cycling, and food web structure GEM monitoring activities will be consistent with GLOBEC concepts

1 6 4 Scientific Legacy of the *Exxon Valdez* Oil Spill (1989 to Present)

Ecological knowledge gained in the years following the 1989 *Exxon Valdez* oil spill forms a substantial portion of the foundation of the GEM Program In 1994 the *Exxon Valdez* Oil Spill Restoration Plan was adopted to guide the development and implementation of a comprehensive, interdisciplinary recovery and rehabilitation program The recovery status of each affected resource is based to the extent possible on knowledge of the resource's role in the ecosystem The scientific legacy of the *Exxon Valdez* Oil Spill Trustee Council (Trustee Council) creates the need to understand the causes of population trends in individual species of plants and animals through time and the need to distinguish human impacts from those of climate and interactions with related species

The studies supported by the Trustee Council since 1989 include more than 1,600 damage assessment studies costing more than $100 million, as well as hundreds of restoration studies costing approximately $170 million These studies have resulted in more than 500 peer-reviewed scientific publications, including numerous dissertations and theses In addition, hundreds of peer-reviewed project reports are available through the Alaska Resources Library and Information Services (ARLIS) and state and university library systems Many final reports are available in electronic format through the Trustee Council offices or ARLIS A current electronic bibliography of scientific publications sponsored by the Trustee Council is available on its web site (www oilspill state ak us) or on request to the Trustee Council (EVROTCB 2002) A list of Trustee Council projects, as well as a complete list of final and annual project reports, also is available on the web site or on request (EVROFAB 2002)

In addition to much specific information on the effects of oil on the plant and animal life in the spill area, the studies also provide a wealth of ecological information Most prominent among the Trustee Council's studies are three ecosystem-scale projects, known by their acronyms SEA, NVP, and APEX

The Sound Ecosystem Assessment (SEA) is the largest of the three studies Funded at $22 million for a seven-year period SEA brought together a team of scientists from many different disciplines to understand the biological and physical factors responsible for producing herring and salmon in Prince William Sound The data collected during SEA are expected to form the basis of numerical models capable of simulating the oceanographic processes that influence the survival and productivity of juvenile pink salmon and herring in Prince William Sound SEA has already provided new insights into the critical factors that influence fisheries production, including ocean currents, nutrient levels, mixing of water masses, salinity, and temperatures These observations have made it possible to model how physical factors influence production of plant and animal plankton, prey, and predators in the food web

The Nearshore Vertebrate Predator (NVP) project is a six-year, $6 5 million study of factors limiting recovery of two fish-eating species, river otters and pigeon guillemots, and two invertebrate-eating species that inhabit nearshore areas, harlequin ducks and sea otters The project looked at oil exposure, as well as natural factors such as food availability, as potential factors in the recovery of these indicator species, and has contributed to increased understanding of the linkages between terrestrial and marine ecosystems

The Alaska Predator Ecosystem Experiment (APEX) is an eight-year, $10 8 million study of ecological relations among seabirds and their prey species The APEX project explored the critical connection between productivities of marine bird populations and forage fish species, in an attempt to understand how wide-ranging ecological changes might be related to fluctuating seabird populations In addition, analyzing the food of marine birds shows promise in providing abundance estimates for key fish species, such as sand lance and herring

The following topics also have been covered by other Trustee Council-funded studies and the results are available in published scientific literature

- Physical and biological oceanography,
- Marine food web structure and dynamics,
- Predator-prey relationships among birds, fish, and mammals,

- The source and fate of carbon among species,
- Developmental changes in trophic level within species,
- Marine growth and survival of salmon,
- Intertidal community ecology, and
- Early life history and stock structure in herring

Many studies have focused on key individual species injured by the oil spill, including pink and sockeye salmon, cutthroat trout, Pacific herring, black oystercatchers, river otters, harbor seals, mussels, and kelp

One of the most extensive series of single-species investigations is the $14 million suite of pink salmon studies These include monitoring the toxic effect of oil, conducting genetic studies related to survival, and supplementing select populations Another extensive series of studies was done on Pacific herring Roughly $6 million has been spent on the restoration of Pacific herring in addition to the funding for the herring component of the Sound Ecosystem Assessment Since the crash of 1993, the population has yet to recruit a highly successful post-spill year-class Current investigative strategies are focused on the full range of causes of the crash, such as disease and ecological factors, including the effects of oceanographic processes on year-class strength and adult distribution and understanding stock structure

More than $6 million has been spent on the restoration of marine mammals, primarily harbor seals, a major source of subsistence food in the diet of Native Alaskans in the northern Gulf of Alaska. Harbor seal populations were declining before the spill, took a big hit at the time of the spill event, and have continued to decline ever since, although the rate of decline seems to have slowed Food availability is the major focus of current research, because disease and other factors have been ruled out as causes

1 6.5 Trustee Council Commitment to Traditional Knowledge and Community Involvement

From 1995 -2002, the Trustee Council provided almost $2 million to the Chugach Regional Resources Commission to facilitate the involvement of local communities in the oil spill restoration program and improve communication between spill area residents, community councils, regional organizations, scientists and the tribal community The facilitators and coordinators have been active participants in all the GEM planning workshops and meetings This project has also funded the development of natural resource management plans in several villages, which tribal representatives believe are a necessary step before incorporating tribal concerns into the GEM Program

This long-term project (1995-2002) was designed to

- Increase meaningful **involvement** of spill area communities in the Trustee Council restoration efforts/process,
- Provide **information** to communities regarding data and scientific research performed by the Trustee Council science program,
- Improve **communication** of findings and results of restoration efforts to spill area residents, village councils, and the appropriate regional organizations,
- Promote the **inclusion of community-based projects**, as well as community involvement in science projects throughout the life of the restoration effort,
- Work with the **formation of local natural resource management programs** that will focus on the stewardship and management of injured resources and lands, and
- Develop a means to compile and utilize **western science and traditional wisdom** in a cooperative manner to further the restoration process in ways that are sensitive to the needs of the communities

The Chugach Regional Resources Commission coordinated this project by employing community facilitators in ten communities, and a spill area-wide community involvement coordinator who facilitated communication between the communities, the Trustee Council, and scientists

Also since 1995, the Trustee Council has funded Youth Area Watch programs through the Chugach School District and Kodiak Island Borough School District These programs involve youth from local spill area communities in the science behind the restoration effort As of 2002, 168 students have participated in the Prince William Sound and Kodiak programs with students participating in such projects as harbor seal biosampling, seabird monitoring, collection oceanographic data on cruises, and analyzing chemicals found in intertidal mussels

In 1994 the Trustee Council received its first call from a community resident to incorporate Traditional Ecological Knowledge of spill area residents into the restoration program Two years later, the Trustee Council's 1996 annual restoration workshop had Traditional Ecological Knowledge as its theme, and led to a set of protocols for incorporating Traditional Ecological Knowledge into restoration projects developed by a committee of Alaska Natives and others and approved later that year by the Trustee Council The Trustee Council has provided funds each year since 1995 toward the goal of incorporating Traditional Ecological Knowledge into the restoration program Efforts have included

- Developing a Traditional Ecological Knowledge handbook and reference guide for biologists documenting the sources of Traditional Ecological Knowledge in the spill area and incorporating it into a western science approach

- Providing funds for Chugach Regional Resource Commission to contract with Traditional Ecological Knowledge expert Henry Huntington for seven years. He has worked directly with Alaska Native elders and hunters as well as scientists to bridge the gap between these two different approaches to understanding the natural world. A result of this process is that several *Exxon Valdez* oil spill projects incorporate Traditional Ecological Knowledge directly into their data sets and results, including projects on community natural resource management, fish and seabird studies, and a series of films about Alutiiq culture (see examples below).

- Conducting two workshops to develop tribal management programs and bringing several scientists to spill area communities to share information.

Examples of projects incorporating Traditional Ecological Knowledge as a result of Trustee Council efforts include:

- Scientist Jody Seitz conducted an extensive project involving Traditional Ecological Knowledge. Researchers interviewed thirty-nine spill area community members to document the historical distribution of forage fish such as juvenile herring, sand lance, capelin, and eulachon. This information was mapped and provided to the Alaska Predator Ecosystem Experiment and Sound Ecosystem Assessment researchers. The results were extremely valuable because they could not have been obtained from other historical sources or from current data collection efforts.

- Scientist Dan Rosenberg solicited local participation from communities and conveyed results of his research on surf scoters, an important subsistence resource. The project idea came from local communities. Rosenberg worked with community members throughout all stages of the project, from project design to writing the final report.

- The Trustee Council provided funding support to the Alaska Native Harbor Seal Commission, which uses Alaska Native hunters to conduct biosampling of harbor seal tissues using lab-approved techniques. In 1999, the commission reached an agreement with the National Marine Fisheries Service to co-manage harbor seal populations.

- Three videos have been produced with Trustee Council funds to provide the public information about Traditional Ecological Knowledge and concerns about subsistence use after the oil spill. The first two, *Alutiiq Pride: A Story of Subsistence* and *Changing Tides in Tatitlek* describe subsistence methods, interview Alaska Native people who experienced the spill first hand, show actual subsistence hunts, and illustrate the importance of subsistence in Alutiiq culture. The third documents the communities of Chenega Bay and Ouzinkie in relation to the effects of the oil spill, residual oil in the spill region, and concerns about paralytic shellfish poisoning toxins, natural toxins found in clams harvested for food. These videos were distributed at no charge to all schools in Alaska via their school districts, all spill area tribal councils, and any other library or school in the U S upon request

The Trustee Council funded Elders/Youth Conferences in 1995 and 1998 that brought together Alaska Native elders, youth, other subsistence users, scientists, and managers to share ideas about subsistence issues and facilitate community involvement The Trustee Council paid for four people from each of twenty spill area communities to attend each conference Participants shared stories, voiced frustration, and asked scientists questions about subsistence issues They also developed ideas for youth to get more involved through spirit camps, internships, and educational opportunities These workshops facilitated collaboration between communities of the spill area, while concerns and ideas generated at the conference were reported to the Trustee Council

1.7 References

ARMRB 1993 Alaska Regional Marine Research Board, Alaska research plan School of Fisheries and Ocean Sciences, University of Alaska Fairbanks

DOI, NOAA, and ADF&G 1998a (U S Department of the Interior, National Oceanic and Atmospheric Administration, and Alaska Department of Fish and Game) Draft Bering Sea ecosystem research plan Alaska Department of Fish and Game, Commercial Fisheries Division Juneau

DOI, NOAA, and ADF&G 1998b (U S Department of the Interior, National Oceanic and Atmospheric Administration, and Alaska Department of Fish and Game) Bering Sea ecosystem - a call to action Alaska Department of Fish and Game, Commercial Fisheries Division Juneau

EVROFAB 2002 *Exxon Valdez* Oil Spill Restoration Office bibliography of final and annual reports Anchorage, Alaska, *Exxon Valdez* Oil Spill Trustee Council

EVROTCB 2002 *Exxon Valdez* Oil Spill Restoration Office bibliography of published oil spill investigations Anchorage, Alaska, *Exxon Valdez* Oil Spill Trustee Council

NRC 2000 (National Research Council) Ecological indicators for the nation National Academy Press Washington, D C

U S GLOBEC 1997 Global Ocean Ecosystems Dynamics (GLOBEC) science plan IGBP (International Geosphere-Biosphere Programme) Secretariat, The Royal Swedish Academy of Sciences Stockholm, Sweden

United States of America and State of Alaska 1991 Memorandum of agreement and consent decree, A91-081 CIV

2. CONCEPTUAL FOUNDATION AND CENTRAL HYPOTHESIS

In This Chapter

- Conceptual Foundation
- Central Hypothesis
- Habitat Types and Time-Space Scales
- Central Hypothesis by Habitat Type

2.1 Introduction to the GEM Conceptual Foundation

The intellectual framework of the GEM Program is a hierarchy composed of a conceptual foundation, central hypothesis, habitat-specific hypotheses, research questions, and ultimately, testable hypotheses based on the specific questions (Figure 2.1). Four habitat-specific hypotheses, based on the central hypothesis, form the core of the GEM monitoring plan. The conceptual foundation provides an overarching explanation, or verbal model, of how the Gulf of Alaska ecosystems produce biological resources. As such, the conceptual foundation is not itself a testable hypothesis on the sources of change in ecosystems, but rather, the origin of hypotheses, both general and testable. Habitat-specific hypotheses are based on assumptions about how natural and anthropogenic factors influence ecosystem functioning within each of the habitat types, recognizing that different factors may be important in different habitats. This chapter presents the narrative of the GEM conceptual foundation for the Gulf of Alaska, addresses cross-habitat connections and regional variability, and adapts the narrative of the conceptual foundation to describe the four habitat types used by GEM.

