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GULF OF ALASKA ECOSYSTEM MONITORING AND RESEARCH PROGRAM

WORKING DRAFT SCIENCE PLAN
Fiscal years 2003-2007

February 3, 2003

Gulf of Alaska Ecosystem Monitoring and Research Program
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Foreword

The GEM Science Plan has been developed through a process involving the Scientific and Technical Advisory Committee (STAC), the Public Advisory Committee and the GEM Habitat Subcommittee with opportunity for input from the public and stakeholders The Science Plan is modeled closely after the GEM Program Document, with particular emphasis on Chapter 2 - the Conceptual Foundation and Chapter 4 - Program Implementation In addition to this document, the National Research Council (NRC) review of the GEM program was also a primary source of guidance for the Science Plan For the sake of brevity, the Science Plan does not reproduce materials available in either of these documents, although some summaries have been provided for the sake of context The GEM Program Document, as adopted by the *Exxon Valdez* Oil Spill Trustee Council in July 2002, and the NRC review, originally made available in May, 2002, are available on the GEM website, http //www oilspill state ak us/gem/index html

As explained in the GEM Program Document and advised by the NRC review, the Science Plan is necessarily a living document that will be regularly updated by using all the tools, strategies and management processes available to GEM The process of building and changing the Science Plan must be deliberate and carefully accomplished, guided by GEM's conceptual foundation and new information GEM is an unprecedented opportunity to do very long-term monitoring and research on the marine ecosystems of the northern Gulf of Alaska With that in mind, the GEM Science Plan has been written in the spirit of providing a platform from which GEM can both build long-term data sets and adapt to changing ideas about detecting and understanding changes in the valued marine-related resources of the Gulf of Alaska

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Anchorage, Alaska
February 1, 2003

Summary of GEM FY 04 Actions by projects and staff

The following lists of bullets summarize the major actions in each habitat type and identify the ways in which they are to be accomplished by project selected in response to the FY 04 Invitation (project) or by staff (staff) Please see the main document for detailed explanations of rationales and out year schedules

Alaska Coastal Current

- Maintain support for the Seward GAK1 time series (project), PWS current monitoring (project), continuous plankton recorder (project), thermosalinograph, and fluorometer (project) on vessels of opportunity Investigate possibilities for real time data extraction (staff)
- Evaluate options for partnering with the Alaska Marine Highway System for thermosalinograph, fluorometer, and eventually nutrient monitoring on ferry routes throughout the northern GOA (project)
- Continue to monitor nitrate over the shelf and basin as part of the NMFS-OCC/GLOBEC salmon survey in July/August 2004 (project)
- Continue development of interdisciplinary fisheries oceanography measurement project at Anchor Point in Cook Inlet to understand dynamics of Alaska Coastal Current in relation to management of sockeye salmon fishery (project)
- Develop a web based system for distributing information and peer reviewed, author-attributed data sets from the GEM program (project)
- Establish web pages for each habitat and the GEM Model (Cross Habitat activities) on the EVOS web site, which would contain relevant EVOS publications, reports, data sets, and other information (staff)
- Provide links to web sites displaying graphical information with data from current projects, including Seward Line Station 1 (GAK1), Continuous Plankton Recorder, thermosalinograph and fluorometer (staff)
- Initiate GEM biophysical model development (project)
- Continue process of establishing operational fisheries oceanography programs in Cook Inlet (staff) Develop relationships with fishery managers in Cook Inlet in preparation for long-term development of fishery management tools, and to coordinate GEM ecosystem model development with fishery management needs (staff)

Nearshore

- Establish web pages for each habitat and the GEM Model (Cross Habitat activities) on the EVOS web site which would contain relevant EVOS publications, reports, data sets, and other information (staff)
- Coordinate and facilitate interaction among investigators in nearshore projects to plan for FY 05 Invitation for Proposals (projects and staff)

Watersheds

- Complete work and analyze cores of sediments from sockeye-bearing lakes on the Kenai Peninsula and Prince William Sound to understand the natural variability of production in these systems in the distant past (up to 5,000y) (project)
- Identify and demonstrate statistically rigorous sampling strategies for detecting marine signals and proxies from plants and animals in the marine watersheds and nearby nearshore areas (project)
- Identify and demonstrate cost effective community based sampling strategies for citizen monitoring of marine-related variables and proxies in watersheds and nearby nearshore areas Demonstrate how to incorporate proven approaches to community based monitoring of the aquatic environment, including QA/QC of citizen monitoring data (project)
- Establish web pages for the Watershed habitat and the GEM Model (Cross Habitat activities) on the EVOS web site which would contain relevant EVOS publications and reports and other information (staff)
- Investigate opportunities to improve and/or extend the quality and availability of existing community based data collection projects for key physical, chemical, and biological variables in coastal watersheds of the GEM region (staff)
- Participate with regional partners in developing a strategic plan to use and improve remote sensing data acquisition, analysis, and modeling of coastal watersheds of the GEM region (staff)

Offshore

- Actions in the offshore are combined with those of the ACC for FY 04

Guide for Readers

The GEM Science Plan is a working document for the reference of those who work with the Program on a regular basis, or who may have an interest in reviewing the actions underway or planned for program implementation As a working document for a new program, some of the sections are currently place holders for materials to be developed over time and may have very little content at present Readers who are familiar with the GEM Program may skip directly to the section entitled "GEM Science Plan," while those who are new to the program should start with the Background Materials

Background materials highlighting key features of the GEM Program Document are included here as a convenience For more complete information the reader should see the full document at http //www oilspill state ak us/gem/documents html

Background Materials

Mission and Goals

The mission of the Gulf of Alaska Ecosystem Monitoring and Research (GEM) Program, as adopted by the *Exxon Valdez* Oil Spill Trustee Council in July 2002, 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***

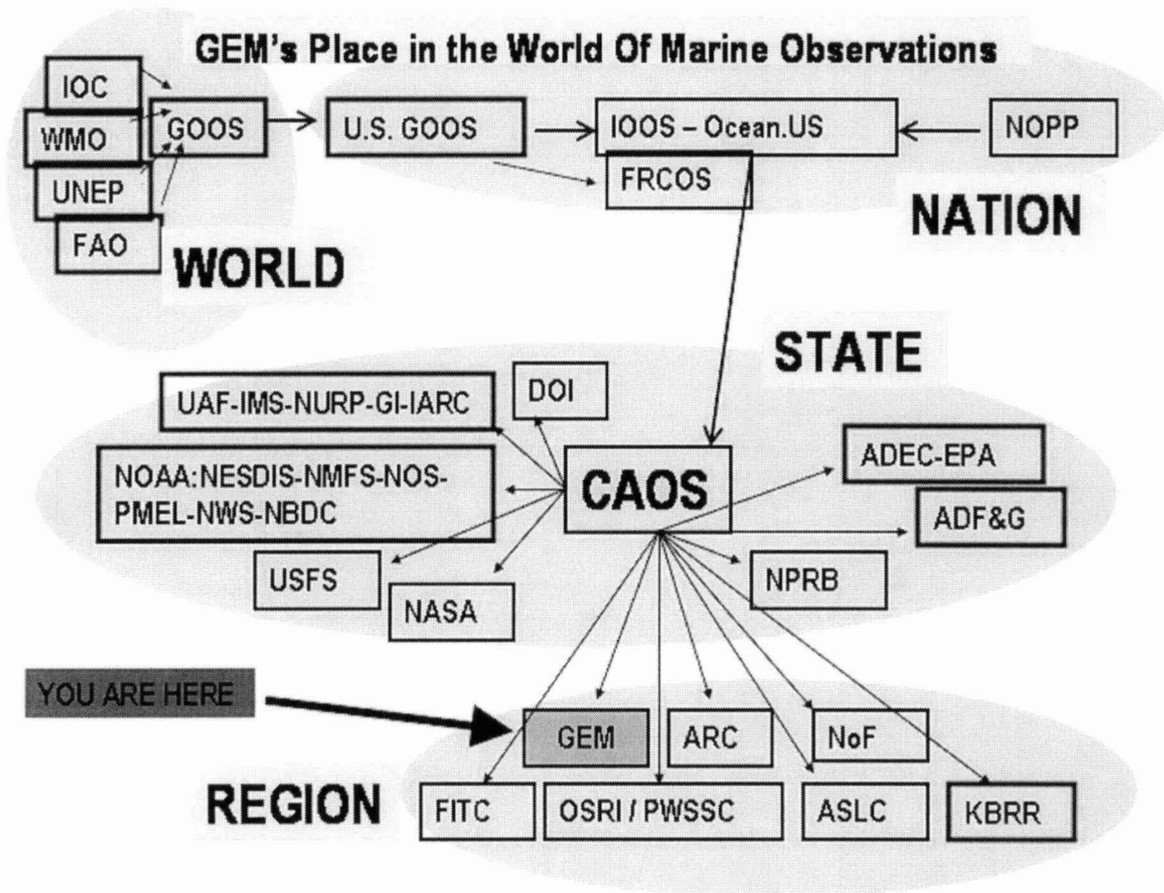
The goals of the GEM Program are to

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
2 **Understand** Identify causes of change in the marine ecosystem, including natural variation, human influences, and their interaction
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
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
5 **Predict** Develop the capacity to predict the status and trends of natural resources for use by resource managers and consumers

Global Context

As an emerging regional marine science program, GEM must insure that its actions are compatible and complementary to national and global programs that serve the same purposes Indeed, given the large spatial scales over which biological and physical phenomena operate, it would be impossible to understand and predict changes in the region's natural resources without the cooperation and support of partners with broader geographic mandates The large spatial scales require ecosystem-based natural resource management to have a global perspective Developing a global context requires developing the understanding of how phenomena at distant localities affect local conditions and biology For example, warming of the Pacific Ocean at the equator early in the calendar year may lead to weather changes in the Gulf of Alaska in the fall and winter of the same calendar year and change the abundance of salmon five calendar years later Establishing the global context requires linking events at widely divergent times and places to explain events in the here and now

GEM is one building block in a global observing system currently under construction (figure on following page) GEM is an integral component of the now-developing Coastal Alaska Observatory System (CAOS) and the U S Integrated and Sustained Ocean Observing System (IOOS), pieces of the efforts are underway from the international to the regional governmental level to make a global ocean observing system (GOOS) a functional analog to the system now in place for meteorology Due to the efforts of global organizations (e g , World Meteorological Organization), advances in computer processing speed, the growth of satellite observing systems, and the growing political awareness of the local consequences of global change, it is now realistic to envision GEM as a significant component of this global observing system Linking biological and physical observations over thousands of miles through models to understand changes in single species is a daunting task, but one that is becoming increasingly possible



As part of a larger ocean observing system, the challenge of the GEM Science Plan is to bring the terminology needed in ocean observing into common use by the public. The meteorological community has made household words out of terms such as barometric pressure, relative humidity, wind direction and magnitude, air temperature and precipitation. While the public does not know how models forecasting weather work, the public is comfortable with the terminology and uses some of the information in daily planning. Words such as sea surface temperature, salinity, sea level pressure, fluorescence, nitrates, and silicates are not household words now; part of GEM's task is to make them recognizable. These are the variables that are critical to creating the physical and biological models important in detecting and understanding change over time. An equally important parallel role will be for GEM to assist the public in understanding how these measurements can be used to understand and manage ecosystems.