2.1.1 The Gulf of Alaska at a Glance

The conceptual foundation for the Gulf of Alaska ecosystem explains how its plant and animal populations are controlled through time. A broad, interdisciplinary conceptual foundation serves as a flexible framework for determining the type of monitoring and research activities that will be undertaken in implementing the GEM Program. The conceptual foundation is the product of syntheses of the latest scientific information and an assessment of

The conceptual foundation focuses on how the marine ecosystem in the Gulf of Alaska works leading ecological hypotheses. It encapsulates the Trustee Council's understanding of how the Gulf of Alaska operates as an ecological system and how its biological resources, including highly valued populations of animals, are regulated.

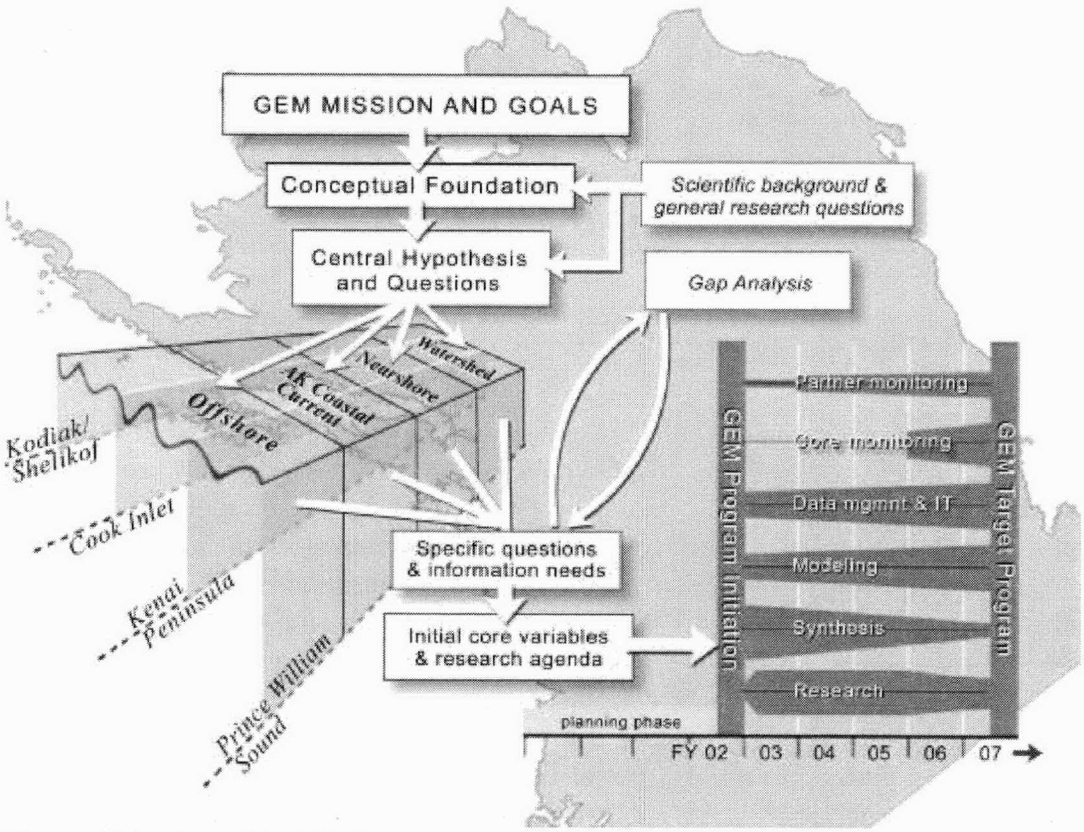

Figure 2.1 Overview of the GEM Program structure showing the relation of key concepts to the habitat types, implementation tools, and the schedule of implementation.

Specific citations to the scientific literature are omitted for the sake of brevity, however these may be found in the scientific synthesis of Chapter 7 in the complete GEM document available on the Trustee Council's web site at www.oilspill.state.ak.us. Taking the watersheds and marine areas of the Gulf of Alaska together at a single glance, the importance of key geological features in shaping the natural physical and biological forces that control productivity is apparent (Figure 2.2). Note that features illustrated in Figure 2.2 are printed in bold in the following text. Natural forces are shaped by the surface topography of the Gulf. Storm tracks moving across the North Pacific from west to east can drive **Aleutian Low Pressure Systems (Aleutian Low)** deep into the Gulf of Alaska until the encounter with **boundary mountains** causes the release of **precipitation** and **airborne contaminants**. **Freshwater runoff** strengthens the **Alaska Coastal Current** even as it brings airborne and terrestrial pollutants into the **watersheds** and **food webs**.

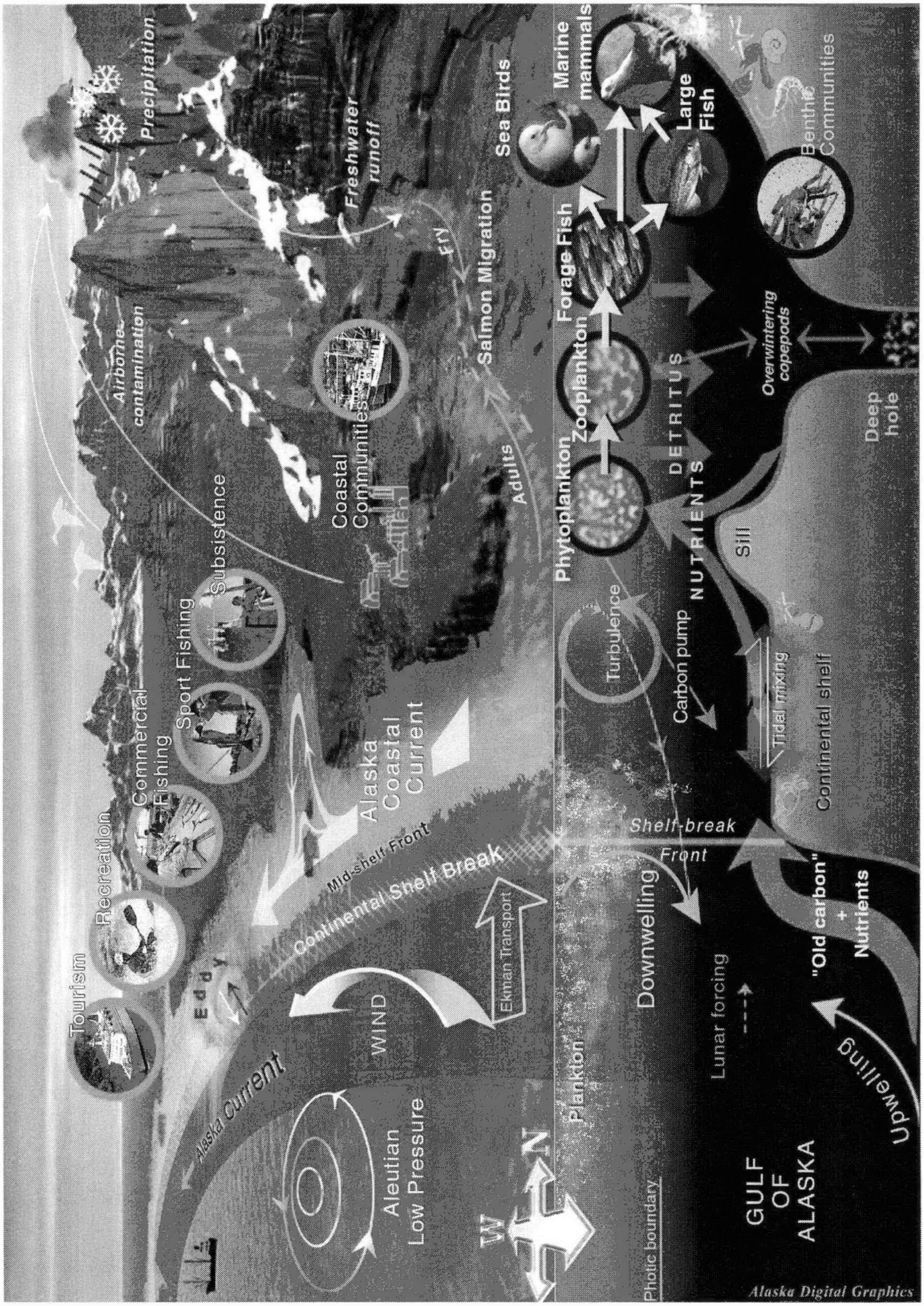

Figure 2.2 The phys ical and biological elements of the ecosystems of the northern Gulf of Alaska from the mountains surrounding the watersheds to the oceanic waters offshore.

Natural forces that control biological productivity are also shaped by the submarine topography (bathymetry) of the **continental shelf** Deep waters **upwell** across the **continental shelf break**, subsequently being carried across the **photic boundary** into areas of photosynthetic activity by the motion of surface currents, (**Alaska Coastal Current, Alaska Current**), **lunar forcing**, the motion of the earth, and **tidal mixing** These deep waters carry **old carbon and nutrients** up into the food webs of the shelf and onshore areas Where the deep waters encounter islands, seamounts and **sills**, the resulting currents may deform the boundaries of the frontal zones of the Alaska Coastal Current (**mid-shelf front**) and Alaska Current (**shelf-break front**), creating **eddies** that entrain plankton and other plants and animals for long periods of time

Natural physical forces control productivity by limiting the amount of food and availability of habitats During the winter especially, the **Aleutian Low** produces **wind**-driven transport of surface marine waters (**Ekman transport**), bringing water onshore Movement of water onshore creates **downwelling** that takes plankton and associated nutrients out of the photic zone On the other hand, the wind may act to hold the nutrients dissolved in water and held in **detritus** in the photic zone in some areas, because wind also produces **turbulence** that mixes the surface water Turbulent mixing causes nutrients to be retained in surface waters, and retention increases production of **phytoplankton**, the base of the food web in surface waters Production of **zooplankton**, secondary productivity, is the trophic connection (linkage) of phytoplankton to production of **forage fish**, which in turn links primary productivity to **seabirds, large fish, marine mammals**, and **benthic and intertidal communities**

The biogeochemical cycle is an important collection of natural biological and physical processes controlling the productivities of both marine and terrestrial environments The mechanisms that move carbon from the surface to the deep waters, are known collectively as the **carbon pump** Atmospheric carbon moves into seawater as carbon dioxide to be incorporated by phytoplankton during photosynthesis Carbon also enters the sea as carbonates leached from the land by freshwater runoff, as plant debris, and as other biological input, such as immigrations of salmon (**salmon fry**) and other anadromous species Carbon moves to benthic communities and to deep water as detritus and emigrant animals (**overwintering copepods** and migrating fish such as myctophids) Emigrant animals (**adult salmon** and other anadromous species) also move marine carbon (and phosphorous and nitrogen) into the watersheds

As illustrated by the interactions of biological and physical components of the biogeochemical cycle, natural biological forces modify the effects of natural physical forces on birds, fish, and mammals Because of biological-physical interactions, natural physical forces that cause changes in **primary productivity** do not necessarily cause proportional changes in populations of birds, fish, mammals, and benthic animals For example, the effects of physical forces on the amount of food available from primary productivity are modified through other natural forces, such as **predation and competition** among individuals, collectively known as the **trophic linkages** Populations that respond strongly to physical forcing of primary productivity on approximately the same time scales are termed "strongly coupled," and those that exhibit variable responses are termed "weakly coupled" with respect to those physical variables Note that physical forcing changes not only the food available from primary productivity, but also the extent of habitats available for reproduction and feeding

Human actions also serve to change the ways in which populations of plants and animals respond to the natural physical forces that affect the responses of reproduction, growth, and survival through limiting food and habitat Human actions such as water withdrawals, sewage discharge, and development of **coastal communities** change productivity by altering habitat availability and trophic linkages The economy of Alaska depends heavily on extraction of natural resources (primarily oil, fish, and shellfish followed by timber and minerals) Fishing and other extractive uses (**subsistence, sport, commercial**) affect death rates through removals Other forms of human action are more subtle, but no less effective, controls on productivity In the Northern Gulf of Alaska, recreation and tourism, oil and gas development, logging, road building and urbanization, marine transportation and subsistence harvests are all activities that have the potential to affect fish and wildlife populations and habitat **Recreation and tourism** may alter growth and reproduction by disturbing rookeries and introducing pollutants **Commercial marine transport** may alter productivity by introducing pollutants (oil spills) and noxious exotic species as competitors and predators Currently, the human impact on Alaska's marine ecosystems is relatively small compared to impacts in most of the developed world Even here, however, natural resource managers have concerns about localized pollution, the potential impacts of some fisheries, extreme changes in some fish and wildlife populations, and the little known impacts of contaminants and global warming

In summary, Figure 2 2 shows that the Gulf of Alaska and its watersheds are part of a larger oceanic ecosystem in which natural physical forces such as currents, upwelling, downwelling, precipitation and runoff, acting over large and small distances, play important roles in determining basic biological productivity Natural physical forces respond primarily to seasonal shifts in the weather, and in particular to long-term changes in the intensity and location of the Aleutian Low in winter Increased upwelling offshore appears to increase inputs of nutrients to surface waters, which increases productivity of plankton Increased winds appear to increase the transport of zooplankton shoreward toward and past the shelf-break How often and how much offshore zooplankton sources contribute to coastal food webs depends on natural physical and biological forces such as predation, migration, currents and structure of the fronts, formation and stability of eddies, degree and extent of turbulence, and responses of plankton to short and long-term changes in temperature and salinity

A wide range of human impacts interacts with natural biological and physical forces to change productivity and community structure in the Gulf of Alaska. Approximately 71,000 full-time residents live within the area directly affected by the oil spill and two to three times that number use the area seasonally for work and recreation. The spill area population, combined with that of the nearby population centers of Anchorage and Wasilla, totals more than 60 percent of the state's 627,000 permanent residents. When the resident population is combined with the more than one million tourists who visit the state each year, it becomes clear that the natural resources of the Gulf of Alaska cannot be immune to the pressures associated with human uses and activities. Human activities have the most direct and obvious impacts at those sites in watersheds and intertidal areas where human populations are high. Nonetheless, some human activities affect populations of birds, fish, shellfish, and mammals far offshore, and also have impacts far from the sites of the actions. In short, human activities and natural forces together act over global to local scales to drive and shape marine and terrestrial life in the Gulf of Alaska and its tributary watersheds.

Because of the tremendous uncertainty about sources of long-term changes, the conceptual foundation does not provide a specific model (testable hypothesis) for ecosystem change. Rather, the GEM conceptual foundation is designed to be broad enough to serve as a tool to organize thinking and research over long time periods, to encompass ecosystem interconnections, and to link information from traditional knowledge and scientific disciplines. It takes into account both oceanic and terrestrial ecosystems and addresses the influence of climate and human activity in influencing biological productivity within these interconnected systems. By using this broad, scientifically grounded conceptual foundation, the GEM Program will be able to adapt to changes in understanding ecosystem processes without having to sacrifice long-term research and monitoring goals (NRC 2002).

The GEM Program will, however, need to develop specific testable hypotheses, as derived from a general, or central hypothesis, in order to implement the monitoring and research program. As a start on a central hypothesis, consider the one provided by the National Research Council (NRC 2002, p. 27), as follows,

> ***The Gulf of Alaska, its surrounding watersheds, and human populations are an interconnected set of ecosystems that must be studied and monitored as an integrated whole. Within this interconnected set, at time scales of years to decades, climate and human impacts are the two most important driving forces in determining primary production and its transfer to upper trophic-level organisms of concern to humans.***

The National Research Council summary identifies climate and human impacts as the two most important determinants of biological production, among the many forcing factors recognized as significant in the conceptual foundation. Nonetheless, the biological communities that support the birds, fish and mammals are subject to a variety of biological and physical agents and factors of change, any one of which can at times play an important, and even dominant, role in controlling populations of birds, fish, shellfish and mammals A formal statement of the central hypothesis that starts with and considers the full suite of forcing factors is needed to allow research and monitoring to identify the most important forcing factors for species and habitats of the GEM region

2.2 The Central Hypothesis and Habitat Types

Identifying the forcing factors, human and natural, that drive biological production requires framing hypotheses and questions that point the way for a scientific monitoring and research program The central hypothesis formally states widely held beliefs about what drives changes in living marine-related resources in time and space

> ***Natural forces and human activities working over global to local scales bring about short term and long lasting changes in the biological communities that support birds, fish, shellfish and mammals Natural forces and human activities bring about change by altering relationships among defining characteristics of habitats and ecosystems such as heat and salt distribution, insolation, biological energy flow, freshwater flow, biogeochemical cycles, food web structure, fishery impacts, and pollutant levels***

Although widely accepted as fact, the specific mechanisms that cause change are largely untested in the GEM region, and the relative importance of the forcing factors is unknown Current speculations, supported by limited observations, are that forcing by winds, precipitation, predation, currents, natural competitors for food and habitat, fisheries, and pollutants change living marine-related resources over different scales of time and space through alteration of critical properties of habitats and ecosystems (Figures 2 3 and 2 4)

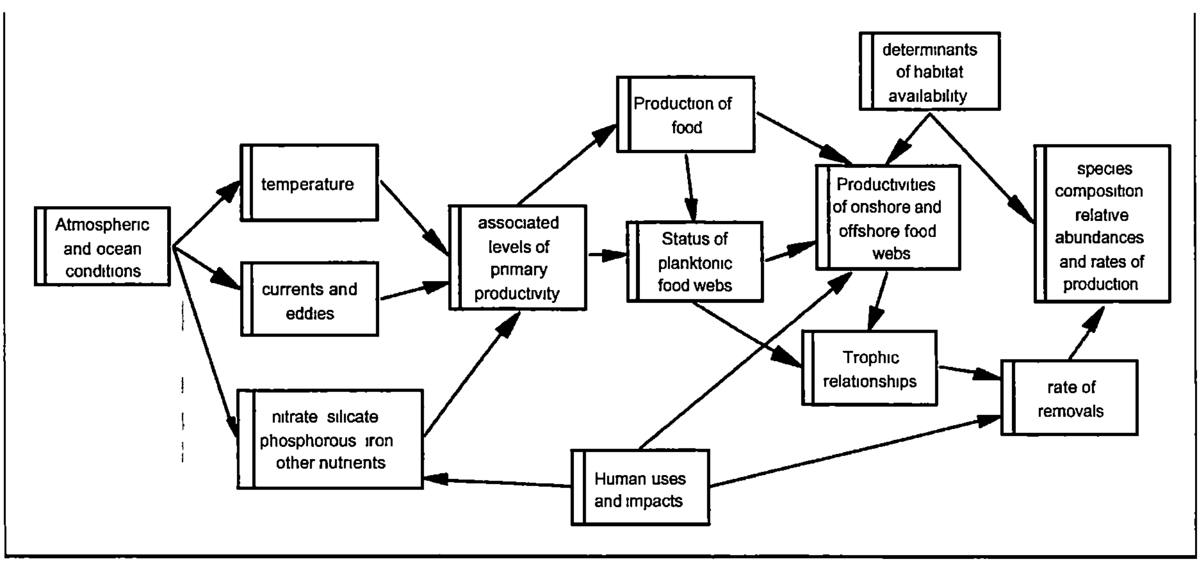

Figure 2 3 Possible connections among specific mechanisms and agents of change in living marine-related resources

Although the central hypothesis may appear to be a bland statement of the obvious, it is an essential first step in applying the scientific method to address the many open, and sometimes highly contentious, scientific questions about whether, and to what extent, human activities are responsible for degradation of habitats and declines in populations of animals The central hypothesis states what is thought to be known in general, preparing the way for questions that test the validity of this knowledge For example it is reasonable to ask of the central hypothesis, "What are the natural forces and are they equally important in all types of habitat?" Critically examining the starting point through posing and answering questions, is intended to point out the need for more specific hypotheses, which in turn lead to more specific questions, and so forth

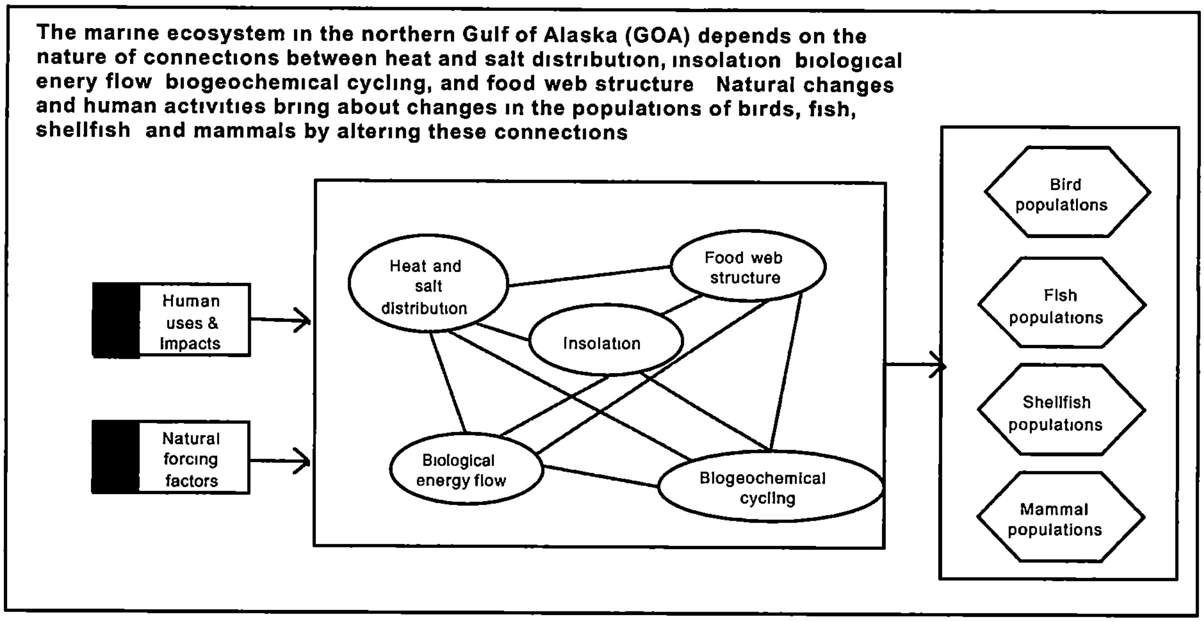

Figure 2 4 Relations among major parts of the GEM conceptual foundation

The central hypothesis is given more specificity through adaptation to habitat types in the following section Before adding specificity to the central hypothesis, the habitat types need definition, and the context of conducting studies at time-space scales appropriate to the phenomenon needs to be provided

To better organize the GEM Program, four habitat types, representative of the GEM region, have been identified as themes around which the interdisciplinary monitoring and research activities that address GEM's central hypothesis will be organized These habitat types are watersheds, the intertidal and subtidal areas, the Alaska Coastal Current, and the offshore areas (the continental shelf break and the Alaska Gyre) These habitats were selected after evaluating information about how natural forces and human activities control biological productivity in the northern Gulf of Alaska The habitats are composed of identifiable, although not rigid, collections of characteristic microhabitats, resident and migratory species, and physical features. The physical locations are described below:

- Watersheds—freshwater and terrestrial habitats from the mountains to the extent of a river's plume.
- Intertidal and subtidal areas—brackish and salt-water coastal habitats that extend offshore to the 20-m depth contour.
- Alaska Coastal Current—a swift coastal current of lower salinities (25 to 31 psu) typically found within 35 km of the shore.
- Offshore—the continental shelf break (between the 200-m and 1,000-m depth contours) and the Alaska Gyre in waters outside the 1,000-m depth contour.