GEM Conceptual Foundation

The GEM conceptual foundation is the backbone of the Science Plan. It is the broadest of a cascading series of increasingly specific ideas about how marine-related ecosystems function that form the intellectual framework of the GEM Program. This framework is composed of a conceptual foundation, central hypothesis, habitat-specific hypotheses, research questions, and ultimately, testable hypotheses based on the specific questions. The conceptual foundation provides a verbal model of how the Gulf of Alaska (GOA) ecosystems produce biological resources As such, the conceptual foundation is not a testable hypothesis, but rather, the origin of hypotheses and of the Science Plan

In summary, the GEM conceptual foundation describes how

> ***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 advective 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***

GEM Central Hypothesis

Identifying the forcing factors, human and natural, that drive biological production requires framing hypotheses and questions that point the way for a monitoring and research program The central hypothesis formally states widely held beliefs about what drives change 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***

Habitat Types

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 The habitats are composed of identifiable, although not rigid, collections of characteristic microhabitats, resident and migratory species, and physical features Cross-habitat processes and transfers must be included and addressed The habits are

- Alaska Coastal Current – a swift coastal current of lower salinities (25 to 31 psu) typically found within 35 km of the shore
- Nearshore (Intertidal and Subtidal) areas – brackish and salt-water coastal habitats that extend offshore to the 20-m depth contour
- Watersheds – freshwater and terrestrial habitats from the mountains to the extent of a river's plume

- 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 GEM program will sustain monitoring and database accumulation (including relevant metadata and data from partner agencies) of habitat and biotic community variables in these four habitat types Each of these habitats has distinctive environmental processes and biota Each requires different expertise and equipment for gathering scientifically credible data, although GEM's community involvement strategy recognizes that not all such data need be gathered by persons who are formally educated ecological professionals

Community Involvement

Community involvement is one of two key implementation strategies for GEM Since its inception, the *Exxon Valdez* Oil Spill Trustee Council has been committed to public participation and local community involvement in all aspects of the restoration program The Trustee Council recognizes the tremendous loss of livelihood and cultural heritage caused by the 1989 oil spill and has devoted a major portion of the restoration funds to the restoration of natural and archaeological resources that are important culturally and economically This effort has included significant public and community involvement and outreach As the Gulf of Alaska Ecosystem Monitoring and Research (GEM) program develops, the Trustee Council will continue to rely on community involvement, use of local and traditional knowledge, public participation, education, and outreach These will be major components of the Trustee Council's long-term effort to restore and better understand the northern Gulf ecosystem

Sustaining a healthy ecosystem depends ultimately on the ability and will to influence human activities in order to avoid negative impacts to the ecosystem and its resources The ability to do so is constrained both by the limits of knowledge and understanding and by the extent to which human activities can be managed The latter is dependent largely on the willingness of those who use the ecosystem and its resources to help develop, support, and cooperate in management and stewardship actions The degree to which the region's communities and affected organizations are involved in GEM will be a major factor in establishing the sense of cooperation and shared mission that will determine the eventual success of GEM as a whole

Community involvement spans a broad spectrum, from receiving information in useful and comprehensible formats, to helping set program goals and objectives, to participating in and conducting research and monitoring projects For community involvement to succeed, GEM will need to provide certain infrastructure and other support Data management practices will need to accommodate community-generated data and provide access for community members Research and monitoring conducted in or near communities or harvest areas will require structured interactions among scientists and community members and stakeholders to stimulate ideas, to analyze and interpret results, and to reach a common understanding about how these efforts contribute to GEM's overall research and monitoring efforts The data and results from GEM will need to be interpreted and disseminated in comprehensible form to communities, organizations, and the general public to explain what GEM has accomplished and to promote the application of its findings by those who use or influence the Gulf ecosystem

Community involvement is thus an integral part of GEM as well as a distinct activity requiring dedicated attention and resources The effectiveness of individual community involvement activities will be evaluated on a regular basis, as will the community involvement component as a whole This process will allow the continued refinement, adaptation, and improvement of the community involvement effort

Management Products

As an implementation strategy, GEM data and information are to be gathered with a view toward their eventual application in natural resource management activities Over time GEM will become a source of the kinds of information that resource managers can use to advise resource dependent communities of the possibilities of changes in their livelihoods, as well as to minimize the adverse effects of human activities on biological production In so doing GEM will add value to the natural resources for coastal communities by helping conservation efforts and by enhancing abilities to anticipate changes in natural resources The long-term record produced by GEM will be a premier tool in providing these management products

Assumptions and Approaches

Key assumptions and approaches from the GEM Program document that figure prominently in the science plan are listed here

- Long-term data sets of physical and biological observations are essential to detect and understand ecosystem change over time Observations are essential to understand how ocean currents move food and energy into the trophic webs of seabirds, marine mammals and fish Platforms for the observations include moorings, vessel transects and surveys that are relevant to specific aspects of the marine ecosystems of the northern Gulf of Alaska
- The long-time series data produced must provide information on the status and future of productivity in the northern Gulf of Alaska marine ecosystem and be relevant to the interests of those concerned with balancing the management for human uses of its natural resources with natural variability, however, it is recognized that such data schemes and information derived from them will not be immediately available
- The information is to be collected over the long-term in geographic areas not routinely addressed by other information gathering activities of state, federal and intersecting interests The variables are to be those most common to methods of determining the status and future of marine ecosystems
- The initial approach to the Science Plan is to place a priority on detection of change Implementation will be guided by the sequence of the goals of the program to first, attain the ability to <u>detect</u> changes in the environment, then to <u>understand</u> the origin of those changes, to <u>inform</u> about changes and their origins, to use the information to <u>solve</u> problems created by changes, and lastly to <u>predict</u> changes
- Achieving the overall mission of GEM ("Sustain a healthy and biologically diverse ecosystem in the northern Gulf of Alaska and the human use of marine resources in that ecosystem") requires applying the understanding generated by GEM projects to management and stewardship of the region's resources This in turn requires long-term involvement by communities, tribes, stakeholders, and affected organizations in the region As such, community involvement will be strongly encouraged and facilitated throughout the development and implementation of the GEM Science Plan

- The Science Plan will be developed iteratively, beginning as stated above with the near-term goal of identifying geographical sampling sites and physical and biological variables for monitoring Monitoring will be phased in as soon as practicable, but always with active scientific involvement in evaluation of both the data and the ecosystems from which it is drawn For example, even a one-year time series of data can characterize basic seasonality for any given site, a three year series will start to characterize interannual variability, and a few decades of data will start to show the longer periods in the spectrum of environmental change
- Selection of sites and variables will require completion of tasks in a progression synthesis of environmental information already available, including analysis of gaps in information and theory, initial identification of sites and variables, process and statistical modeling with particular emphasis on the sampling requirements and unit costs for producing useful long-term time series, and identification of partnerships that will extend the sampling range and data production capability of GEM
- Initial efforts need to be largely focused on development of long-term monitoring activities (i e moorings, stations, transects, surveys) in the habitat types of the nearshore (intertidal and subtidal) and Alaska Coastal Current, as determined by the gap analysis, the conceptual foundation, and fiscal constraints Developments in the watersheds and offshore areas need to follow further developments of the conceptual foundation and efforts of other parties in the watersheds and offshore, as also indicated by the gap analysis and fiscal constraints

Bibliography of key references on background materials

Gem Program Document adopted July 2002
http //www oilspill state ak us/gem/documents html

NRC 2002 A Century of Ecosystem Science Planning Long-Term Research in the Gulf of Alaska Committee to Review the Gulf of Alaska Ecosystem Monitoring Program, National Research Council National Academies Press, Washington, D C
http //www oilspill state ak us/gem/documents html

GEM Science Plan

Introduction

The Science Plan is a working reference document that includes the information on locations, objectives and rationales for GEM projects in the context of current information and activities in the region The Science Plan contains the following information

- Geographic scope and scale within which data acquisition occurs,
- Latest relevant scientific information on habitat types and the processes that connect them,
- Hypotheses across and within habitat types that organize the information into coherent explanations of what controls change in the region's populations of birds, shellfish and mammals,
- Gaps in knowledge of population control mechanisms that need to be filled in order to detect, understand and predict changes in the region's animal populations,
- Summaries and details of the existing data collection programs and how GEM efforts are designed to complement them,
- GEM work in progress,
- GEM work that needs to be done as soon as possible,
- Current expectations for work in the future, and
- Current and prospective status of the two GEM implementation strategies community involvement and management applications and products

Overview

As a brief overview, the largest information gaps in the northern Gulf of Alaska relate to how food and energy originating in the offshore marine environments are transported through the Alaska Coastal Current and nearshore areas to the watersheds Accordingly, detecting changes in the variables that characterize the transfer of food and energy through the northern Gulf of Alaska is a top priority for the GEM Program The GEM Program calls for building upward from oceanography through food and energy toward the large body of information that has accumulated within the management agencies over the past century on the abundance and biology of single species of large vertebrates such as seabirds, pelagic and anadromous fish, and marine and coastal mammals In watershed and nearshore habitats where human activities are most prominent, it is important to find measures of how anthropogenic factors combine with human factors to influence these ecosystems By filling gaps in how physical and human forces alter the transport of food and energy, changes in the large vertebrate species and prominent invertebrates, such as birds, shellfish, fish and mammals, can be understood in relation to a broad array of biological and physical observations throughout the region In the long run, this comprehensive understanding of the ecosystems of the Gulf of Alaska is intended to lead to predictions of use to resource managers In terms of types of long time series in these habitat types, observations on smaller to microscopic species of marine plants and animals, and physical and chemical observations from below the sea surface are widely lacking (GEM Program Document, Appendix D)

Initial efforts will focus on development of long-term moorings, stations, transects, and surveys in the nearshore and Alaska Coastal Current habitats, recognizing that the most expensive sampling zones to reach on a frequently recurring basis are the ACC and, at some point in the future, the offshore Gulf of Alaska The limits on GEM fiscal resources likely will require maximum use of volunteer observing ships (VOS), which are commercial vessels that carry various monitoring instruments Preparing for instrumentation of VOS and establishing the necessary relationships with ship operators and crews should be a priority early in the program

In addition, a whole ecosystem (natural resource) model, the GEM model, as recommended by the National Research Council (NRC 2002) would link biological and physical observations across the habitat types, as well as the North Pacific, in order to understand changes in single species of interest to managers and concerned others This ecosystem model must be developed with a global perspective given the large spatial scales over which biological and physical phenomena operate

Identification and prioritization of the variables for the GEM program depend in large part on what is needed to operate the GEM ecosystem model High priority variables needed in the GEM program are a composite of the variables essential to the workings of the GEM ecosystem model and its components the ocean current model, the nutrient-phytoplankton-zooplankton (NPZ) models, and the Sound Ecosystem Assessment (SEA) pink salmon model (Willette et al 2001, Patrick et al 2003) (see Appendix F of the GEM Program Document) In assembling the GEM ecosystem model, emphasis will be placed on detecting changes in the variables that characterize the currents and the transfer of food and energy throughout the north Gulf of Alaska In this way, changes in the large vertebrate species that are routinely monitored by state and federal government agencies can be better understood in relation to a broad array of biological and physical observations throughout the region

Geographic Scope and Scale

The end point for monitoring is a geographically distributed network that produces long-term observations on the state of the marine ecosystem in the GEM region, using basic spatially structured survey methods At some point in the future the data stream from the geographically distributed network of sampling activities is expected to enable adaptive approaches to data acquisition, such as using GEM's coupled biophysical model in data assimilation mode The GEM biophysical model outlined below is an important part of the program that provides linkages across habitat types The geographically distributed approach sets a broad spatial scale for monitoring within the spill affected area and adjacent waters, using a combination of GEM activities with those of other entities The trajectory of the 1989 oil spill provides a map for organizing the initial sampling program

GEM projects are expected to be organized around an environmental axis defined by the surface trajectory of the oil spilled in 1989 (figure ACC-1) This trajectory also defines the advective transfers of many marine ecological components in the northern Gulf of Alaska, and is coincident with the path of the Alaska Coastal Current (ACC) in the oil spill affected areas Areas where the oil came ashore emphasize the intersection between the ACC and the nearshore habitat types The region of interest begins in Prince William Sound (PWS), including its watersheds and adjacent intertidal and subtidal areas The region extends throughout the sound, then emerges with the flow into the region of the buoyancy driven Alaska Coastal Current

(ACC). The ACC branches just southwest of PWS, with one limb flowing along the eastern shore of Kodiak Island, while the other limb turns toward Cook Inlet, Shelikof Strait and the Aleutian Peninsula (figure ACC-2). Because the ACC interacts with the offshore Alaskan Stream, a major North Pacific boundary current, the region of interest extends seaward and out into the main subarctic water mass of the Gulf of Alaska.

Figure ACC-1. The path of the 1989 oil spill. Driven by wind and currents, the pathway of the oil from the *Exxon Valdez* highlighted the importance of advective transfers of momentum, energy, nutrients and food in the northern Gulf of Alaska.

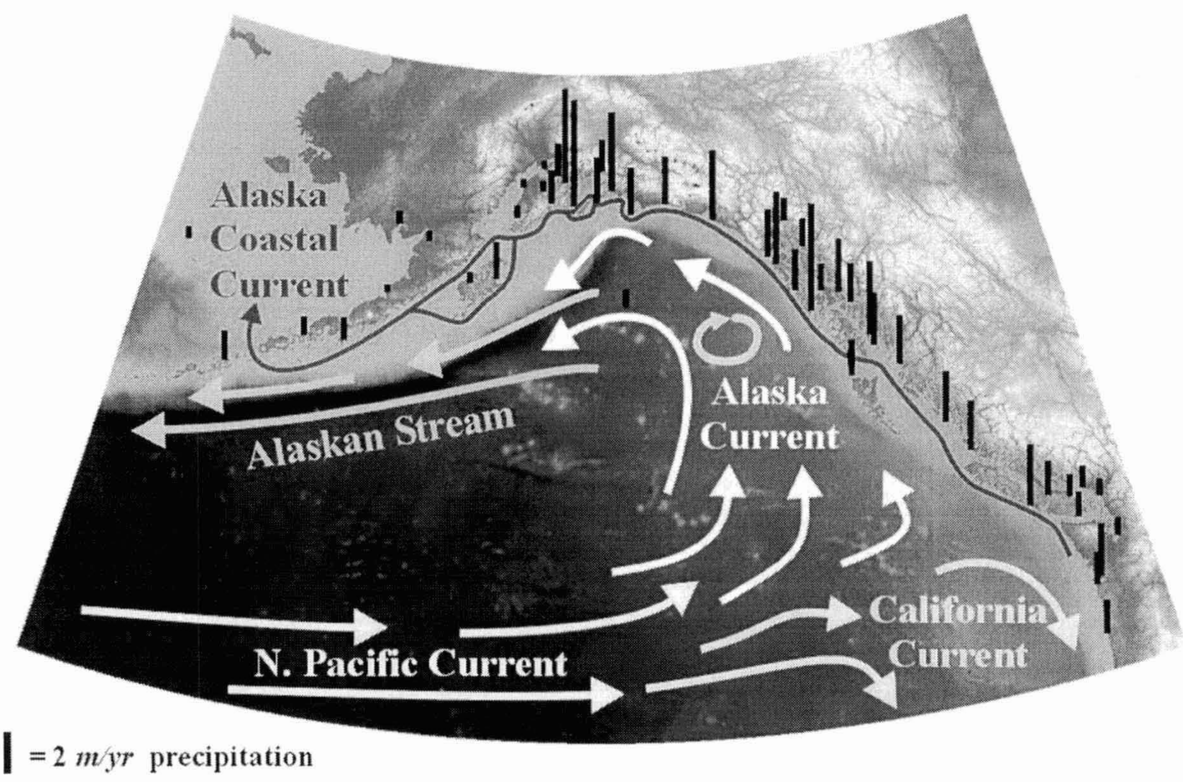


Figure ACC-2 Schematic surface circulation fields in the Gulf of Alaska and mean annual precipitation totals from coastal stations (black vertical bars) and for the central gulf Figure courtesy of Weingartner and Danielson after Baumgartner and Reichel (1975)