The decision to use habitats as a mechanism for stratifying funding and allocating resources will require the GEM Program to ensure that cross-habitat processes and transfers are not forgotten or ignored. Having an appreciation for the scales of time and space over which the processes responsible for biological production occur is essential for designing monitoring and research intended to detect and understand changes in the ecosystem (Figure 2.5). To understand the composition and extent of ecosystems, it is necessary to ask and answer questions about the distances and time associated with the variation in the biological and physical phenomena. As stated eloquently by Ricklefs (1990, p. 169), "Every phenomenon, regardless of its scale in space and time, includes finer scale

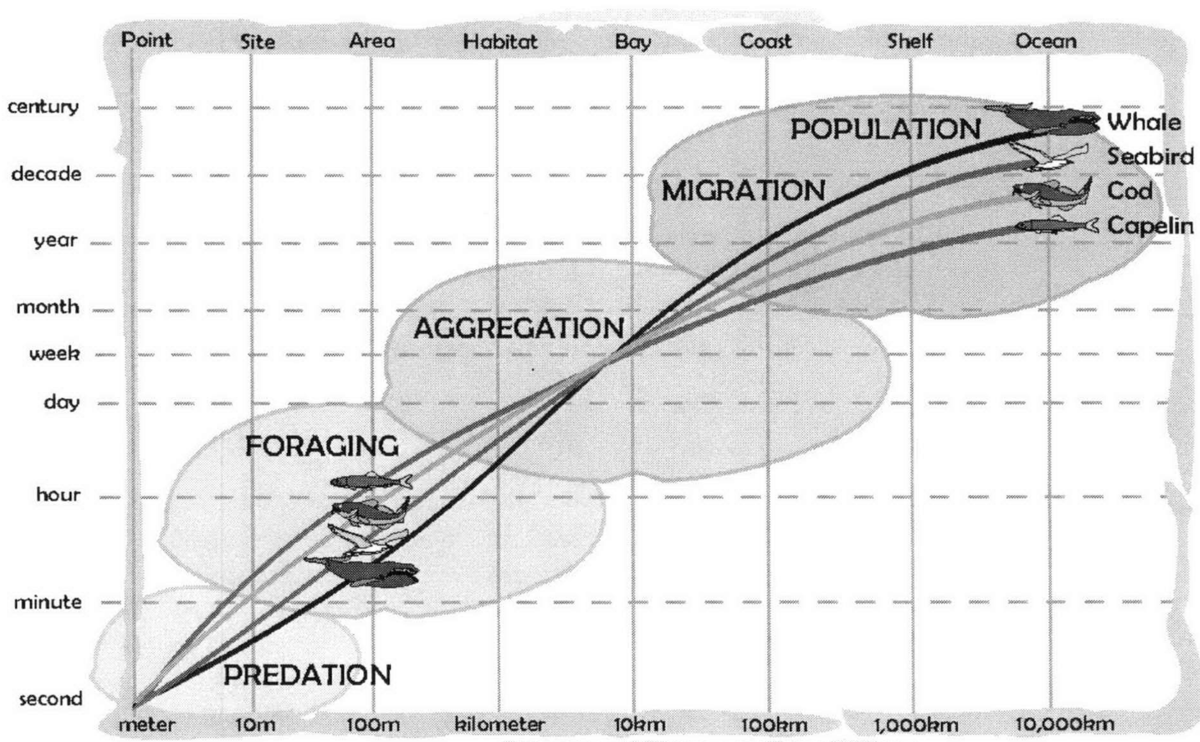

Figure 2.5 Scales of time and space corresponding to key elements and processes in ecosystems of the Gulf of Alaska. *Illustration provided by John Piatt.*

processes and patterns and is embedded in a matrix of processes and patterns having larger dimensions" Indeed, spatial and temporal scales are part of the definitions of physical and biological processes such as advection and growth Taking account of spatial and temporal scales is critical to studying linkages between natural forces and biological responses (Francis et al 1998)

Cross-habitat linkages and processes will be incorporated into the GEM Program in several ways that will be described in more detail in later chapters The primary mechanisms for ensuring they are addressed will be through ongoing synthesis of research results and oversight by the Scientific and Technical Advisory Committee It is also expected that modeling efforts will be regional in focus rather than habitat specific

2 2 1 Central Hypothesis by Habitat Type

The central hypothesis is adapted to each habitat type

Watersheds

Natural forces (such as climate) and human activities (such as habitat degradation and fishing) serve as distant and local factors in causing short-term and long-lasting changes in marine-related biological production in watersheds

Intertidal and Subtidal

Natural forces (such as currents and predation) and human activities (such as increased urbanization and localized pollution) serve as distant and local factors, in causing short-term and long-lasting changes in community structure and dynamics of the intertidal and subtidal habitats

Alaska Coastal Current

Natural forces (such as variability in the strength, structure and dynamics of the Alaska Coastal Current) and human activities (such as fishing and pollution) cause local and distant changes in production of phytoplankton, zooplankton, birds, fish, and mammals

Offshore

Natural forces (such as changes in the strength of the Alaska Current and Alaskan Stream, mixed layer depth of the gyre, wind stress and downwelling) and human activities (such as pollution) play significant roles in determining production of carbon and its shoreward transport

As noted above, these hypotheses can be used as a general guide to monitoring and research, but they need to be further refined into questions which identify a core set of measurements for implementation of long-term monitoring and research Further refinement of the hypotheses will be undertaken during development of the GEM Science Plan (Chapter 4) Basic definitions of the tools for implementing the program, as provided in Chapter 3, are needed before launching into the details of implementation found in Chapter 4

Before moving on to the definition of implementation tools, it should be noted that information for developing these specific questions into a monitoring and research program comes from many sources, including analysis of ongoing and existing research results, evaluation of agency monitoring programs and activities, and input from a variety of interest groups including scientists, resource managers and the communities Over the long-term one of the most valuable resources for identifying research questions may be the legacy of scientific information and results from community involvement projects from the *Exxon Valdez* Oil Spill Restoration Program The following chapter describes the process by which gap analysis, synthesis, and research are used to implement the GEM Program and guide selection of variables for long-term monitoring Chapter 4 introduces potential research questions that may be used to begin development of the GEM Science Plan

2.3 References

Francis, R C , S R Hare, A B Hollowed, and W S Wooster 1998 Effects of interdecadal climate variability on the oceanic ecosystems of the northeast Pacific Fisheries Oceanography 7 1-21

NRC 2002 (National Research Council) A century of ecosystem science planning long-term research in the Gulf of Alaska Washington, D C , National Academy Press

Ricklefs, R E 1990 Scaling patterns and process in marine ecosystems Pages 169-178 in Sherman, K , L M Alexander, and B D Gold, editors Large marine ecosystems patterns, processes and yields American Association for the Advancement of Science, Washington, D C

3. TOOLS AND STRATEGIES

In This Chapter

- Tools: Gap Analysis, Synthesis, Research, Monitoring, Modeling and Data Management
- Strategies: Community Involvement and Traditional Knowledge, and Resource Management Applicability

3.1 Introduction

The hypotheses presented in Chapter 2 are refined into a series of initial research questions through the use of gap analysis, synthesis and research, as supported by modeling and data management. These tools also will be used to continually refine and implement GEM's long-term core monitoring program. To further develop the program, the Trustee Council will use two major strategies: incorporation of community involvement and traditional knowledge, and potential for resource management applicability (Figure 3.1).

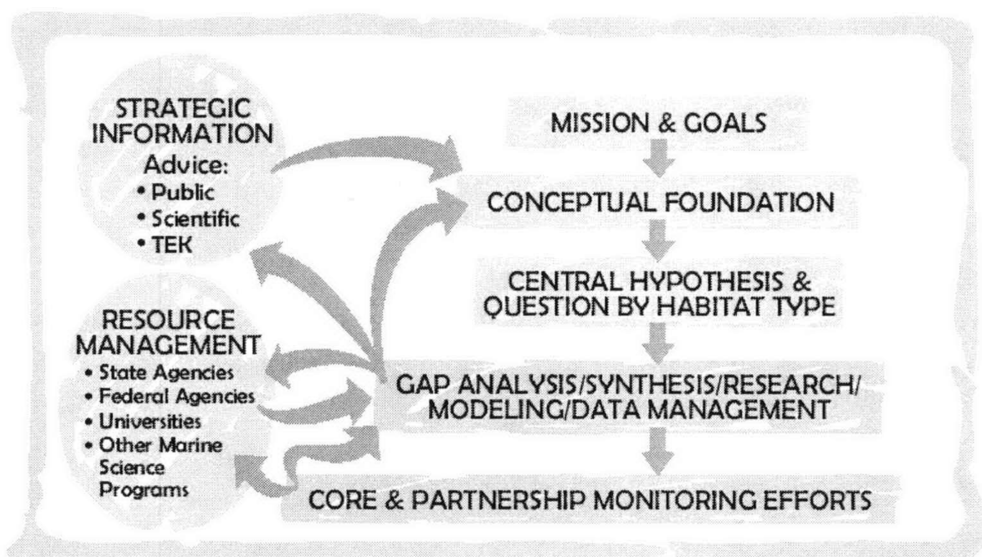

Figure 3.1 GEM Structure

This chapter defines and discusses these tools and strategies and explains how each will be used to implement the GEM Program.

3.2 Program Tools

Research questions emerge from a consideration of the central hypothesis and the hypotheses for each habitat presented in the previous chapter Potential research questions and the information necessary to answer them will be developed through the science planning process (Chapter 4) The recommendations on the information needed to develop the Science Plan were produced through a process of "gap analysis," as defined in the following section From the starting point of preliminary questions and the information needed to answer them, the GEM Program is intended to follow a path of synthesis, research, and monitoring to detect, understand, and, eventually, predict changes in living marine-related resources of the northern Gulf of Alaska Modeling and data management are critical elements in evaluating and managing the GEM long-term research program, and will closely support synthesis and research activities

3 2 1 Gap Analysis

In the process of starting the GEM Program, key hypotheses about how the Gulf of Alaska ecosystem functions will be evaluated and refined into a set of potential questions for each of the primary habitat types in the Gulf of Alaska (Chapter 4) The major information gathering programs in the North Pacific were reviewed to identify where they are collecting data that could be used to answer the questions, and where there are gaps in the information that would need to be filled by future research This ongoing identification of information needs, or gap analysis, is an important part of the process of identifying the starting points for monitoring and research, for avoiding duplicating the efforts of others, and for continuing to refine the program as it progresses This analysis will continue during implementation of the GEM Program, with initial general questions being replaced by increasingly specific questions as knowledge about the ecosystem increases

It is important to have a clear understanding of how the nature of the question determines the nature and outcome of the gap analysis The gap analysis has four essential parts a question, identification of information necessary to answer the question, a survey of relevant available information, and identification of gaps in the available information

The first part, the question, is fundamental to the gap analysis and defines the survey of all relevant information needed to answer it A general question calls for a general gap analysis, and a more detailed question calls for a more detailed gap analysis The gap analysis seeks to identify what information is currently being collected that could help answer the question and what information, for which no data are being collected currently, is needed to answer the question The data gaps become the priorities for focusing research and monitoring activities

A continuing gap analysis, supported by a regularly updated database of current and historical information-gathering projects in the Gulf of Alaska and adjacent areas, is essential to implementing the GEM Program This analysis will be performed by the staff and researchers and will be key to finding new partners for monitoring activities, identifying new opportunities for research and synthesis, and providing increased opportunities for collaboration, without risking duplication of effort or the possibility of failing to obtain needed data. In the short term, this database will provide information needed to select core monitoring variables and locations. In the longer term, the supporting database will become a valuable tool for resource managers, policy makers, other scientists, stakeholders, and the general public. As the GEM Program moves from the general hypotheses about what controls and connects biological production within and between habitats, and toward specific questions and testable hypotheses, the gap analysis will become highly specific.

3.2.2 Synthesis

A second starting point for developing the GEM Program is synthesis, because all good science ultimately involves synthesis. In the words of biologist E. O. Wilson (1998):

> *We are drowning in information while starving for wisdom. The world henceforth will be run by synthesizers, people able to put together the right information, think critically about it, and make important choices wisely.*

Synthesis builds on and updates the current understanding of the northern Gulf of Alaska. It brings together existing data from any number of disciplines, times, and regions to evaluate different aspects of the GEM Program's conceptual foundation, central hypotheses, and related ideas. Synthesis has three broad uses. First, it is used to provide direction for developing hypotheses to be tested and, combined with research and monitoring, to update and refine the program structure and implementation plan. In this respect, synthesis is an ongoing evaluative process throughout the life of the GEM Program that will help to ensure that the program is meeting its goals and objectives. Second, synthesis is used as a tool to inform stakeholders and the public about the developing understanding of the factors responsible for change in the marine environment. Some of the most important synthesizers of GEM monitoring and research will be the public. Synthesis will be useful in workshops, meetings, publications, and other methods for communicating information to the public. And third, synthesis is used to help solve resource management problems, by identifying new applications of existing information or by identifying opportunities to solve existing problems by collecting new information. Synthesis is a logical place to begin the cycle of monitoring and research, but once used to initiate a project or component, it becomes a companion to monitoring and research and an ongoing part of the overall program.

For the purposes of the GEM Program, synthesis is distinguished from research and from retrospective analysis, a form of research. Unlike research, synthesis does not necessarily start from a specific hypothesis or question. Instead, synthesis takes an interdisciplinary approach to evaluating existing information or data to identify potential new applications and uses. As such, synthesis is a critical component in ensuring that cross-disciplinary and cross-habitat linkages and processes are adequately considered during research and monitoring. Synthesis may be supported by various forms of retrospective analysis (discussed below).

3.2.3 Research

Research is defined under GEM as collecting relatively short time series of new observations to evaluate a testable hypothesis relating to the conceptual foundation or a specific aspect of the monitoring program. In the early stages of GEM Program implementation, research will be critical in helping to identify the core variables around which the long-term monitoring activities will be developed. For example, when synthesis, modeling, or other analysis indicates the need for measuring a core variable, research may be necessary to understand how to gather the data in a specific locality and/or to determine and evaluate the appropriate measurement technology. Research may build on or use existing data and may also build models. Testing current understandings through research provides the basis for making changes to the monitoring program.

Retrospective analysis is treated in the GEM Program as a specialized form of research, sometimes used as an integral component of synthesis, that employs existing time series data to evaluate a testable hypothesis or other questions of similar specificity relating to monitoring, often supported by statistical modeling. Retrospective analysis contributes to building numerical models and to synthesis.

Research, in the form of *process studies*, plays a vital role in moving beyond the correlative relationships that arise from the monitoring efforts to understand the underlying mechanisms controlling biological production both within and across habitat types. Process studies develop information on the mechanisms through which energy and matter are transferred across varying scales of time and space. This critical deeper understanding is essential to provide a framework and substance for the numerical modeling and synthesis. Large-scale process studies may encompass ecosystem-level processes occurring across multiple trophic levels, water masses, and habitat types, whereas small-scale studies may deal with mechanisms as specific as the digestion rates of individual animals. Processes such as predation, nutrient transport, and heat transfer are critical to understanding changes in living marine-related resources. Process studies support model building by defining relationships among individuals and species and between phenomena such as primary production and physical forcing. Process studies also contribute to other forms of research, such as retrospective analysis, and to synthesis.

The short-term end point for GEM Program synthesis and research is implementation of core monitoring activities that are refined as suggested by new information. The continuing roles for synthesis and research, as supported by modeling, are to advance understanding of the relationships among and within the habitat types of the ecosystems, plant and animal species, physical and chemical oceanographic processes, and climate in the northern Gulf of Alaska in accordance with the conceptual foundation Continual refinement and testing of hypotheses, synthesis across geographic areas and species, and modeling of biological and physical processes are expected As seen in Figure 3 1, synthesis is expected to play a dominant role in defining the monitoring program during the early years of the program, with the relative amount of revenues devoted to synthesis declining as long-term monitoring sites are selected and implemented Synthesis will nonetheless continue to be important indefinitely, as a means for understanding and improving the flow information produced by the monitoring programs

3 2.4 Monitoring

As defined for the purposes of the GEM Program, monitoring is the action of repeatedly collecting long-time series observations At the level of data acquisition, monitoring differs from research primarily in the length of time over which the measurements are taken, and the nature of methods and devices employed Monitoring differs from research by employing methods and devices that are "tried and true," whereas research may use experimental devices or novel methods to acquire data For example, observations now considered monitoring, such as satellite observations of sea surface height, were once seen as novel research Such satellite observations remain in the research domain to some extent, as efforts to refine the spatial resolution of the available data continue

The decision on what and where to monitor is based on the results of research and synthesis to identify core variables The development of long time series of data is essential to detecting and understanding change in the ecosystem When combined with research and modeling, monitoring can demonstrate how ecosystems change over time and in response to various inputs As such, it provides a sound scientific basis for making a variety of management decisions potentially affecting ecosystem resources Appropriate temporal and spatial scales for the hypotheses being analyzed are important aspects of detecting change, and, are therefore, key considerations in the design of monitoring

Monitoring in the GEM Program will be organized into core monitoring and partnership monitoring Because of its critical importance to meeting the program's goals and objectives, *core monitoring* based on a set of core variables will be fully supported by the GEM Program *Partnership monitoring* is envisioned to extend the GEM core monitoring program by teaming with partners involved in research that is also relevant to the hypotheses that GEM will be testing Partnership monitoring will be partially supported by leveraging GEM resources with the resources of the partner organization

The end point for monitoring is a geographically distributed network gathering data on the state of the marine ecosystem in the GEM region, using spatially structured survey methods This implies a broad spatial scale for monitoring, as a combination of GEM with that of other entities These data are transformed into information for user groups by using synthesis, research, modeling, data management, and information transfer

3.2.5 Modeling

Modeling is used to make the relationships between the parts and processes of the ecosystem clear, and as such, serve as a critical element in making connections between habitats and across disciplines. Models are tools for organizing data and telling a story and can be written in a variety of media as verbal, visual, statistical, or numerical models. In the GEM Program, the specific purposes of modeling are to help accomplish the following:

- Inform, communicate, and provide common problem definition;
- Identify core variables and relationships;
- Set priorities;
- Improve and develop experimental designs to attain monitoring objectives;
- Evaluate cross-habitat linkages and transfers; and
- Improve decision-making and risk assessment.

Modeling, monitoring, and data management strategies need to work in concert for each to be fully effective (Figure 3.2). Modeling is a pivotal link between monitoring and data management and information transfer on the one hand, and synthesis and research on the other. Modeling feeds back information to the monitoring program in the form of recommendations on how the monitoring system can be made more effective. Modeling also helps interpret data for the use of synthesis and research activities.

There are numerous synonyms for the types of models defined for the purposes of the GEM Program. Verbal models are also known as "qualitative" and

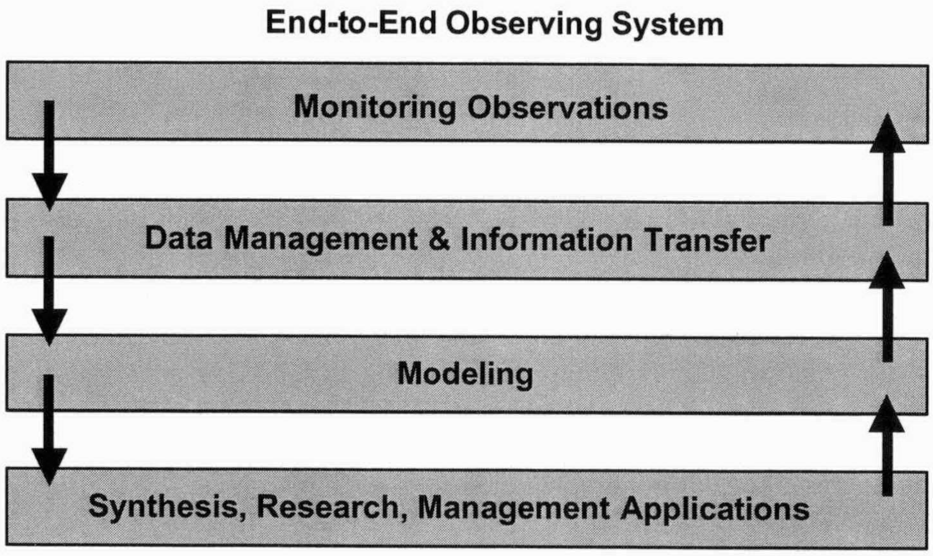

Figure 3.2 The End-to-End Observing System in which the monitoring observations are linked by data management and information transfer to end users, including modeling, synthesis, research, and management applications. *(Adapted from Tom Malone [U.S. Global Ocean Observing System Steering Committee 2000])*

"conceptual", statistical models are also known as "correlative" and "stochastic", and numerical models are also known as "deterministic" and "mechanistic " Note that "prediction," "simulation," and "analysis" are not types of models, but uses of models For example, the use of any kind of statistical or numerical model to reproduce the behavior of a process, such as population growth, is known as a simulation All four types of models will be used in the GEM Program In the near-term, however, models of biological phenomena are expected to be mostly verbal, visual, and statistical, whereas models of physical and chemical phenomena are likely to be primarily numerical, in addition to being verbal and statistical