The GEM Model. Cross Habitat Synthesis

The GEM program will organize its thinking using a model (GEM Program Document, Chapter 8, Appendix F) of physical and biological processes in the region The physical and biological processes of the biogeochemical cycle unite the GEM habitat types The influences of climate and oceanography change the rates of transfer of food and nutrients, which are parts of the biogeochemical cycle, to alter the structure of the food webs in the northern Gulf of Alaska As identified in the conceptual foundation, the offshore habitat type - and particularly the central Gulf of Alaska - are the origin of nutrients and carbon that are destined for the nearshore and watersheds via the Alaska Coastal Current Some of the nutrients and carbon will be returned from the watersheds to return to the offshore again via the nearshore and ACC Throughout this biogeochemical cycle, the transport of nutrients and carbon both drive and determine the structure of food webs, stimulating primary and higher order production within all the habitat types

Transport mechanisms that are critical to originating and supporting biological production may be used to characterize the habitat types The offshore is the upwelling-downwelling domain, the ACC and watershed are advective domains, and the nearshore is a combined upwelling-downwelling and advective domain The nearshore and Alaska Coastal Current habitats are central connections between the watersheds and offshore Models created in response to short term needs such as the SEA pink salmon model, do not necessarily require that the "big picture" be completely defined before they can be implemented Issues of time and space scales will need to be addressed when local solutions are coupled to other models In fact, knowledge of how the smaller pieces work is needed in order to make the connections to the big picture models Among the "smaller short term solutions" are the SEA model of phytoplankton and zooplankton production and survivals of juvenile pink salmon (Pearcy 2001, Eslinger et al 2001, Patrick et al 2003) are of particular interest

In addition to the published SEA models, a number of physical and biological modeling efforts are available as starting points for the GEM model (GEM Program Document, Chapter 8) In addition, a number of important biological and physical models directly applicable to Prince William Sound have recently been published (see Pearcy 2001) In the Prince William Sound work, known as SEA, interdisciplinary models of the control of year class strength in herring and pink salmon have been developed and tested against a substantial body of field data (Cooney et al 2001a) In the process of examining the survival mechanisms for herring and pink salmon, the models touched on physical mechanisms that control the distribution of nutrients and food, and how the distributions of nutrients and food determine trophic relationships that involve many other species For example, SEA's mathematical model of early marine survival of pink salmon was used to test and validate the production control mechanisms of prey switching by predators, salmon foraging behavior, and salmon size and growth as tested against field as mechanisms determining year class strength (Willette et al 2001)

Another important discovery of the modeling work of Willette et al (2001) and other interdisciplinary SEA modeling efforts that is important to building the GEM model is the lack of independence in the classic concepts of "top down" and "bottom up" control of biological production The concepts are so interdependent that they cannot be studied separately to any purpose that would prove meaningful in natural resource management Studying physics and chemistry (bottom up) or a single species in relation to its predator and food species (top down) in isolation from one another cannot unravel the mysteries of control mechanisms for biological production A sound theoretical basis for the control of biological production, as articulated in explicit biophysical models that permit testing hypotheses, is absolutely essential to understand mechanisms of control of biological production (Cooney et al 2001b, Willette et al 2001, Eslinger et al 2001, Wang et al 2001) The primary challenge in producing the GEM model is to develop the interdisciplinary working team necessary to articulate a truly comprehensive biophysical model of biological production (Wooster 1987)

GEM Cross Habitat Working Concepts

GEM's central hypothesis (GEM Program Document, Chapter 2 2) was designed to be broad enough to contain subordinate hypotheses consistent with the latest scientific knowledge A less elaborate version of the central hypothesis, the Cross habitat Working Concept, serves as the basic scientific guide for the GEM program The current GEM *Cross Habitat working concept* is

> **Changes in advective and upwelling processes, brought about by periodic and aperiodic changes in climate, and by periodic changes in the input of energy, control production of animals and structures food webs across all the habitat types on decadal scales in the northern Gulf of Alaska by limiting the amounts, distribution mechanisms and pathways for nutrients and food**

Changes in biological production on large time and space scales are brought about primarily by changes in energy passing through the system, but the mechanisms for change are not known Human influences, such as fishing, aquaculture activities and pollution tend to function on smaller scales, but not necessarily (i e global warming), and to be more dominant in the watersheds and nearshore habitat types, but not exclusively (GEM Program Document, Chapters 2, 6 and 7) Variations in the input of solar energy plays an important role on annual and very long term (100Ky) variability in biological production, and forcing from lunar gravity appears related to changes in biological production with time periods of about twenty years (18 6y lunar tidal cycle) (Parker et al 1995, GEM Program Document, Chapter 7)

On the spatial scale of the northern Gulf of Alaska and on decadal time scales, GEM's working concept is regarded by the scientific community as a self-evident truism, although much remains to be learned about the details For smaller time and space scales the validity of the working concept is unknown Nonetheless, human interests, and especially those of natural resource managers, are most certainly focused on the smaller time and space scales Hence the role of GEM is to test the working concept as thoroughly as budgets permit on shorter time and space scales, while helping regional efforts to work out the details of how the "big picture" working concept actually functions For example, it may be possible to identify localities in which mechanisms of biological production function in isolation from external forcing for time periods long enough to set year class strength in a fishery, or to determine the fate of an endangered species In the long-term such localities are not unlikely to be isolated from external forcing, nor are they likely to be insensitive to initial or boundary conditions provided by physical and biological processes in adjacent habitats

In cases where less than decadal scale variability is of interest, an alternative working concept must be brought into play In the upper trophic levels species with higher mobility can overcome the effects of boundary conditions and external forcing by simply moving to other areas Indeed this is the value of migration as an evolutionary strategy The relocation processes, as measured by short term abundance of mobile large species, could mask the forcing, boundary and initial conditions provided by the transfers of energy, momentum and nutrients from other localities and forcing from processes associated with solar and lunar energy inputs Tractable subsystems, such as those identified by the SEA pink salmon model (Willette et al 2001, Patrick et al 2003), need to be studied and understood in order to learn how well the GEM Cross Habitat working concept may apply on smaller scales

Whatever the validity of the cross habitat working concept may be, it is clear that the ACC is a key habitat type for studying the cross habitat connections in the GEM region Distribution mechanisms and pathways are thought to link the offshore to the nearshore and watersheds through the Alaska Coastal Current (GEM Program Document, Chapter 7 6 3) For example, the ACC potentially is important to the circulation dynamics of PWS, clearly, it is a critical advective and migratory path for material and organisms between the GOA and PWS, and it is likely to play similar pivotal roles in energy and nutrient transfer from the central GOA to lower Cook Inlet, Shelikof Strait and eastern Kodiak

GEM Cross Habitat Projects

GEM cross habitat projects gather data that are expected to be used in the design and location of long-term monitoring projects In some cases these data have already been used in studies that have detected long-term changes in the climate and biological production of the GEM region Descriptions of these projects may be repeated in other sections of the Science Plan, since they also figure prominently in the data gathering in each of the habitat types in which they operate The actions in FY 03 are summarized below, for proposed actions in FY 04 and beyond see the individual habitat sections

<u>Actions in FY 03</u>

030614 - A feasibility study of monitoring near-surface temperature, salinity, and fluorescence fields in the Northeast Pacific Ocean – S Okkonen The objective for this proposed research is to a use a thermosalinograph and fluorometer to be installed on a crude oil tanker, and to acquire continuous, long-term measurements of the near-surface temperature, salinity, and fluorescence fields along the tanker route between Valdez, Alaska and Long Beach, California

030624 - A CPR-Based Survey to Monitor the Gulf of Alaska and Detect Ecosystem Change – S Batten This project continues, and further develops, the Continuous Plankton Recorder surveys from Ships of Opportunity begun in 2000 through the North Pacific Marine Research Initiative and continued through 2002 under GEM (project 02624) The project will test the CPR as an almost real-time indicator of ecosystem change across the GOA (the ACC and offshore)

030640 - Toward Long-Term Oceanographic Monitoring of the Gulf of Alaska Ecosystem – T Weingartner Project supports a mooring measuring temperature and salinity at depth intervals at the site of the longest continuous time series of physical oceanographic data in Alaska waters, GAK1 (Seward Line Station One) Fluorescence has been added to the surface observations in response to a request for measure of biological activity relevant to understanding distribution of juvenile pink salmon

030654 - Surface Nutrients over the Shelf and Basin in Summer – Bottom up Control of Ecosystem Diversity – P Stabeno This two-year project will measure nitrate over the shelf and basin as part of the NMFS-OCC/GLOBEC salmon survey in July/August of 2003 and 2004 Nutrient maps will be used to support NPZ models and satellite-derived models of nitrate and new production, to examine mechanisms of nutrient supply such as mixing over banks and transport up submarine canyons, and to assist resource management of salmon and other commercially important species

Tools and Strategies

Introduction

As explained in the GEM Program Document, the Science Plan is being developed are refined into a series of initial research questions through the use of tools (gap analysis, synthesis and research, modeling and data management, GEM PD Chapter 3) and the strategies of supporting management applications and fostering community involvement and local knowledge Tools and strategies transcend habitat type boundaries and are integral to the attainment of all GEM goals

Synthesis Needs and Schedule

A synthesis of scientific literature and existing data gathering programs is needed to serve as the introduction to the Science Plan sections for three of the four GEM habitat types the Alaska Coastal Current, nearshore and watersheds Bearing in mind that the boundaries of habitats are not rigidly drawn (Chapter 2, GEM Program Document), the synthesis effort should concentrate on one habitat type, however, each proposal must address linkages of its habitat type with the other habitat types

<u>FY 04 Proposed Actions</u>

- Alaska coastal current (acc) synthesis would address recent advances in biology and physical sciences relevant to the ACC, discuss how recent advances might change existing concepts, point out leading and emerging hypotheses and describe how these might support or change the Science Plan's working concepts for the habitat type
- Nearshore (Intertidal/Subtidal) synthesis document would build on the Science Plan and the design work of Schoch et al (2002a, see GEM Science Plan)to address recent advances in biology and physical sciences relevant to the nearshore and point to the opportunities and needs for establishing a geographically distributed network of monitoring sites
- Watershed synthesis builds on the watershed sections of the Science Plan and GEM Program Document to incorporate recent advances in biology and physical sciences It would address opportunities and needs for establishing watershed monitoring sites during FY 06

Modeling Needs and Schedule

Building the GEM model requires starting from existing physical and biological models, hence, the means of cooperation, coordination, integration and achieving cost efficiencies with existing modeling efforts Procedures and strategies for interdisciplinary cooperation need to be defined, as well as ways and means of communicating the contents, functions and outputs from the model to a variety of different disciplines and across a variety of common operating systems Data assimilation strategies for selecting time and space scales for biological and physical monitoring are essential

FY 04 Proposed Actions

- Build the infrastructure necessary to create, develop and maintain the GEM Model as an interdisciplinary team of modelers is to be assembled with experience in biological and physical modeling in the Gulf of Alaska
- Describe the process of implementing the smaller, but critical, components of the GEM model such as SEA pink salmon survival model, in all aspects including field sampling, estimation of parameters from data, software, hardware, and data management and information transfer

Community Involvement and Management Applications Needs and Schedule

Projects in this category are designed either to enlist the participation of specific communities in developing and/or implementing the GEM Program

Actions in FY 03

030636 - Commercial Fishing Management Applications – K Adams and R Mullins
Status This project is in the process of building bridges between the scientific community, which is describing and attempting to predict variation in biological production, and the commercial fishing community in Prince William Sound, which is attempting to find management applications for this new information In addition, the project seeks to provide a fisheries community presence to participate in GEM development

030575 - GEM Community Involvement Team of community involvement specialists is expected to deliver the following products more detailed Community Involvement sections for each Habitat section and expansion of the Community Involvement section above to include (a) more detailed descriptions of those aspects of community involvement that span all components of a project (e g , data management and the dissemination of results and information) and (b) discussion of characteristics shared by most or all community involvement projects that may differ significantly from projects driven by agencies or the academic community