The long-term modeling end points for monitoring, synthesis, and research in GEM are working biophysical models that make managers, policy makers, and resource users aware of changes in natural resources, help them understand the human and natural origins of these changes, and give them some idea of what to expect in the future A detailed discussion of the definitions and strategies for modeling in the GEM Program is provided in the complete GEM Program Document (see Chapter 8)

3 2.6 Data Management and Information Transfer

Data management and information transfer are the processes of acquiring in the field, receiving in the office, formatting, and storing data, providing quality control and assurance, developing and managing databases, and making the data understandable and available to users A detailed discussion is provided in the complete GEM Program Document (see Chapter 9) It includes the development of information products based on interpreted data and the delivery of these products, including user interfaces The immediate objective of data management and information transfer is to ensure that the data collected by projects under GEM are well documented, safely stored, and accessible to the public within a reasonable period of time after collection An ongoing objective of data management and information transfer in the GEM Program is to achieve to the greatest extent possible the documentation, storage and public access for past data acquired with *Exxon Valdez* oil spill funds under the Natural Resource Damage Assessment and Restoration programs of the Trustee Council

The long-term end point for GEM data management and information transfer is a system that manages the rapid and efficient flow of data and information based on core monitoring projects to end users, and that facilitates the flow of data and information between and among GEM partners and the user community

GEM data management is a program support function intended to accomplish the following

- Support cross-disciplinary integration of physical and biological information, and traditional knowledge within a structured, decision-making framework,

- Support synthesis, research, and modeling that evaluate testable hypotheses on the roles of natural forces and human activities in controlling biological production, and
- Lay the groundwork for future use of distributed, Web-based analysis and management tools as the monitoring program becomes fully operational

By necessity, the data incorporated into the GEM Program will be derived from a variety of sources and formats, which will include retrospective data sets and traditional knowledge and may contain spatial and temporal components Synthesis and research will need to incorporate data not directly collected by the GEM Program, such as satellite remote-sensing information and fishery catch data Incorporation of these data into regional models and decision-making systems will require tools for data ingestion and query, especially to facilitate modeling Because the output from the GEM Program will be used by people from a wide variety of disciplines and backgrounds, the user interfaces must be easy to understand and accessible through a distributed network, such as the Internet

Data management and acquisition policies are essential to ensure the rapid transfer of information to end users Although the data must flow through the system as quickly as possible, quality control and assurance procedures and the prerogatives of scientists to publish interpretations of the data need to be respected One approach that may prove useful is the establishment of "peer reviewed" data sets that allow the scientists involved to receive credit for their efforts in the publications of other scientists who may use the data

Information transfer products will depend on the nature of the monitoring and research activities that are yet to be chosen Possibilities for these products, based on the experience of other monitoring and research programs, could include models and measures relevant to determining the productivity of key species such as salmon

3.3 GEM Program Strategies

The previous section discussed the standard tools that will be used to develop and evaluate data and manage information in the GEM Program This section presents two strategies that also will be important in guiding the GEM Program incorporating traditional knowledge and community involvement, and potential for resource management applicability These strategies will be applied to the GEM Program as a whole and will influence the way that the tools presented in the previous section are used

3 3 1 Incorporating Community Involvement and Traditional Knowledge

Community involvement and the incorporation of traditional knowledge in the GEM Program are critical to the program's long-term success The significance of traditional knowledge is becoming increasingly recognized (IUCN 1986, Martinez 1994, Kimmer 2000) and can play a role in providing early warning signs of ecosystem change (Ford 2001) Local residents are expected to provide ecological knowledge that can be incorporated into established scientific models They also can be a source of research questions which help ensure research that is relevant to both ecological and community needs Community-based monitoring efforts can efficiently collect essential data and build local stewardship as well as long-term support for the GEM Program

The *Exxon Valdez* oil spill settlement requires meaningful public involvement in all Trustee Council programs, as well as a Public Advisory Committee Residents of coastal communities have a direct interest in scientific and management decisions and activities concerning the fish and wildlife resource s and environments on which they depend for their livelihoods and sustenance (Huntington 1992) The Trustee Council believes that encouraging local awareness and participation in research and monitoring enhances long-term stewardship of living marine resources

Community involvement can occur in many ways Several approaches have been tried in the *Exxon Valdez* oil spill restoration program and elsewhere in Alaska and other northern regions, and GEM will draw on these experiences to design specific processes for involving communities and their expertise(Huntington 2000, Brown-Schwalenberg et al 1998, Fehr and Hurst 1996, Hansen 1994, Brooke 1993) One avenue is through active membership on the 20-member Public Advisory Committee, made up of representatives of tribal and incorporated communities, stakeholders, scientists and members of the general public Another is through active participation of public members on various scientific subcommittees and work groups and during targeted workshops to help plan and guide the GEM Program as it develops Other ways include having citizens, students and communities implement local monitoring activities

Traditional and local ecological knowledge can provide important observations and insights about changes in the status and health of marine resources (Huntington 1998) With Trustee Council funding, Alaska Native tribes in the GEM research area are currently developing natural resource plans that will help identify important resources and potential threats and be useful in designing local monitoring schemes that help answer key questions for the GEM Program

The Trustee Council has always listened closely to the views and interests of the people living in the spill-affected region, and responded to their concerns consistent with the legal restrictions of the *Exxon Valdez* oil spill settlement funds Under the terms of the settlement, restoration funds can only be used to respond to injuries to the public's natural resources – not injury to individuals or to communities However, the communities have the well being of these resources at heart, and any program to provide for the long-term health of the resources, has the benefit of providing for the long-term health of the local communities

3 3.2 Potential for Resource Management Applicability

The GEM Program is intended to increase and enhance the information managers and stakeholders use to cope with changes in natural resources To accomplish this, GEM will seek to acquire data with significant potential for use in resource management applications, ensure that data is converted into useful information in a timely manner, and invite research and synthesis projects that both involve and benefit natural resource management agencies

Salmon fishery management illustrates management concerns that are common to most natural resources The typical salmon fishery operates on a resource that depends on a variety of habitat types (freshwater, nearshore, and offshore) during the course of its life cycle (Figure 3 3) Management of the salmon fishery requires detecting and understanding the consequences for production of habitat management decisions (Box 1 9, Figure 3 3) throughout the salmon's life cycle GEM seeks to provide data relevant to answering specific questions about how a range of habitat types function to produce salmon and other species The cyclic nature of the salmon fishery in time and space makes it clear that biological production in one habitat type cannot be understood in isolation from production in the other habitat types in which the salmon completes its life cycle GEM questions are directed at understanding not only specific mechanisms of production in representative habitat types, but also the connections among habitat types

GEM questions are directed at understanding not only specific mechanisms of production in representative habitat types, but also the connections among habitat types

The management applications actually achieved will depend on a variety of factors, including the degree to which resource managers participate in the review, development, and implementation of the GEM Program

3.4 Conclusion

The tools and strategies described above are used together to make the GEM Program scientifically sound, compatible with other programs, relevant to communities and resource managers, and open to the information local residents may provide Using the tools and strategies to implement the GEM Program is addressed in the following chapter

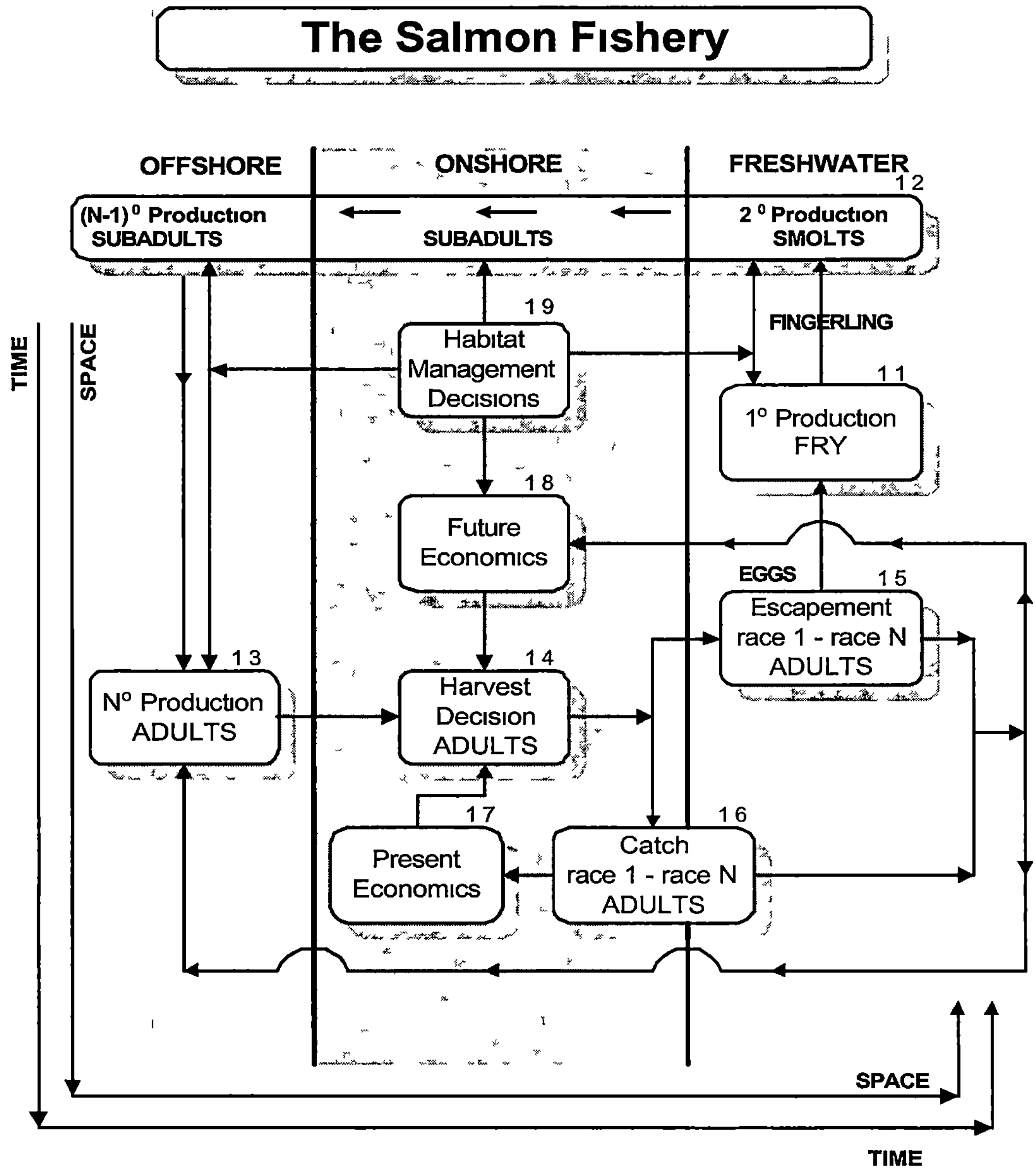

Figure 3 3 Diagram of the salmon fishery with life cycle stages harvest and habitat management decisions in geographic and temporal contexts *(Mundy 1998)*

3 5 References

Brooke, L F 1993 The participation of indigenous peoples and the application of their environmental and ecological knowledge in the Arctic environmental protection strategy Inuit Circumpolar Conference Ottawa

Brown-Schwalenberg, P , H P Huntington, and H Short 1998 Traditional knowledge and environmental recovery experiences from the Exxon Valdez oil spill Bridging traditional ecological knowledge and ecosystem science, August 1998, Flagstaff, AZ

Fehr, A and W Hurst 1996 A seminar on two ways of knowing indigenous and scientific knowledge Inuvik, NWT, Aurora Research Institute

Ford, J 2001 The relevance of indigenous knowledge to contemporary sustainability Northwest Science Forum 75 183-188

Hansen, B 1994 Report on the seminar of integration of indigenous peoples and their knowledge Reykjavik, Iceland, Copenhagen Ministry for the Environment (Iceland), Ministry of the Environment (Denmark), and the Home Rule of Greenland (Denmark Office)

Huntington, H P 1992 Wildlife management and subsistence hunting in Alaska Belhaven Press London

Huntington, H P 1998 Observations on the utility of the semi-directive interview for documenting traditional ecological knowledge Arctic 51 237-242

Huntington, H P 2000 Using traditional ecological knowledge in science methods and applications Ecological Applications 10 1270-1274

IUCN 1986 (International Union for Conservation of Nature) Tradition, conservation and development Occasional newsletter of the Commission on Ecology's Working Group on Traditional Knowledge No 4 International Union for Conservation of Nature UK

Kimmer, R W 2000 Native knowledge for Native ecosystems Journal of Forestry 98 4-9

Martinez, D 1994 Traditional environmental knowledge connects land and culture Winds of Change 89-94

Mundy, P R. 1998 Principles and criteria for sustainable salmon management Alaska Department of Fish and Game http //www cf adfg state ak us/geninfo/pubs/ pubshome htm

Myers, K W , R V Walker, H R Carlson, and J H Helle 2000 Synthesis and review of U S research on the physical and biological factors affecting ocean production of salmon Pages 1-9 in Helle, J H , Y Ishida, D Noakes, and V Radchenko, editors Recent changes in ocean production of Pacific salmon North Pacific Anadromous Fish Commission Bulletin, Vancouver

NRC 2002 National Research Council) A century of ecosystem science planning long-term research in the Gulf of Alaska Washington, D C , National Academy Press

Ricklefs, R E 1990 Scaling patterns and process in marine ecosystems Pages 169-178 in Sherman, K , L M Alexander, and B D Gold, editors Large marine ecosystems patterns, processes and yields American Association for the Advancement of Science, Washington, D C

U S GOOS Steering Committee 2000 Third meeting of the U S Global Ocean Observing System steering committee June 29-30, 2000 Huntington Beach, California U S GOOS

Wilson, E O 1998 Consilience the unity of knowledge Vintage Books, A Division of Random House, Inc New York

4. PROGRAM IMPLEMENTATION

In This Chapter

- Introduction to the GEM Science Plan
- GEM Program Implementation

This chapter describes the starting point for developing the GEM Science Plan. As such, it should be considered a work in constant progress. Once completed the GEM Science Plan will be periodically updated in response to direction from the Scientific and Technical Advisory Committee, its subcommittees, and using input from communities and the general public (see Chapter 5). Changes to potential research questions during the early years of the program could be substantial.

4.1 Introduction

Before the general hypotheses developed and presented in Chapters 2 and 3 can be used to guide the GEM research and monitoring program, they need to be refined into a set of specific research hypotheses. These hypotheses then need to be evaluated to determine what data need to be collected and analyzed to test them. This process for defining, asking, and getting the data to evaluate the detailed hypotheses, also known as research and monitoring, will be described by the GEM Science Plan. The goal of the Science Plan is to implement a long-term monitoring program, which can only be done after the requisite synthesis and research have been completed.

This chapter is the first step in developing the Science Plan. The science planning process will extend the GEM conceptual foundation (through the primary physical and biological processes, and human activities believed to be most important in affecting change in the Gulf of Alaska) to each general habitat type. From this information, and building on the habitat hypotheses, a series of potential questions will be developed that can be used as a starting point for identifying initial research activities. Initial development of the research hypotheses and questions will be undertaken by the Trustee Council's Scientific and Technical Advisory Committee in late 2002. These hypotheses and questions will be further defined and refined by subcommittees, workshops, the Public Advisory Committee, and the general public through a process of active public participation. The first draft of the Science Plan is expected to be completed by the end of 2002. This plan will be used to identify the early research and monitoring projects needed to advance the GEM Program. As knowledge of the ecosystem increases, the Science Plan is expected to gain greater specificity and refinement through ongoing hypothesis testing, gap analysis, and identification of specific information needs

In addition to the development of habitat-specific research questions, an initial implementation plan for the GEM Program during a 5-year period, from FY 03 to FY 07, will also be included in the Science Plan This implementation plan will incorporate the following elements

- A *proposed schedule for implementation*, FY 03 to FY 07, for core and partnership activities, models, and data management
- Lists of probable or *prospective partners* that are actively doing related monitoring or research in the habitat type
- Development of *models* as a way to synthesize monitoring and research results and transfer information to end users
- *Candidate (possible) core monitoring activities* recommended based on the conjunction of partnership opportunities and opportunities for measuring biological and physical quantities related to the key question and information gaps
- *Candidate (possible) core variables* recommended based on approaches suggested by the literature reviewed in the scientific background (see Chapter 7 in the complete GEM Program document)

The proposed schedule for implementing GEM monitoring activities in the watershed, intertidal/subtidal, and Alaska Coastal Current habitat areas is likely to be similar, but modeling and data management needs will differ in each habitat For offshore research, GEM will primarily be involved in partnering activities, since research offshore is already being undertaken by a number of other large-scale programs As a result, the schedule for implementation largely is dependent on the implementation schedules for partner programs

4.2 Conclusions: Moving the GEM Program Forward

To maintain the value of the long-term monitoring program, data collection and sampling protocols will necessarily be conservative, changing only with demonstration of substantial need, and then only after careful deliberation Therefore, it is critical that GEM choose its monitoring projects with caution and deliberation The process envisioned will select research projects in the early years of the program that show promise of leading eventually to inclusion in the long-term monitoring program Research will be focused around initial research hypotheses and questions developed through the Science and Technical Advisory Committee and subcommittee processes (see Chapter 5) In the initial years of the program, research projects will be selected through a solicitation process The Trustee Council will issue the request for proposals with recommendations from the Science and Technical Committee, the Public Advisory

Committee and community involvement (see Chapter 5) As the GEM Program matures, requests for proposals may become increasingly targeted toward requests for specific research and monitoring projects and capabilities However, a portion of the available funds will continue to be allocated to the innovative synthesis and research proposals necessary to maintain high standards of scientific rigor and cost effectiveness Workshops and subcommittees will be important mechanisms to involve the public, including resource managers, communities and other stakeholders, in selecting research and monitoring activities

5. PROGRAM MANAGEMENT: ADMINISTRATION, PUBLIC AND COMMUNITY ADVICE AND INVOLVEMENT, SCIENTIFIC GUIDANCE, AND DATA POLICIES

In This Chapter

- Program Administration
- Providing for Public and Community Advice and Involvement
- Process for Providing Scientific Advice, Review and Management
- Establishing Data Management Office and Policies

5.1 Administration

The administration and management of the GEM Program must be cost-efficient, have a high degree of scientific credibility, and provide for public access and accountability

The GEM Program will be administered by a core professional staff that is not directly affiliated with any particular agency, institution, or program This is currently the case with the management of the *Exxon Valdez* Oil Spill Trustee Council Office (Figure 5 1) An executive director will oversee the financial, program management and administrative, scientific, and public involvement aspects of the program The executive director and staff, while housed for administrative purposes in a single government agency, will work under a cooperative agreement for all six trustees The Trustee Council and staff will actively solicit advice on science and policy matters, including review of monitoring and research activities, from experts, including the Scientific and Technical Advisory Committee, and from the public, including the Public Advisory Committee

5 1 1 The Work Plan

A Work Plan will document the current activities that implement the program As projects for monitoring and research are approved by the Trustee Council, they will become part of the Work Plan The Trustee Council may be asked to adopt a new Work Plan each year, or they may be asked to adopt new groups of projects into the Work Plan on a periodic basis

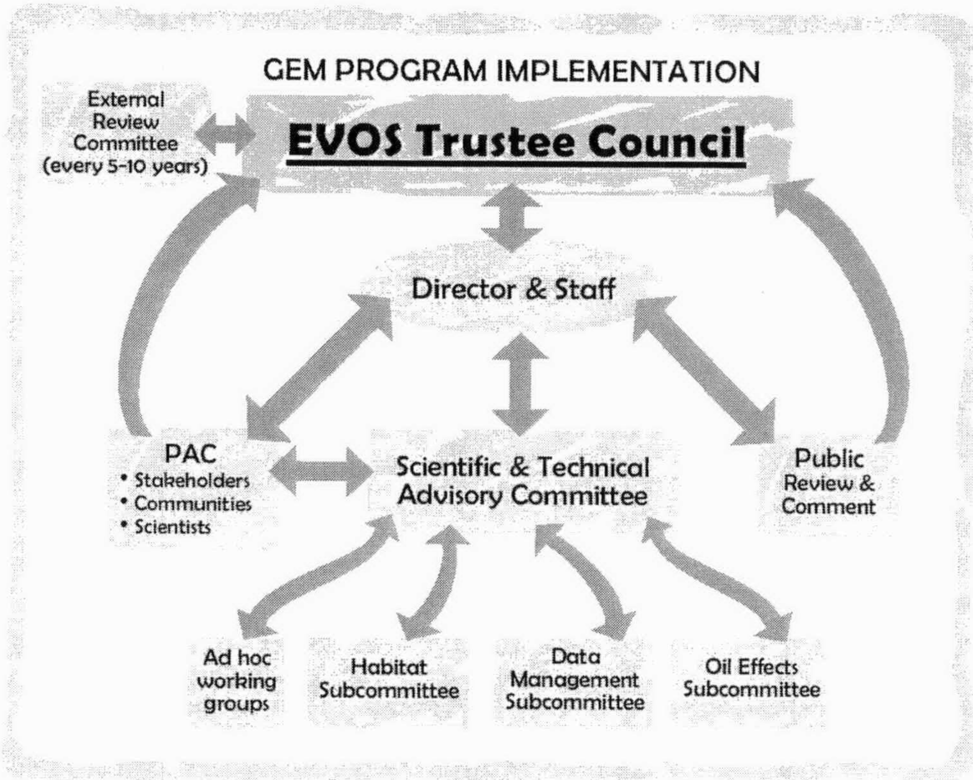

Figure 5.1 The organizational elements involved in GEM implementation. Modified in response to comments from the National Research Council.

5.1.2 Proposal Development and Evaluation Process

The proposal development and evaluation process will have the following elements or steps, which are also shown in Figure 5.2. As implementation of the GEM Program begins, however, these steps may be modified as efficiencies and improvements are found.

- A "State of the Gulf" workshop will be held periodically, at which the current status of the health of the Gulf of Alaska ecosystem will be assessed. Project investigators, peer reviewers, resource managers, stakeholders, and the public will be invited to this meeting, at which research and monitoring results will be presented and discussed. In some years, this workshop will be replaced by or augmented with a process of consultations and workshops with various committees and work groups of science and public advisors to evaluate and affirm or revise priorities.
- An *Invitation to Submit Proposals,* which will specify the types of proposals that are priorities for consideration to implement the mission and goals of the GEM Program, will be issued periodically. Research proposals are envisioned to be of finite duration and have short-term goals (for example, 2 to 5 years). Monitoring projects will be evaluated and renewed on longer time scales (such as once every 5 years). The *Invitation(s)* will be the vehicle

for notifying the scientific community, the public and others that proposals will be considered during a certain period of time.