Proposed Actions in FY 04

- Continue development of interdisciplinary fishery management applications in PWS, extend to Cook Inlet
- Develop a small-scale scientific symposium for coastal communities to serve those who are not able to travel to Anchorage for the annual EVOS sponsored symposia
- Produce GIS maps of resources for specific coastal communities

Lingering Oil Effects

Introduction

The Trustee Council continues to be concerned about *Exxon Valdez* oil remaining in the marine environment and any effects it may be having on injured resources Injured resources are identified and their current status described on the Trustee Council's web site, http //www oilspill state ak us/facts/status html Current objectives for the Lingering Oil Effects section of the Trustee Council's program are focused on examining the fate and effects of the remaining oil on injured resources and services and especially populations of two species in western Prince William Sound, harlequin ducks and sea otters These populations have shown continuing exposure to hydrocarbons in localities where potentially toxic forms of the oil from the *Exxon Valdez* are known to persist Objectives for FY 04 also include learning about the status of subsistence uses of the injured resources in the spill affected areas for comparison to an earlier survey

The reasons why some populations of injured species in Prince William Sound have not met the criteria established for their recovery in the nearly 14 years since the oil spill are still not clear For some species it has not been possible to clearly separate the possible toxic effects of oiling from the possible effects of natural causes such as climate change and predation For this reason, GEM projects that address injured species and ecosystems are designed to understand the effects of natural forces on populations and their productivity The knowledge gained may permit at least a retrospective understanding of oil injury versus other impacts for species injured by *Exxon Valdez* oil, and provide the background on natural forces necessary to understand effects of oiling in future oil spills

Information gaps and questions

Information gaps and questions remain regarding the fate and effects of *Exxon Valdez* oil in western Prince William Sound Proposals specifically addressing these effects on populations of sea otters and harlequin ducks are of interest Proposals are also requested to examine the status of subsistence activities in the spill affected areas In addition to the objectives and examples described here, proposers may use this invitation to suggest other approaches to aid the recovery of resources and services injured by the oil spill However, the Trustee Council's emphasis in FY 04 will be on development of the GEM Program as its primary restoration activity

Lingering Oil Research Needs and Schedule

Proposed actions in FY 04

- Identify bioavailability of lingering oil in Prince William Sound through studies of sea otters and harlequin ducks in the area
- Establish a strategy for monitoring persistence of *Exxon Valdez* oil, and its relationship to other sources of contamination in PWS
- Evaluate the status of subsistence uses by collecting, analyzing, and reporting information about current subsistence uses in a subset of oil spill area communities using methodology that is comparable with previous research results

Alaska Coastal Current

Current scientific thinking

The deep waters of the central Gulf of Alaska contain high levels of nutrients, but the ecological mechanisms whereby the nutrients of the deep offshore waters are transformed into the animal biomass that fuels the human economies and cultures of southcentral Alaska are largely unknown Much of the Gulf of Alaska is a very deep (circa 4000m) reservoir of salty water bearing carbon and nutrients that would fuel biological production if transported to the surface waters of the GEM habitat types Paradoxically, the ocean processes such as thermohaline circulation and upwelling that transport deeper waters toward the relatively shallow depths appear to be absent or short-lived in the northern Gulf The opposite condition from upwelling, coastal downwelling, is usually the case in the Gulf, particularly in winter It is known that cross-shelf, surface Ekman transport in winter cannot account for the high nutrient concentrations observed on the inner shelf in spring (Childers 2000, Whitledge 2000) Other mechanisms are possible In summer, when downwelling relaxes, salty, nutrient-rich water from offshore invades the inner shelf (Royer 1975) but the annual extent of the invasion varies, and it may be controlled by forces with periods of approximately two decades (Parker et al 1995) Vertical mixing is strong through the winter and redistributes fresh water, salt, and possibly nutrients throughout the water column, so perhaps a combination of mechanisms is involved in the annual nutrient re-supply to the inner shelf (GEM Program Document, Chapter 7 6 4)

Even though upwelling appears to occur only briefly in the Gulf (GEM Program Document, Chapter 7 6 2, Royer 1982, 2000, Reed and Schumacher 1986), the northern and western Gulf and adjacent waters are nonetheless highly productive of benthic, pelagic and littoral vertebrates (fish, birds and mammals) and benthic invertebrates such as crustaceans and mollusks (i e Feder and Jewett 1986, Cooney 1986, Martin 1997, Witherell 1999, Kruse et al 2000, Rogers et al 1986, Highsmith et al 1994, Purcell et al 2000, Rooper and Haldorson 2000) Solving the mystery of the missing ecological mechanisms is essential to explain how the ingredients necessary for biological production of plants and animals (nutrients and food) are transported to be converted into the populations of fish, shellfish, birds and mammals that are the centers of attention for natural resource management agencies and coastal economies

A reasonable working concept, to be more fully stated below, starts with the processes that change the strength of the factors driving the currents of the region (GEM Program Document, Chapter 7 6 4) Both the area of the ACC and adjacent shelf and slope are strongly affected by advection (mostly horizontal transport of momentum, energy, and dissolved and suspended materials by ocean currents), implying that climate perturbations, even those occurring far from the GEM study area, can be efficiently communicated into the northwestern GOA by ocean circulation (GEM Program Document, Chapter 7 6 2, p 130) The strong advection also implies that processes occurring as far upstream as northwestern United States might substantially influence biological production within the GEM habitat types

Strong circumstantial evidence links changes in factors governing the strength of GOA currents in general, and the ACC in particular, to changes in biological production in the all of the GEM habitat types Correlations between time patterns of changes in physical and biological phenomena provide some clues, but no solutions to our mystery Changes in populations of birds, fish and mammals inhabiting the ACC have been shown to be correlated with temporal changes in weather (Hare et al 1999, Mantua et al 1997, Anderson and Piatt 1999, Francis et al 1998) and forcing from the moon's gravity, lunar forcing (Parker et al 1995) Lunar tidal forcing with a period of 18 6 years has been associated with high latitude climate forcing, periodic changes in intensity of transport of nutrients by tidal mixing, and periodic changes in fish recruitment (Royer 1993, Parker et al 1995) Biological and physical effects of the lunar tidal cycle may extend beyond effects associated with tidal mixing in the nearshore habitat type About one-third of the energy input to the sea by lunar forcing serves to mix deep-water masses with adjacent waters such as the ACC (Egbert and Ray 2000)

Lunar forcing may reinforce the effects of weather patterns such as the Pacific Decadal Oscillation, PDO, or the El Nino Southern Oscillation, ENSO, on delivery of food and nutrients to surface waters of the ACC The lunar tidal cycle appears to be approximately synchronous with the PDO Changing weather patterns also alter the expression of the ACC (Royer 1981a) and can profoundly alter aspects of circulation (i e upwelling, downwelling) and stability of the photic zone (vertical mixing) (GEM Program Document, Chapter 7 2 2 3)

In addition to the correlative evidence, strong direct evidence from major programs such as FOCI and SEA, as well as from independent investigations, links changes in factors governing the strength of ocean currents to changes in biological production in the GEM habitat types (Bailey et al 1999, Pearcy 2001, GEM Program Document, Chapter 7 10 4) The ever expanding body of scientific observations has been validated in mathematical models of the coupling between processes of biological production (i e primary production, trophic transfers such as grazing and predation and physical processes such as vertical mixing and advection) (GEM Program Document, Chapter 7 10 4, 8, and Appendix F) Taken as a whole, these new insights on how species of larger vertebrates interact with prey, predators and competitors, as well as how these associations among species are ultimately influenced by shifts in ocean climate and human activities, form a new gateway to understanding the ecosystems of the GEM habitat types The mechanisms identified, measured and validated so far all point to factors associated with the dynamics of the Alaska Coastal Current and adjacent waters as sources of the ecological mechanisms controlling biological change in the GEM habitat types These mechanisms work through control of the rate of input and distribution of nutrients and food, with concomitant or subsequent effects on grazing and predator-prey relationships

The Sound Ecosystem Assessment Program, SEA, measured ocean conditions, primary production, distributions of food and predators in the nearshore and ACC habitat types of Prince William Sound Sampling was defined by hypotheses regarding regulation of food production and trophic transfers, and the hypotheses were tested through modeling Forcing by spring winds was found to be instrumental in determining the magnitude in upper-layer zooplankton biomass during the 1990s, and overall, between 1981 – 1997 it is likely that the standing stock of zooplankton in PWS was influenced by both periodic advection and nutrient-constraining processes (Eslinger et al 2001) Linkages of wind forcing, nutrient delivery mechanisms, and advective processes to juvenile pink salmon survival were identified through the profound effects of zooplankton density on feeding behavior of the salmon's predators, and on the growth and behavior of salmon (Willette et al 2001) Processes of starvation and predation vary as the leading mechanisms of mortality for Pacific herring, *Clupea pallasi,* and pink salmon, *Oncorhynchus gorbuscha,* although the timings of critical events differed substantially between the species (Cooney et al 2001a) Further direct evidence linking changes in factors governing the strength of ocean currents to changes in biological production in the GEM habitat types comes from the Fisheries Oceanography Coordinated Investigations, FOCI, in the Shelikof Strait area near Kodiak FOCI has achieved an understanding of the effect of oceanographic conditions as mechanisms controlling survival and recruitment of a commercially exploited fish species (walleye pollock, *Theragra chalcogramma*) The understanding is sufficiently well developed to allow it to contribute to the management of the species (Megrey et al 1996)

ACC Working Concept

The working concept that will be used to guide research and monitoring in the GEM ACC habitat is

> **The Alaska Coastal Current is the region of the GOA through which momentum, energy, nutrients and food originating in deeper waters, waters farther offshore, and upstream are distributed to surface waters, the nearshore, downstream and ultimately to watersheds Distribution mechanisms for nutrients and carbon and pathways are thought to link the offshore to the nearshore and watersheds through the Alaska Coastal Current (GEM Program Document, Chapter 7 6 3) Changes in advective processes within the ACC, brought about by periodic and aperiodic changes in climate, and by periodic changes in the input of energy, control production of animals and structure food webs across all the habitat types on decadal scales by limiting the amounts, distribution mechanisms, rates of distribution, and pathways for nutrients and food**

The ACC potentially is important to the circulation dynamics of PWS, clearly, it is a critical advective and migratory path for material and organisms between the GOA and PWS, and it is likely to play similar roles in lower Cook Inlet, Shelikof Strait and eastern Kodiak A collection of related research questions and hypotheses is included in the GEM Program Document Appendix H Some statements that follow from the ACC working concept are as follows

- Ocean and coastal currents control availability and long-term average rate of delivery of the basic factors essential to animal growth food and energy
- Populations of birds, fish and marine mammals in south-central Alaska are determined by cross-shelf transport of nutrients
- Changing environmental conditions directly alter primary production, which is reflected up through the food chain to affect harvests by top predators, including man
- Organisms are adapted to certain environmental conditions Altered environmental conditions shift the balance and efficiency of ecosystems via survival or migration to affect harvests by top predators

- Data collected from technology placed on vessels of the Alaska Marine Highway system can identify relationships between the ACC and populations of key species and can detect change in these populations as a result of changes in the ACC

Information gaps and questions

At present a relatively large number of relevant surface atmospheric, and marine data gathering projects are active in the ACC habitat type, however most of these are of uncertain duration GEM presently supports two long time series moorings to collect temperature, salinity, fluorescence, and current vectors below the sea surface GEM is developing a project to enhance abilities to use optical data from satellites for modeling efforts Time series from a ship of opportunity for temperature, salinity, fluorescence, zooplankton, and phytoplankton are supported by GEM in the ACC and offshore Other agencies support a variety of projects of limited duration or annually appropriated which collect a wealth of information on physical and biological oceanography, including currents, phytoplankton, zooplankton, and juvenile salmon

Nonetheless, relatively few long-term monitoring projects collecting data below the sea's surface are active, although the National Weather Service marine stations and satellite coverage provide long-term monitoring on atmospheric and sea surface conditions Some types of satellite observations can be occluded by clouds, which is a common event in the Gulf of Alaska (see GEM Program Document, Appendix D and sections below on EVOSTC and Non-EVOSTC ACC-related projects by agency) Measurements of the physical and biological properties and ecological mechanisms that control animal population growth are major gaps in knowledge that need to be filled before the goals of the GEM Program can be attained In a review of fisheries oceanography literature, Cooney et al (2001b) concluded that most studies of fish population recruitment dynamics were unable to explain mechanistic linkages between fish production and changes due to either human actions or natural forcing Where do we look to fill the gaps? Detecting and understanding temporal changes in the strength of downwelling, upwelling vertical mixing, and their effects on the distributions of food and nutrients are essential to understanding changes in populations of birds, fish and mammals Corresponding changes in the distribution of food and nutrients are expected to be expressed in changes in salinity, temperature, marine current vectors, surface wind vectors, and sea level, and are expected to be essential to understanding changes in populations of birds, fish and mammals

Gaps in knowledge on the effects of the ACC and factors that are covariates and proxies for the distribution of nutrients and food in the GEM habitat types extend to important adjacent water bodies, Prince William Sound (PWS), Cook Inlet, and Shelikof Strait For example, much of the available evidence points to PWS as an important part of the GOA ecosystem (cf Eslinger et al 2001), but the biological and physical mechanisms which enable numerous species of organisms and nutrients to be exchanged between shelf waters and PWS are poorly understood PWS has a large central basin of about 60 by 90 km with depths of 350 – 750 m that has been shown to serve as a repository for nutrients and food transported from the ACC and Alaska Current, but the seasonality and sources of variability influencing this exchange are largely unknown (Schmidt 1977, Niebauer et al 1994, Gay and Vaughan 2001, Cooney et al 2001b)

Gaps in knowledge of water circulation patterns within and nearby PWS limit the understanding of what controls biological production of high profile species such as pink salmon and herring in PWS (Cooney et al 2001a) The basic concept that flow of surface waters through PWS is generally counterclockwise with shelf waters entering through Hinchinbrook Entrance in the east and exiting through Montague Strait in the west appears to be an ideal that is often violated (Vaughan et al 2001) The knowledge of the extent and seasonality of communication of PWS water masses with the continental slope through Hinchinbrook Entrance via Hinchinbrook Canyon is vital to understanding origins of biological production in PWS, as well as to understanding the mechanisms by which the rich nutrients and food of the Alaska Current and Subarctic Gyre reach the ACC, nearshore, and watershed habitats (Niebauer et al 1994, Vaughan et al 2001) Is the Hinchinbrook Canyon an advective pathway linking the offshore to the other GEM habitat types? Reliable transport estimates of mass and property exchanges between the sound and the shelf are not available Is it possible to verify the observations of Niebauer et al (1994) that suggest that as much as 40 percent of the sound's volume is exchanged in summer (May – September) and 200 percent of the volume is exchanged in winter (October through April)?

***Example Research Questions** What are the relative roles of local nutrient recycling versus deep-water supply and cross-shelf transport in PWS, Cook Inlet and Kodiak Island? Does the intense upwelling in outer Cook Inlet vary significantly interannually or interdecadally ? Do long-term changes in some tidal nodes (e g , an 18 6-year nodal cycle) affect nutrient supply in this region? Are PWS, Cook Inlet and the Kodiak shelf net importers or net exporters of nutrients, carbon and energy? (See GEM Program Document, Appendix H for additional examples)*

***Example Research Questions** What combinations of physical conditions and primary and secondary production lead to favorable conditions for higher trophic level consumers (fish, birds, mammals), and what is the spatial and temporal variability and frequency of occurrence of these combinations? (Consult GEM Program Document Appendix H, for other examples)*

GEM ACC Research Needs and Schedule

GEM research and monitoring in the ACC has two basic needs The first need is to establish long-time series of physical and biological measurements (temperature, salinity, fluorescence, nitrates, silicates, zooplankton, nekton) on the role of the ACC in transporting nutrients and influencing primary and secondary productivity The variables will be chosen to serve in the GEM model, which serves to develop a comprehensive understanding of the Gulf of Alaska's ecosystems As the cost of making these basic measurements becomes clear through assimilation of data into the GEM model, the frequency and spatial scale of sampling may be adjusted The second need for the GEM ACC program is to develop the GEM model (GEM Program Document, Chapter 8, NRC 2002) through developing the ability for GEM to collaborate with existing programs and models

GEM research needs in the ACC are

Detect Initiate development of the long-time series of physical and biological measurements in the ACC in support of the GEM ecosystem model The GEM Program will continue to work on developing a method for collecting data on the flow of currents into and out of Prince William Sound

Actions in FY 03

- Further develop the Continuous Plankton Recorder, thermosalinograph and fluorometer surveys from Ships of Opportunity
- Monitor nitrate over the shelf and basin as part of the NMFS-OCC/GLOBEC salmon survey in July/August 2003

Proposed Actions in FY 04

- Maintain support for the Seward GAK1 time series, PWS current monitoring, continuous plankton recorder, thermosalinograph, and fluorometer on vessels of opportunity Investigate possibilities for real time data extraction
- Evaluate options for partnering with the Alaska Marine Highway System for thermosalinograph, fluorometer, and eventually nutrient monitoring on ferry routes throughout the northern GOA
- Continue to monitor nitrate over the shelf and basin as part of the NMFS-OCC/GLOBEC salmon survey in July/August 2004

Detect Develop synoptic data on physical oceanography and fisheries dynamics of the ACC in preparation for long-term development of the ability to apply physical oceanographic data to operational fisheries management problems in Cook Inlet

Actions in FY 03

- Initiate development of interdisciplinary fisheries oceanography measurement project at Anchor Point in Cook Inlet to understand dynamics of Alaska Coastal Current in relation to management of sockeye salmon fishery

Proposed Actions in FY 04

- Continue development of interdisciplinary fisheries oceanography measurement project at Anchor Point in Cook Inlet to understand dynamics of Alaska Coastal Current in relation to management of sockeye salmon fishery

Understand

Proposed Actions in FY 04 and beyond

- Long-term understanding will be developed through an ecosystem model that links biological and physical observations across the habitat types and the North Pacific to understand changes in single species of interest to managers and concerned others The understanding includes how natural changes (e g , climate change) will affect the ACC and how changes in the ACC will in turn affect key organisms, i e birds, fish and mammals, and activities, e g , fisheries, of interest to humans

Inform

Actions in FY 03

- Build bridges between the scientific community, which is describing and attempting to predict variation in biological production, and the commercial fishing community in Prince William Sound, which is attempting to find management applications for this new information
- Develop partnerships with fishery managers in Cook Inlet to apply synoptic physical oceanography and fishery catches to regulatory process

Proposed Actions in FY 04

- Develop a web based system for distributing information and peer reviewed, author-attributed data sets from the GEM program
- Establish web pages for each habitat and the GEM Model (Cross Habitat activities) on the EVOS web site Web page to contain relevant EVOS publications, reports, data sets, and other information
- Provide links to web sites displaying graphical information with data from current projects, including Seward Line Station 1 (GAK1), Continuous Plankton Recorder, thermosalinograph and fluorometer

Proposed Actions in FY 05 – FY 07

- Make all data from the ACC projects available as soon as practicable over the web in a format convenient to most users

Solve

Proposed Actions in FY 04

- Initiate GEM biophysical model development
- Continue process of establishing operational fisheries oceanography programs in Cook Inlet Develop relationships with fishery managers in Cook Inlet in preparation for long-term development of fishery management tools, and to coordinate GEM ecosystem model development with fishery management needs

Proposed Actions in FY 05 and beyond

- Combine data on human impacts on fish species (catch) with oceanography and climate to provide advice on when to schedule fishing periods in Cook Inlet
- Develop advice to fishery and hatchery managers in Prince William Sound on prospects for adult returns of pink salmon

Predict All GEM efforts are pointed toward developing a comprehensive understanding of the ecosystems of the Gulf of Alaska that will permit prediction of changes in abundance of valued marine resources

Proposed Actions in FY 05 – FY 07

- Routine short-term predictions, such as timing of arrival of fish on fishing grounds in response to weather patterns shortly before the start of the season, should be possible within about five years, with the first predictions coming as early as FY 05
- Predictions of levels of pink salmon returns to Prince William Sound one year ahead may be possible within the FY 05 – FY 07 time frame, depending on availability of funding Note that the uncertainties associated with a one-year-ahead forecast are many times greater than with a forecast covering a few days or weeks
- Extension of forecasting to other species, and to longer time frames will require decadal scale efforts and patience

EVOSTC ACC-related projects

030614 - A monitoring program for near-surface temperature, salinity, and fluorescence fields in the Northeast Pacific Ocean – S Okkonen The objective for this proposed research is to maintain and upgrade a thermosalinograph and fluorometer, installed on a crude oil tanker, to continue research on acquisition of continuous, long-term measurements of the near-surface temperature, salinity, and fluorescence fields in the Alaska Coastal current and offshore areas of the Gulf of Alaska

030624 - A CPR-Based Survey to Monitor the Gulf of Alaska and Detect Ecosystem Change – S Batten This project continues, and further develops, the Continuous Plankton Recorder surveys from Ships of Opportunity begun in 2000 through the North Pacific Marine Research initiative and continued through 2002 under GEM (project 02624) The project will test the CPR as an almost real-time indicator of ecosystem change across the GoA (the ACC and off-shore)

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Non-EVOSTC projects

Narrative

The monitoring and research efforts of GEM should be viewed within the context of complementary data gathering activities, retrospective data sets and models of potential partner agencies in the Coastal Gulf of Alaska Persons submitting proposals, reviewing proposals, and administering ongoing research and monitoring projects should routinely compare proposed and ongoing activities to the list of Non-EVOSTC projects by agency, as a first step toward the coordination and leveraging goals of GEM for all projects When similar items are found, additional information on the projects is available in databases of GEM and other databases and agencies (i e CIIMMS, PMEL and PICES) through links on the GEM website or directly from the agencies A brief introduction to non-EVOSTC data sources and how they may be used in the GEM ACC Program follows

In the Alaska Coastal Current, projects of the National Marine Fisheries Service, NMFS, provide a wealth of historical and current observations on occurrence and abundance of a large number of fish and invertebrate species In addition NMFS has models of physical and biological oceanography in relation to fisheries, in cooperation with other parts of the National Oceanic and Atmospheric Administration, NOAA Of particular interest for controlling the costs of monitoring in the ACC is the availability of research ship time onto which additional observations might be added Long-term stable research cruises of interest are the vessel-based transects of the Ocean Carrying Capacity Study (NMFS) which cross the continental shelf and shelf break in the Gulf of Alaska, the area and depth stratified trawls of the NMFS biennial survey which cover the shelf and the shelf break to a depth of 1000m, and the vessel-based surveys of the International Pacific Halibut Commission, IPHC on the shelf and coastal embayments throughout the GOA

ACC projects should be cognizant of the opportunities presented by the long-term, real time atmospheric and surface ocean physical data of the National Weather Service (NWS) NWS maintains weather stations of potential interest to GEM on both moorings and coastal land sites The potential for partnering with NWS through the National Data Buoy Center (NDBC) by adding instrumentation to moorings and coastal stations that can be communicated through the real-time data communication systems should be considered when planning new projects or re-evaluating ongoing projects

Limited time length efforts funded by the National Science Foundation (NSF) and other federal entities should be consulted in the preparation and evaluation of GEM proposals and projects For example the short-term efforts of the GLOBEC program (multi-institutional NSF and NOAA-funded) are producing plankton, fish, physical and chemical observations in the ACC and offshore habitat types through calendar 2005 Other NSF-funded programs, such as Gulf of Alaska Recirculation Study (GARS) provide a wealth of information for syntheses, including retrospective analyses, and modeling Another source fixed-term oceanographic and atmospheric data for the Gulf of Alaska is the Oceanic and Atmospheric Research (OAR) arm of NOAA, which has ongoing research interests in the Gulf of Alaska

Remote sensing data sources should be routinely consulted as a means to reduce long-term data acquisition costs for proposed and ongoing GEM activities For example the National Aeronautics and Space Administration (NASA) has compiled time series information on surface sea surface conditions in the Gulf of Alaska through its U S Global Climate Research Program (USCGRP) The National Environmental Satellite Data Service (NESDIS - NOAA) has online terrestrial, coastal and marine data available as free downloads from its National Geophysical Data Center (NGDC) web site

List by agency

IPHC - Long line fishing grid surveys of coastal Alaska
NESDIS - National Geophysical Data Center (NGDC), GSHHS - A Global Self-consistent, Hierarchical, High-resolution Shoreline Database
NMFS - Ocean Surface Current Simulator Model (OSCURS)
NMFS - Ocean Carrying Capacity Study (OCC)
NMFS - Master Oceanographic Observational Data Set (MOODS), Extensive Oceanographic Profile Data, All Oceans
NMFS - West Coast Upwelling Indices Data Files
NMFS - Pavlof Bay Temperature Recording Mooring
NMFS - Shelikof Strait FOCI
NOAA - GLOBEC Northeast Pacific Program Retrospective Analysis of Growth Rate and Recruitment for Sablefish, Anoploma fimbria, from the Gulf of Alaska and the California Current System
NOAA - GLOBEC Northeast Pacific Program Analysis of Ichthyoplankton Abundance, Distribution, and Species Associations in the Western Gulf of Alaska
NOAA - GLOBEC Northeast Pacific Program Long-term Variability in Salmon Abundance in the Gulf of Alaska and California Current Systems
NOAA - GLOBEC Northeast Pacific Program A Retrospective Study of Top Predator Trophic Positions, Productivity, and Growth in the Gulf of Alaska for 1960-75 and 1975-90
NOAA - GLOBEC Northeast Pacific Program Patterns, Sources and Mechanisms of Decadal-Scale Environmental Variability in the Northeast Pacific A Retrospective and Modeling Analysis
NOAA - GLOBEC Northeast Pacific Program Remote Sensing of the Northeast Pacific Retrospective and Concurrent Time Series Analysis Using Multiple Sensors on Multiple Scales
NOAA - GLOBEC Northeast Pacific Program Physical-Chemical Structures, Primary Production and Distribution of Zooplankton and Planktivorous Fish on the Gulf of Alaska Shelf
NOAA - GLOBEC Northeast Pacific Program Retrospective Analysis of Northeast Pacific Microzooplankton
NOAA - GLOBEC Northeast Pacific Program Coupled Bio-Physical Models for the Coastal Gulf of Alaska
NOAA - GLOBEC Northeast Pacific Program Coupled Bio-physical Models for the Coastal Gulf of Alaska
NOAA - GLOBEC Northeast Pacific Program Retrospective Analysis of Northeast Pacific Microzooplankton A Window on Physical Forcing of Food Web Structure
NPRB - A continuous plankton recorder monitoring program for the eastern North Pacific & southern Bering Sea
NWS - Buoy Observations