- Proposals received in response to the *Invitation* will be circulated for technical peer review (see below). In addition, proposals will be reviewed by the Science and Technical Advisory Committee and appropriate subcommittees for their ability to contribute to the information-gathering needs of the central hypothesis and questions, and also for how they contribute to meeting the programmatic goals and strategies of the Trustee Council (see Chapters 1 and 3), such as promoting community involvement, developing resource management applications, and leveraging funds from other sources. Past performance of principal investigators will be assessed. Staff will also review all budgets.
- Comments from the Public Advisory Committee and the general public will be solicited. A reasonable period of time for public comment will be built into the review process.
- The executive director will present to the Trustee Council the recommendations of the Science and Technical Advisory Committee and Public Advisory Committee, a summary of any additional public comment, and additional recommendations if appropriate.

The Trustee Council, after receiving advice from its public and scientific advisors and staff, will vote on which proposals to fund.

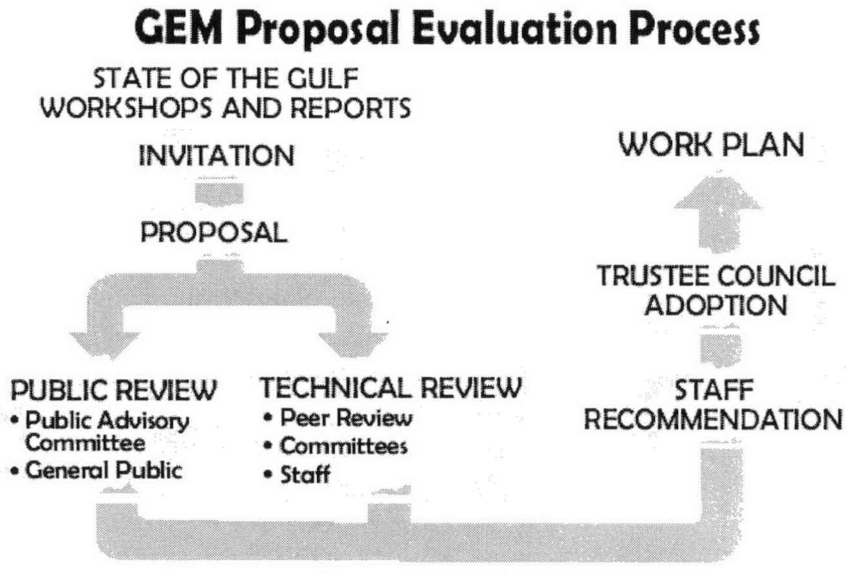

Figure 5.2 GEM Proposal Evaluation Process

5 1 3 Reports and Publications

Annual and final reports will be required for all projects, following established procedures To ensure that investigators are making satisfactory progress toward project objectives, staff will review annual reports In addition, annual reports may possibly be sent out for independent peer review Final reports will be subject to independent peer review, and comments from the independent peer reviewers must be addressed in the final versions of final reports All final reports will be archived at the Alaska Resources Library and Information Service and available on the Trustee Council's web page

Publications in the peer-reviewed literature will be expected of program participants

5 1 4 Peer Review

Each project, as well as some annual and all final reports, will be peer-reviewed by appropriate experts identified by staff who, as a rule, are not also conducting projects funded by the Trustee Council The peer review may be either paid or volunteer, whichever is most expeditious and appropriate The external peer review process will provide a rigorous critique of the scientific merits of all monitoring and research proposals and selected reports Review functions may be carried out in writing, by telephone and occasionally on site or in person

Special review panels may be convened from time to time to evaluate and make recommendations about aspects of the GEM Program At other times, special panels may meet with project investigators and others to fully explore particular topics, problems, or projects

5.1.5 External Program Review

The Trustee Council is committed to review of the program by an outside entity, such as the National Research Council, at periodic intervals This review will look at the program's structure and implementation to ensure that the GEM mission and goals are being achieved

5.2 Public and Community Advice and Involvement

The importance of public participation in the Trustee Council process, as well as establishment of a public advisory group to advise the trustees, was specifically recognized in the *Exxon Valdez* settlement and is an integral part of the agreement between the state and federal governments

The Trustee Council is committed to public input and public outreach as vital components of the long-term GEM Program Figure 5 1 illustrates the role of public participation in the GEM Program

5 2.1 Public Advisory Committee

The Public Advisory Group (PAG) in effect from 1991 - 2002 has 17 members representing 12 interest groups and the public at large, as well as two ex-officio members from the Alaska Legislature The charter for a new Public Advisory Committee will be certified in September 2002 The Public Advisory Committee will consist of 20 members, representing 14 distinct public interests The Public Advisory Committee will meet at least twice a year to provide broad program and policy guidance to the Trustee Council and staff on the overall development and progress of the GEM Program The group will take an active role in setting priorities and ensuring that the overall program is responsive to public interests and needs

5.2 2 Public Advice

The Public Advisory Committee is not the only source of public advice for the Trustee Council Opportunities for public advice and comment are incorporated throughout the process The Trustee Council is a public entity subject to the State of Alaska Open Meetings Act and corresponding federal laws All meetings are public, noticed to the public, and include a formal public comment period Newsletters, annual reports, public meetings in communities in the spill-affection region, and the Trustee Council's Web site (www oilspill state ak us) are all tools to promote and encourage public input and participation

5.2.3 Public and Community Involvement

The Trustee Council is committed to incorporating public and community involvement in the GEM Program at all levels This means not just providing advice on proposals and policies, but involving communities early on in developing research hypotheses and questions and helping decide what variables to monitor and in what locations

Developing a program that includes extensive community involvement will be a challenge, and will necessarily evolve over time The Trustee Council is funding several planning projects in FY 02-FY 03 to further develop ways to better incorporate local and community involvement in the GEM Program

Ongoing efforts include, but are not limited to, these elements

- Community meetings where community members are asked to identify and provide information on issues and questions that are most important to them
- Public, stakeholder and community membership on the Public Advisory Committee Expansion of the committee size to allow greater participation by communities and stakeholders

- Community representation on all subcommittees and work groups used in developing and implementing the GEM Program Making funding available to encourage participation in subcommittees and work groups
- Joint meetings between the Scientific and Technical Advisory Committee and the Public Advisory Committee to foster communication between scientific interests and community interests
- Membership of at least one Science and Technical Advisory Committee member on the Public Advisory Committee
- A proposal solicitation and review process that encourages community-based proposals
- The inclusion of community-based monitoring programs and traditional knowledge in the GEM Program, especially in the watershed and intertidal/subtidal habitats

5.3 Scientific Advice, Review and Management

In addition to peer review of individual proposals and public review and advice, a committee and work group approach will be used to guide GEM Program development and implementation

5.3 1 GEM Science Director

The GEM Program Science Director will work closely with other scientific advisory bodies, and will be the staff member tasked with overseeing implementation of the science program and informing interested communities of the program's results The Science Director will work with other Trustee Council staff in overseeing implementation of research and monitoring activities, ensuring timely delivery and dissemination of research results, and maintaining the GEM database The Science Director makes recommendations to the Executive Director and the Trustee Council on program implementation and development

5 3.2 Scientific and Technical Advisory Committee

The Science and Technical Advisory Committee is a standing committee that is expected to provide the primary scientific advice to the Executive Director on how well the collection of proposed monitoring and research projects (the work plan) and the GEM Program meet the mission and goals of the program and test the conceptual foundation

The Science and Technical Advisory Committee has three primary functions

1 Provide leadership in identifying and developing testable hypotheses relevant to the conceptual foundation of the GEM plan, consistent with the mission, goals and policies of the Trustee Council

2 Make recommendations to the Executive Director and GEM Science Director on preparation of the science program and implementation plans, proposal solicitation and peer review, and selection of research, monitoring, synthesis, modeling and other studies best suited to meeting the goals of the GEM Program

3 Provide support and oversight to subcommittees and ad hoc work groups as needed (see below)

The Science and Technical Advisory Committee is composed of emeritus and senior scientists and others selected primarily for their broad expertise and leadership who serve for four-year, staggered renewable terms At least one of the scientists serving on the Science and Technical Advisory Committee also serves on the Public Advisory Committee The Science and Technical Advisory Committee members are not principal investigators for GEM projects Institutional and professional affiliations are of interest in selecting members, because connections to other marine science programs are valuable for ensuring collaboration and coordination on GEM Program implementation The GEM Science Director is a co-chair and non-voting member of the Science and Technical Advisory Committee

5 3 3 Subcommittees

Subcommittees are standing committees organized to address specific aspects of the GEM Program, to facilitate coordination among scientists, resource managers, and the public and communities, and to help the Science and Technical Advisory Committee provide leadership and oversight for the program

The functions of the subcommittee(s) are to

- Recommend to the Science and Technical Advisory Committee testable hypotheses, items for invitation and peer reviewers,
- Identify and help guide implementation of core monitoring stations and variables that are relevant to the key questions and testable hypotheses,
- Advise on, or possibly convene special review panels or work groups about, aspects of the GEM Program

The subcommittees are composed of scientists, resource managers, educators, and community members selected for knowledge, expertise or familiarity with the issue around which the subcommittee is created For example, subcommittees could be developed around each of the broad habitat types (watersheds, intertidal and subtidal, Alaska Coastal Current, and offshore) or just one overall habitat, lingering oil effects, data management systems and information technology, modeling, monitoring or other GEM Program areas Subcommittee members can be principal investigators on current GEM funded projects Institutional, professional, and other affiliations will also be of interest in selecting members to promote collaboration and cooperation

5.3.4 Work Groups

The Science and Technical Advisory Committee and subcommittees may periodically form ad hoc work groups to develop specific products as requested. Work groups could also be charged with solving a particular problem in a finite amount of time, such as the proper location of an oceanographic mooring.

5.3.5 Workshops

The Science and Technical Advisory Committee or subcommittees may recommend organizing workshops to provide input on core variables for monitoring, research activities, community involvement strategies, and other program elements. The GEM Program anticipates that workshops will play an important role in implementing the science program and disseminating the results of GEM research to resource managers and communities.

5.4 Data Management and Information Transfer

The Data Management Office will be an essential component of the GEM Program. The office will be headed by a Data Systems Manager who will evaluate continuously the evolving information management needs of the GEM Program, and identify and recommend cost-effective solutions to the Executive and Science directors. Over time the mix of in-house supporting staff and out-sourced tasking may vary, but there will be a long-term commitment to providing consistent and high quality data management support (data quality, archive, and analysis) to the GEM Program. Staff in the Data Management Office will coordinate with other agencies in regard to data management and information transfer, manage computing resources, develop software programs, and maintain web sites in support of the GEM Program. In addition, staff in the Data Management Office will be responsible for developing and ensuring compliance with data policies and procedures.

Data management and information transfer policies are an integral part of GEM Program management. Clear and effective approaches for information gathering, archiving and dissemination are essential to the successful operation of a long-term ecosystem science project such as the GEM Program. Because the GEM Program is regional in geographic scope, with goals of cooperation, coordination, and integration with existing marine science programs, data management and information transfer policies are to be compatible with, and similar to, existing norms for state, federal, and nongovernmental marine science programs. Whenever possible, existing norms will be adapted or adopted for use by the Trustee Council. Standards adopted by the Federal Geographic Data Committee, GLOBEC, and the U.S. Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP), and other organizations will be considered for developing GEM data management and information transfer policies. Options and procedures for data management and information transfer are considered in more detail in the complete GEM Program Document (see Chapter 9)

The GEM data management and information transfer policies will incorporate the following broad elements

- A commitment to making data and models available in a well documented and understood form
- Full and open sharing of data and models at low cost, after verification and validation
- Timely availability of data and models
- Acceptance of and adherence to the data policies as a condition for participation in the GEM Program and receipt of funding
- Adherence to data collection and storage standards
- Availability of data and models on the GEM public web site, or through a national public archive
- Long-term archiving of all data and models in a designated storage facility
- Proper metadata, including identification of the origin of all data and models with a citation