NWS - Coastal-Marine Automated Network (C-MAN)
NWS - Moored Buoys
NWS - SeaBreeze CD-ROM
OAR (NOAA) - Distribution and Elemental Composition of Suspended Matter in Alaskan Coastal Waters
OAR (NOAA) - On Exchange of Water Between the Gulf of Alaska and the Bering Sea through Unimak Pass
OAR (NOAA) - Gulf of Alaska CTD Data Collected under the Environmental Services Data and Information Management (ESDIM) Data Rescue
OAR (NOAA) - Bering Sea and Gulf of Alaska Winds (1946-1982)
NSF - Gulf of Alaska Recirculation Study (GARS)
NSF - Upper Ocean Circulation in the Subpolar and Northern Subtropical Pacific
USGCRG - Repeat Hydrography and Special Analysis Centre
USGCRG - One-Time Survey Cruise 17N
USGCRG - Subsurface Floats
USGCRG - Surface Drifting Buoys
USGCRG - Joint Archive for Shipboard Acoustic Doppler Current Profilers (ADCP)
USGCRG - Upper Ocean Thermal Data
USGCRG - Sea Surface Salinity
USGCRG - Surface Meteorological Data and Surface Fluxes
USGCRG - Tide Gauges
UAF - GAK 1 TIME SERIES
UAF - Process modeling of the Alaska Coastal Current
UAF - Physical forcing of marine productivity monitoring moorings on the Gulf of Alaska shelf

Nearshore

Current scientific thinking

Basic scientific concepts of how ecosystems in the intertidal and subtidal are structured by physical and biological phenomena have been well developed for some time (GEM Program Document, Chapter 7 9, Ricketts 1939) For the organization of sampling strategies the most fundamental substratum distinctions are hard bottom (rocks, boulders, cobbles) and soft bottom (mobile sedimentary habitats like sands and muds) Within these two types, geomorphology varies substantially, with biological implications that often induce further habitat partitioning (Page et al 1995, Sundberg et al 1996)

Intertidal

The rocky intertidal ecosystem may represent the best understood natural community of plants and animals on earth Ecologists realized more than forty years ago that this system was uniquely well suited to experimentation because the habitat was accessible and basically two-dimensional and the organisms were manipulable and observable Consequently, ecological science has used sophisticated experimental manipulations to produce a detailed understanding of the complex processes involved in determining patterns of distribution and abundance of rocky intertidal organisms (Paine et al 1996, Dayton 1971, Connell 1972, Underwood and

Denley 1984) Plants and animals of temperate rocky shores exhibit strong patterns of vertical zonation in the intertidal zone Physical stresses tend to limit the upper distributions of species populations and to be more important higher onshore, competition for space and predation tend to limit distributions lower on the shore Surface space for attachment is potentially limiting to both plants and animals in the rocky intertidal zone In the absence of disturbance, space becomes limiting, and competition for that limited space results in competitive exclusion of inferior competitors and monopolization of space by a competitive dominant Physical disturbance, biological disturbance, and recruitment limitation are all processes that can serve to maintain densities below the level at which competitive exclusion occurs (Menge and Sutherland 1987) Because of the importance of such strong biological interactions in determining the community structure and dynamics in this system, changes in abundance of certain keystone species can produce intense direct and indirect effects on other species that cascade through the ecosystem (Menge et al 1994, Wootton 1994, Menge 1995, Paine et al 96)

Intertidal communities occupying unconsolidated sediments (sands and muds) are quite different from those found on rocky shores (Peterson 1991) These softbottom communities are composed of infaunal (buried) invertebrates, mobile microalgae, and abundant transient consumers, such as shorebirds, fishes, and crustaceans (Rafaelli and Hawkins 1996) Macroalgae are sparse, and are found attached to large shell fragments or other stable hard substrata In very low energy environments, large plants, such as salt marsh grasses and forbs high on shore and seagrasses low on shore, occur in intertidal soft sediments (Peterson 1991) The large stretch of intertidal soft-sediment shore in between those vegetated zones has an empty appearance, which is misleading The plants are microscopic and productive, the invertebrate animals are buried out of sight The soft-bottom intertidal habitat represents a critically important feeding ground, especially for shorebirds, because the flat topography allows easier access than is provided by steep rocky coasts and because invertebrates without heavy protective calcium carbonate shells are common, particularly polychaetes and amphipods (Peterson 1991)

The intertidal shorelines of the GOA exhibit a wide range of habitat types True soft-sediment shores are not common, except in Cook Inlet Marshes, fine-grained and coarse-grained sand beaches, and exposed and sheltered tidal flats represent a small fraction of the coastline in the GOA Sheltered and exposed rocky shores, wave-cut platforms, and beaches with varying mixtures of sand, gravel, cobble, and boulders are the dominant habitats in this region (Page et al 1995, Sundberg et al 1996) Abundance, biomass, productivity, and diversity of intertidal communities on the shores of the eastern GOA with nearby glaciers are depressed by proximity to sources of runoff from glacier ice melt The islands in PWS and the Aleutian Islands, for example, have richer intertidal communities than the mainland of the northeast GOA, and the intertidal communities of Kodiak and Afognak tend to be richer than those of the Shelikof Strait mainland on the Alaska Peninsula (Bakus 1978, Highsmith et al 1994) Glacier ice melt depresses intertidal biotic communities by introducing turbidity and freshwater stresses

Winter ice scour seasonally denudes epibiota along the Cook Inlet shores (Bakus 1978) Intense wave exposure can cause substratum instability on intertidal cobble and boulder shores, thereby removing intertidal epibiota directly through abrasion (Sousa 1979) Shores with well rounded cobbles and boulders have accordingly poorer intertidal biotas than those with reduced levels of physical disturbance Bashing from logs also represents an agent of disturbance to those rocky shores exposed to intense wave action in this region (Dayton 1971) Consequently, exposed rocky coastlines may experience more seasonal fluctuations in epibiotic coverage than communities on similar substrata in protected fjords and embayments (Bakus 1978)

Subtidal

Although narrow, the shallow subtidal zone in which primary production does occur is of substantial ecological significance Many of these vegetated habitats, especially seagrass beds, macrophyte beds, and kelps, provide nursery grounds for marine animals from other habitats, unique habitat for a resident community of plant-associated animals, feeding grounds for important consumers, including marine mammals, seaducks, and many fishes and shellfishes, and asource of primary production for export as detritus to the deeper unlit seafloor ecosystem (Schiel and Foster 1986, Duggins et al 1989) In the spill area, eelgrass (Zostera marina) beds are common in shallow sedimentary bottoms at the margins of protected embayments (McRoy 1970), whereas on shallow rocky subtidal habitats, the kelps Agarum, Laminaria, and Nereocystis form dense beds along a large fraction of the coast (Calvin and Ellis 1978, SAI 1980, Dean et al 1996a) Productivity estimates in wet weight for larger kelps Nereocystis and Laminaria in the northeastern GOA range up to 37 to 72 kg/m2/yr (O'Clair and Zimmerman 1986) In this shallow subtidal zone, primary production also occurs in the form of single-celled algae These microbial plants include both the phytoplankton in the water column and benthic microalgae on and in the sediments and rocks of the shallow seafloor Both the planktonic and the benthic microalgae represent ecologically important food sources for herbivorous marine consumers The typically high turnover rates and high food value of these microalgal foods in the shallow subtidal zone helps explain the high production of invertebrate and vertebrate consumers in this environment

The sessile or slow-moving benthic invertebrates on the seafloor represent the bulk of the herbivore trophic level in the subtidal ecosystem This benthic invertebrate fauna in the shallow subtidal zone differs markedly as a function of bottom type (Peterson 1991) Rocky bottoms are inhabited by epifaunal benthic invertebrates, such as sponges, bryozoans, barnacles, anthozoans, tunicates, and mussels Sand and mud bottoms are occupied largely by infaunal (buried) invertebrates, such as polychaete worms, clams, nematodes, and amphipods The feeding or trophic types of benthic invertebrates vary with environment, especially with current flow regime (Rhoads and Young 1970) Under more rapid flows, the benthos is dominated by suspension feeders, animals extracting particulate foods out of suspension in the water column Under slower flows, deposit feeders dominate the benthos, feeding on organic materials deposited on or in the seafloor

The benthos also includes some predatory invertebrates, such as sea stars (for example, leather star, *Dermasterias imbricata*, and sunflower star, *Pycnopodia helianthoides*), crabs (for example, helmet crab, *Telmessus cheiragonus*), some gastropods, and some scavenging invertebrates (Dean et al 1996b) Benthic invertebrates of soft sediments are distinguished by size, with entirely different taxa and even phyla occurring in the separate size classes Macrofauna include the most widely recognized groups such as polychaete worms, clams, gastropods, amphipods, holothurians, and seastars (Hatch 2001, Driskell et al 1996)

Meiofauna include most prominently in the GOA nematodes, harpacticoid copepods, and turbellarians (Feder and Paul 1980) Finally, microfauna include most prominently foraminifera, ciliates, and other protozoans Because the actual species composition of the benthos changes with water depth, the shallow and deep subtidal benthic faunas in the spill zone hold few species in common Soft sediment communities of Alaska are best described and understood in various locations within PWS, as a consequence of the intense study after the oil spill

The shallow subtidal rocky shores that are vegetated also include suites of benthic invertebrates unique to those systems These benthic invertebrates either directly consume the large plants, such as sea urchins, or else are associated with the plant as habitat Those species that depend upon the plant as habitat, such as several species of amphipods, crabs and other crustaceans, gastropods, and polychaetes, often are grazers as well, taking some mixture of macrophytic and epiphytic algae in their diets Grazing by sea urchins on kelps is sufficiently intense in the absence of predation on the urchins, especially by sea otters in the spill area, to create what are known as "urchin barrens" in which the macrophytic vegetation is virtually removed from the seafloor (Estes and Palmisano 1974, Simenstad et al 1978) In fact, this shallow subtidal community on rocky shores of the GOA represents the best example in all of marine ecology of a system controlled by top-down predation Sea otters control abundance of the green sea urchin, Strongylocentrotus droebachiensis When released from that otter predation, sea urchin abundance increases to create fronts of urchins that overgraze and denude the kelps and other macroalgae, leaving only crustose forms behind (Simenstad et al 1978) This loss of macroalgal habitat then reduces the algal associated invertebrate populations and the fishes that use the vegetated habitat as nursery These reductions in turn can influence productivity and abundance of piscivorous seabirds (Estes and Palmisano 1974) Recently, reduction of traditional marine mammal prey of killer whales has induced those apex consumers to switch to eating sea otters in the Aleutians, thereby extending this trophic cascade of strong interactions to yet another level (Estes et al 1998, Estes 1999) Consequently, the shallow subtidal community on rocky shores of the GOA is strongly influenced by predation and provision of biogenic habitat (Estes and Duggins 1995) Human disruption of the apex predators by hunting them (as historically occurred on sea otters [Simenstad et al 1978]) or by reducing their prey (as may conceivably be occurring in the case of the Steller sea lions and harbor seals through overfishing their own prey fishes [NRC 1996]) has great potential to create tremendous cascading effects through the shallow subtidal benthic ecosystem Furthermore, if concentration and biomagnification of organic contaminants such as PCBs, DDT, DDE, and dioxins in the tissues of apex predators, in particular in transient killer whales (Matkin unpublished data), causes impaired reproductive success, then human industrial pollution has great potential to modify these coastal subtidal communities on rocky shores

The shallow subtidal community on rocky shores of the GOA is also strongly influenced by larval distribution and recruitment Recent studies by Partnership for the Interdisciplinary Study of Coastal Oceans (PISCO) (see GEM Program Document, Appendix A for web link) have shown that not only are the effects of competition and predation important in structuring benthic communities, but the sources and sinks of larvae are equally important Larval abundance and behavior, where they come from, how they respond to ocean conditions, where they are retained, where they are reflected, and the dynamics regulating their recruitment are all important processes that ultimately control what lives where Furthermore, knowledge about life histories is insufficient to make broad generalizations about the successes and failures of recruitment events

The shallow subtidal benthic communities in soft sediments of the GOA region function somewhat differently from their counterparts on rocky substrata These communities are important for nutrient regeneration by microbial decomposition and for production of benthic invertebrates that serve as prey for demersal shrimps, crabs, and fishes In some protected areas within bays, however, the shallow subtidal benthos is structured by emergent plants, specifically eelgrass in the GOA These eelgrass beds perform ecological functions similar to those of macrophyte-dominated rocky shores, namely nursery functions, phytal habitat roles, feeding grounds, and sources of primary production (Jewett et al 1999) In the vegetated habitats of the shallow subtidal zone, the demersal fish assemblage is typically more diverse than and quite different from the demersal fishes of the deeper subtidal zone (Hood and Zimmerman 1986) In eelgrass (Zostera) beds as well as in the beds of small kelps and other macrophytes (Agarum, Nereocystis and Laminaria) in the GOA, juveniles of many species that live in deeper waters as adults use this environment as a nursery for their young because of high production of food materials and protection from predators afforded by the shielding vegetation (Dean et al 2000) Furthermore, several fishes are associated with the plant habitat itself, including especially pickers that consume crustaceans and other invertebrates from plant surfaces, a niche that is unavailable in the absence of the vegetation Both types of vegetated habitats in the shallow subtidal zone of the GOA contain larger predatory invertebrates, specifically seastars and crabs In some cases, the same species occupy both eelgrass and kelp habitats (Dean et al 1996)

Nearshore working concept

The working concept that will be used to guide research and monitoring in the GEM nearshore habitat is

> **Biological production and the structure of food webs in nearshore environments are controlled by local primary production, import of nutrients and food from watersheds, the Alaska Coastal current and the offshore, as influenced by predation, physical, and anthropogenic factors**

Information gaps and questions

The consequences of change caused by various natural and human-driven factors on the structure and dynamics of the rocky intertidal communities are not well developed in the scientific literature For example, human harvest by fisheries or subsistence users of important apex predators that exert top-down control on intertidal communities could cause substantial cascading effects through the system But the seastars and gastropods that are the strong predatory interactors in this community in the GOA region are not targets for harvest The mussels that are taken in subsistence harvest provide important ecosystem services as structural habitat for small invertebrates (Suchanek 1985), as a dominant space competitor (Paine 1966), and as a widely used prey resource (Peterson 2001), but mussels do not appear limited in abundance in the GOA region Perhaps some other harvested sessile invertebrate species, such as the black gumboot, would provide a more sensitive measure of long-term human impacts?

Little information exists on the dynamics of long-term change in structure and composition of intertidal communities in soft sediments anywhere Some of the best understanding of important processes actually comes from the northern GOA region The Alaska earthquake of 1964 had a tremendous influence on soft-sediment intertidal communities because of the geomorphological modifications of habitat (NRC 1971) Uplift of the shoreline around Cordova, for example, was great enough to elevate the sedimentary shelf habitat out of the depth range that could be occupied by many species of clams Clam populations in Cordova, a town once called the clam capital of the world, have never recovered from the earthquake The re-invasion of sea otters has similarly caused tremendous changes in clam populations in shallow soft-sediment communities of the northern GOA, mostly in subtidal areas, but also in intertidal sedimentary environments (Kvitek et al 1992)

Long-term nearshore monitoring programs exist in Cook Inlet (Kachemak Bay and Kasitsna Bay) and Prince William Sound (PWSRCAC multiple localities, Alyeska Valdez Arm, National Mussel Watch multiple localities) No program that is coordinated throughout the GEM region is presently operational Existing projects are targeted at human effects, or natural effects, but not both in the same locality

Current scientific thinking on what to study in the nearshore for GEM is guided by the results of an expert consultation and public involvement process (Schoch et al 2002a)

Answers are needed to the following questions

Is long-term monitoring of attributes (plants, animals, sediments, physical oceanography) of soft substrates, hard substrates, or some combination of the two likely to provide the best signal of decadal scale variability due to natural sources?

In consideration of existing programs and sampling strategies (NMW, PWSRCAC, OSRI, KBRR, USGS, PISCO), what are the appropriate localities and variables for detecting decadal scale changes in species diversity and productivity in the GEM region?

What are the best measures of human impacts over decadal scales what are these impacts, other than harvest, trampling, hydrocarbon pollution and organic enrichment?

How much more detailed shore zone mapping of which portions of the nearshore is needed in order to select GEM nearshore monitoring sites?

GEM Nearshore Research Needs and Schedule

The basic need for nearshore research and monitoring activities is a geographically distributed network capable of measuring decadal scale changes in oceanographic variables, habitat type, benthic community structure, human use, contaminant levels, and abundance of selected marine plants, mammals, birds, shellfish and fishes GEM needs to develop a combination of synoptic, intensive, and extensive sites to monitor the above components at nested scales of space and time (Schoch et al 2002b) Intensive sites would be used for process oriented studies and to address questions linked to Gulf-wide hypotheses bearing on Cross Habitat connections The purpose of extensive sites is to monitor key components of the ecosystem over larger spatial scales, i e study more sites less intensively These sites would be used for pattern oriented studies and for addressing issues of concern to the local community Developing means of matching sampling frequency to the appropriate temporal scale for the variables of interest is essential Some portion of the sampling effort may be event driven

Variables selection in the nearshore will be guided by the GEM model (GEM Program Document, Chapter 8, NRC 2002), which serves as a repository for the current comprehensive understanding of the Gulf of Alaska's ecosystems As the cost of making these basic measurements becomes clear through assimilation of data into the GEM model, the frequency and spatial scale of sampling may be adjusted

In chronological order, GEM research needs are

Detect To detect decadal scale changes in species diversity and productivity in the nearshore in the GEM region, in consideration of existing programs and sampling strategies (NMW, PWSRCAC, OSRI, KBRR, USGS, PISCO) and using the best signal of decadal scale variability due to natural sources What are the appropriate localities and variables for detecting changes in attributes (plants, animals, sediments, physical oceanography) of soft substrates, hard substrates, or some combination of the two?

Actions in FY 03

- Develop a comprehensive historical perspective of locations and types of past studies conducted in the nearshore marine communities within Gulf of Alaska, and develop estimates of costs for each element of a proposed monitoring program
- Initiate nearshore biodiversity studies along a pole-to-pole latitudinal gradient by applying protocols developed under the Census of Marine Life program
- Evaluate the relative roles of natural factors (predation, grazing & natural variability) and anthropogenic impacts (harvest) in altering intertidal community structure, using the black chiton, *Katharina tunicate,* as a model
- Collect baseline hydrocarbon data in mussel tissue and subtidal sediments that can be used to determine human impacts on the ecosystem
- Develop pilot monitoring project for soft bottom habitats
- Work with partners to identify coastal habitat mapping needs

Proposed Actions in FY 04

- Provide habitat mapping as necessary to support site selection for nearshore monitoring
- Continue projects to develop nearshore sampling sites
- Continue investigations of measures of human impacts (harvest and PAH)

Inform Develop a web based system for distributing information and peer reviewed author-attributed data sets from the GEM program

Proposed Actions in FY 04

- Establish web pages for each habitat and the GEM Model (Cross Habitat activities) on the EVOS web site Web page to contain relevant EVOS publications, reports, data sets, and other information
- Coordinate and facilitate interaction among investigators in nearshore projects to plan for FY 05 Invitation for Proposals

EVOSTC nearshore projects

A large growth in knowledge of the benthos of the GOA region was triggered by the EVOS in 1989 This work had broad geographic coverage of the rocky intertidal zone The area receiving the most intense study was PWS, where the spill originated Geographic coverage also included two other regions, the Kenai Peninsula-lower Cook Inlet and the Kodiak archipelago-Alaska Peninsula (Page et al 1995, Gilfillan et al 1995a, Gilfillan et al 1996b, Highsmith et al 1994, Highsmith et al 1996, Houghton et al 1996a, Houghton et al 1996b, Sundberg et al 1996) Some of this benthic study following the oil spill was conducted in other habitats (soft substrata [Driskell et al 1996]) and at other depths (shallow and deep subtidal habitats [Houghton et al 1993, Armstrong et al 1995, Dean et al 1996a, Dean et al 1996b, Dean et al 1998, Dean et al 2000, Feder and Blanchard 1998, Jewett et al 1999]) Herring Bay on Knight Island in PWS was a site of especially intense monitoring and experimentation on rocky intertidal communities following the oil spill (van Tamelen et al 1997)

030687 - Monitoring in the Nearshore A Process for Making Reasoned Decisions – J Bodkin and J Dean
Status This is a one-year project that began in FY 03 This project will develop a comprehensive historical perspective of locations and types of past studies conducted in the nearshore marine communities within Gulf of Alaska, and develop estimates of costs for each element of a proposed monitoring program

030666 - Alaska Natural Geography in Shore Areas An Initial Field Project for the Census of Marine Life – B Konar
Status This is a 3-year project which will receive its first year of funding in FY 03 The project will initiate near-shore biodiversity studies along a pole-to-pole latitudinal gradient by applying protocols developed under the Census of Marine Life program

030647 - Investigating the Relative Roles of Natural and Shoreline Harvest in Altering the Community Structure, Dynamics, and Diversity of the Kenai Peninsula's Rocky Intertidal – J Ruesink
Status This is a 2-year project that began in FY 03 This project will evaluate the relative roles of natural factors (predation, grazing & natural variability) and anthropogenic impacts (harvest) in altering intertidal community structure of the black chiton, *Katharina tunicata*

030623 - PWSRCAC-EVOS Long Term Environmental Monitoring Program – J Devens
Status This project was funded for one year beginning in FY 03 The project objective is to provide a program for the collection of baseline hydrocarbon data in mussel tissue and subtidal sediments that can be used to determine impacts of oil sources on the ecosystem It is expected that the data from this project will assist in identifying potential monitoring sites for the GEM nearshore program

030556 - High Resolution Mapping of the Intertidal and Shallow Subtidal Shores in Kachemak Bay – C Schoch
Status This is a continuation of a field mapping project started in FY 02 This project will complete the field mapping and begin building a database of the geomorphology and physical attributes of shallow subtidal and intertidal habitats for the greater Kachemak Bay/Lower Cook Inlet area It is expected that the data from this project will assist in identifying potential monitoring sites for the GEM nearshore program

02613 - Mapping Marine Habitat –Prince William Sound to McCarty Fjord – J Harper

Status This project conducted aerial video mapping of the coastal areas of the outer Kenai coast (McCarty Fjord to Prince William Sound) at extreme low tides employing the shore zone mapping protocols of the Washington ShoreZone mapping project, incorporating all of their features and new ones appropriate for Alaska The results of this project will be available in December 2002 It is expected that the data from this project will assist in identifying potential monitoring sites for the GEM nearshore program

02395 - Planning for Long-Term Monitoring in the Nearshore Designing Studies to Detect Change and Assess Cause – C Schoch
Status This project produced a draft nearshore monitoring plan that provides a framework for future monitoring that focuses on tractable components of the nearshore, and is statistically sensitive to temporal and spatial change The plan is currently undergoing peer review

Non-EVOSTC projects

Narrative

The monitoring and research efforts of GEM should always be viewed through the complementary data gathering activities, retrospective data sets and models of potential partner agencies in the Coastal Gulf of Alaska Persons submitting proposals, reviewing proposals, and administering ongoing research and monitoring projects should routinely compare proposed and ongoing activities to the list of Non-EVOSTC projects by agency, as a first step toward the coordination and leveraging goals of GEM for all projects When similar items are found, additional information on the projects is available in databases of GEM and other agencies (CIIMMS, PMEL and PICES) through links on the GEM website or directly from the agencies A brief introduction to non-EVOSTC data sources and how they may be used in the GEM nearshore habitat type follows

Understanding of community composition and seasonal dynamics of GOA benthos was greatly enhanced over the past thirty years by research related to exploration and development of the oil and gas resources of the region MMS, NOAA NMFS, and Alyeska funded geographically focused benthic survey and monitoring work in the 1970s This work provided the first windows into the quantitative benthic ecology of the region Focus was most intense on lower Cook Inlet, the Aleutian Islands, the Alaska Peninsula, Kodiak Island, and northeast GOA, including the Valdez Arm in PWS (Rosenberg 1972, Hood and Zimmerman 1986)

Currently long-term nearshore monitoring programs exist in Cook Inlet (Kachemak Bay and Kasitsna Bay) and Prince William Sound (PWSRCAC multiple localities, Alyeska Valdez Arm, National Mussel Watch multiple localities)

List by agency

ADF&G - Kitoi Bay Monitoring Center for Alaskan Coastal Studies - Coast Walk program for Kachemak Bay
NOAA - Mussel Watch Project
KBRR - NOS monitoring
UAF - Kasitsna Bay monitoring
PWSRCAC - PAHs in mussels

Watersheds

Current scientific thinking

The importance of marine inputs to the watershed phase and of terrestrial inputs to the marine phase of regional biogeochemical cycle (GEM Program Document, Chapter 7 4 2 3 and 7 5) has been recognized for some time (Mathisen 1972, Chisholm 2000) For further discussion of effects of terrestrial exports to the marine environment see the "Current scientific thinking" section in the nearshore habitat type Comparison of paleoecological records spanning 2,200 yrs before present from anadromous and nonanadromous lakes using proxies of salmon abundance (^{15}N and diatom species composition) to the northern Gulf of Alaska (Karluk and Fraser Lakes on Kodiak Island) show the potential impact of salmon derived nutrients on freshwater ecosystems in the region (Finney et al 2002) The higher incidence of ^{15}N indicative of higher salmon abundance in Karluk Lake was coincident with species of diatoms that are favored by eutrophic conditions Oligotrophic species of diatoms were coincident with lower ^{15}N Levels of ^{15}N were much lower in the nonanadromous Fraser Lake, where diatom species characteristic of oligotrophic circumstances were prevalent for almost the entire 2,200 year record Artificial introduction of salmon to Fraser Lake, starting during the 1950s, were coincident with rises in ^{15}N and changes in species composition of diatoms In an earlier paleoecological study of the same localities, Finney et al (2000) speculated that commercial fisheries that started at the end of the nineteeth century were responsible for the downward trend in observed levels of ^{15}N in Karluk Lake from the late 1800s to present

The results from paleoecological studies are confirmed by empirical evidence from experiments and direct observations in artificial and natural streams *Chlorophyll a* and the biomasses of the biofilm (bacteria and molds) and aquatic macroinvertebrates, such as insects, increase as the amount of salmon carcass biomass increases *Chlorophyll a* has been observed to increase over the full range of carcass biomass, whereas increases in macroinvertebrates stop at some limiting value of carcass loading (Wipfli et al 1998, Wipfli et al 1999) Salmon carcasses stimulate production of multiple trophic levels, including decomposers, in watersheds by providing carbon and nutrients In earlier studies of an Alaskan stream containing Chinook salmon, Piorkowski (1995) supported the hypothesis of Wipfli et al (1998) that salmon carcasses can be important in structuring aquatic food webs In particular, microbial composition and diversity may determine the ability of the stream ecosystem to use nutrients from salmon carcasses, a principal source of marine nitrogen (GEM Program Document, Chapter 7 5) Marine nutrients and carbon move from the marine environment into terrestrial species in the watersheds of the GOA (Wipfli et al 1999), as has been shown to be the case in anadromous fish-bearing watersheds elsewhere in the north Pacific region (Bilby et al 1996)

All available evidence supports the concept that freshwater food webs in anadromous watersheds in the northern Gulf of Alaska and elsewhere are likely to be dependent to some extent on inputs of marine derived nutrients (MDN) It has been shown that a wide variety of terrestrial species that occur in the region bear MDN (^{15}N), such as river otter (Ben-David et al 1998b), coastal mink (Ben-David et al 1997a), riverine mink (Ben-David et al 1997), wolf (Szepanski et al 1999), and marten (Ben-David et al 1997b), and riparian plants such as trees (Bilby et al 1996) In a recent study of a salmon bearing stream in Washington State, Jauquet et al (2002) documented the feeding of 30 species of birds, mammals, invertebrates, and fungi on chum salmon carcasses In theory, any terrestrial plant or animal species that feeds in the marine environment or receives nutrients from anadromous fish, such as Harlequin duck or Sitka spruce, is a pathway to the watersheds for marine carbon and other elements in the form of nutrients

Human activities in watersheds can change the amounts and timing of release of nutrients in watersheds from the terrestrial system into rivers and lakes by changing the seasonal and geographic patterns of runoff (Gordon et al 1992, Leopold et al 1995), destroying habitat for nodulated (nitrogen fixing) plants such as alders and lichens (Gunther 1989, Helfield and Naiman 2002), applying fertilizers to lawns and crops, and removals of anadromous fish such as eulachon and salmon The nitrogen associated with human activities comes from atmospheric sources (^{14}N), with the exception of impacts on anadromous sources, which involve changing levels of ^{15}N

Studying the levels of marine derived isotopes is the most certain way to distinguish between the biological effects of marine and freshwater processes Watersheds and the adjacent marine areas of the nearshore, the Alaska Coastal Current and the offshore are subject to common climatic forcing The effects of the cool ACC and the warmer Alaskan Stream moderate air temperatures GOA ocean temperatures are important in determining climate in the fall and early winter in the northern GOA and may be influential at other times of the year Because the cool glacially influenced waters of the ACC moderate air temperatures along the coast, the strength and stability of the ACC are important in determining climate in adjacent land areas, which means both watersheds and marine ecosystems are subject to common climatic forcing Primary natural forces are winds, tides, precipitation, and insolation

Since many of the major watersheds in the GEM region are in populated areas, they tend to be areas of relatively intense data collection by many different public and private entities Nonetheless, a major gap in knowledge that is not presently being addressed by anyone is the extent to which the functioning of specific watersheds in the GEM region may depend on marine inputs The available body of scientific evidence makes it clear that marine derived nutrients and carbon can be very important to the structure and function of ecosystems in the watersheds However, very little relevant data have been collected in watersheds of the GEM region that permit detection and understanding of these linkages

Watershed working concept

The working concept that will be used to guide research and monitoring in the GEM watershed habitats is

> **Ocean and coastal currents, especially the ACC, influence biological production in coastal watersheds by controlling availability and long-term average rate of delivery of marine nutrients and carbon to watershed flora and fauna and by controlling availability of nutrients and food in the marine habitats frequented by watershed species In turn, watersheds influence biological production in nearshore environments through the export of nutrients, food and pollutants**

Watershed research and monitoring activities will be focused on establishing the degree to which levels of the isotopes common in the marine environment (carbon, nitrogen and sulfur), as measured in the tissues of plants and animals in watersheds, vary annually in response to annual variations in the input of anadromous species A component of the nearshore research is to look at the influence of watersheds on the nearshore

The following statements are based on the working concept

- Levels of the isotopes of carbon, nitrogen and sulfur common in the marine environment, as measured in the tissues of plants and animals in watersheds, vary annually in response to annual variations in the input of anadromous species
- Plant and animal species may vary in the ratio of marine to non-marine isotopes (C, N, S) within watersheds due to their feeding habits and preferred feeding locality within the watershed Examples of some species of interest which are expected to be different from one another in isotopic composition are willow (*Salix* spp), banded kingfisher (?), dipper (?), northern pike (*Esox* spp), and sockeye salmon (*Oncorhynchus nerka*)
- Plant and animal species may vary in the ratio of marine to non-marine isotopes (C, N, S) among watersheds due to the relative magnitude of terrestrial or atmospheric inputs, which is in turn related to the species composition and abundance of plant species For example, the relative importance of atmospheric nitrogen is proportional to the activity of nodulated (nitrogen-fixing) plant species such as alders Species such as juvenile sockeye salmon and stickle backs should differ in isotopic composition among watersheds in highly forested watersheds such as the Kenai River, and in recently glaciated watersheds such as Delight and Desire Lakes
- Existing water quality monitoring programs may have information on nitrates and ammonium that would serve to establish marine linkages Elevated nitrates and/or ammonium at certain localities and times of the year may provide an indication of levels of spawning anadromous fish
- Nourishment of watershed flora and fauna from marine sources means that freshwater production can be determined to some extent by the magnitude of marine inputs to freshwater habitats
- Nearshore production and community structure are influenced by transfers from the watershed of water, limiting nutrients, sediment, and organisms These exchanges are measurable, for example, as signatures in isotopic composition, sediment records, tree rings, otoliths, and population records The timing of glaciation, through its effect on abundance and species composition of riparian and other terrestrial vegetation in the watershed, should determine the relative composition of marine isotopes in the tissues of plants and animals

Information gaps and questions

No monitoring projects for marine-related linkages are presently operational, and only one research project (02649 Reconstructing Sockeye Populations in the Gulf of Alaska over the Last Several Thousand Years The Natural Background to Future Changes) is directly measuring marine-related phenomena in the GEM area watersheds This is a retrospective study of sockeye abundance in Prince William Sound and the Kenai River watershed using the stable isotope tracers present in the sediments of spawning lakes The goal is to describe changes in sockeye salmon abundance over the last several millennia and to relate these changes to shifts in the climate/ocean system of the GOA and to human activities

A second project (02612 Detecting and Understanding Marine-Terrestrial Linkages in a Developing Watershed Nutrient Cycling in the Kenai River Watershed) has recently been completed This project has developed a draft Kenai River Watershed Study Plan that describes an integrated and interdisciplinary approach for understanding nutrient and energy pathways and terrestrial-aquatic linkages in the Kenai River Watershed When final, the study is expected to contribute to the design of sampling for marine-related nutrients and food sources in the Kenai River watershed

GEM Watershed Research Needs and Schedule

The focus of the GEM watershed program will be to conduct research on how to measure the known marine related indicators stable isotopes of carbon, nitrogen and sulfur (C, N, S) and proxies for marine related sources of nutrients and food Answers are needed to the following questions What are the best indicators? Are C, N, and S equally useful as indicators of marine linkages in all types of watersheds? Are concentrations of nitrates and ammonium in freshwater suitable proxies for stable isotopes? Are there other suitable proxies for marine-related indicators? What is the variability of marine related indicators in bodily tissues among species within watersheds? Which species or species guilds are best suited to measuring marine linkages? How do suitable species vary among different types of watersheds, i e , heavily forested, anadromous, non-anadromous, recently glaciated, heavy human development, pristine, and so forth? What are the indicators of terrestrial influences in nearshore marine environments?

Detect In concert with the development of the GEM biophysical model, a monitoring program to detect annual changes in levels of marine nutrients and carbon on biologically meaningful time and space scales in selected watersheds is to be designed and developed Sampling of terrestrial signals in nearshore areas adjacent to watersheds may be incorporated Sampling strategies must show how, if key variables are measured, recorded and made available to researchers with the proper spatial scale, temporal scale, cost effectiveness and technology, they will detect changes in the GEM ecosystem Watersheds should be selected to permit such comparisons as volcanic to non-volcanic, heavily forested to recently glaciated, anadromous to non-anadromous, and developed to pristine

Actions in FY 03

- Provide bridge funding for Ninilchik River water flow gauge to allow time for permanent non-GEM funding to be obtained for stream flow recording
- Use cores of sediments from sockeye-bearing lakes on the Kenai Peninsula and Prince William Sound to understand the natural variability of production in these systems in the distant past (up to 5,000y)
- Participate in multi-institutional effort to plan watershed research in the Kenai River watershed in order to identify research opportunities and partners for GEM

Proposed Actions in FY 04

- Complete work and analyze cores of sediments from sockeye-bearing lakes on the Kenai Peninsula and Prince William Sound to understand the natural variability of production in these systems in the distant past (up to 5,000y)

- Identify and demonstrate statistically rigorous sampling strategies for detecting marine signals and proxies from plants and animals in the marine watersheds and nearby nearshore areas
- Identify and demonstrate cost effective community based sampling strategies for citizen monitoring of marine-related variables and proxies in watersheds and nearby nearshore areas Action is to demonstrate how to incorporate proven approaches to community based monitoring of the aquatic environment, including QA/QC of citizen monitoring data

Proposed Actions in FY 05

- In those instances where the marine signal can be reliably and precisely measured, perform statistical design work, based on the data already collected to allow understanding of how much it would cost to field monitoring studies to detect changes of certain magnitudes in the marine signal on various temporal and spatial scales
- Identify and develop measures of human effects that can be applied in all watersheds where marine related variables are being developed

Proposed Actions in FY 06 – 07

- Using statistical methods and the watershed component of the GEM biophysical model determine the efficacy of isotopic and proxy measures of MDN as an indicator of change in key watersheds across the GEM region
- Use watershed component of GEM biophysical model to begin development of a plan and cost estimates for a broad based systematic network to collect marine-related variables and proxies and essential physical data that focuses comprehensive coverage (many variables, high precision) on a few key watersheds and synoptic coverage (few variables, lower precision) on a wide variety of watersheds across the GEM region
- Promote and facilitate partnerships with agencies, NGOs, and community groups to close gaps in comprehensive data collection of marine related variables in key watersheds identified by the biophysical modeling Understand To understand origins of long-term natural variation in key physical, chemical, and biological variables in coastal watersheds of the GEM region

Understand To understand if proximate human influences are perturbing key physical, chemical, and biological variables beyond the range of natural variation in coastal watersheds of the GEM region

Proposed Actions in FY 05

- Initiate development of watershed component of the GEM biophysical model to advise on sampling strategies for marine related nutrients and food in watersheds In support of GEM watershed modeling, develop, obtain, or identify a readily accessible GIS or web-based database of existing anadromous fish productivity data in the GEM region and determine where there are gaps in the spatial coverage, variables measured, and quality of data

Proposed Actions FY 06 -07

- Implement more detailed modeling and data assimilation experiments Basic statistical and ecosystem modeling of the species and processes involved in the input of marine nutrients and carbon is implemented to refine the concepts of biologically meaningful marine related variables, and to assimilate data to refine the sampling design

Inform Develop a web based system for distributing information and peer reviewed author-attributed data sets from the GEM program

Proposed Actions in FY 04

- Establish web pages for the Watershed habitat and the GEM Model (Cross Habitat activities) on the EVOS web site Web page to contain relevant EVOS publications and reports and other information

Proposed actions in FY 05 – 07

- Hold regular work-sessions where researchers of GEM watersheds can collaborate on methods, analysis, and modeling efforts

Solve Develop tools, technologies and information that can help resource managers and regulators collect data on key physical, chemical, and biological variables in coastal watersheds of the GEM region and improve management of marine resources and address problems that may arise from human activities

Proposed Actions in FY 04 – 07

- Investigate opportunities to improve and/or extend the quality and availability of existing community based data collection projects for key physical, chemical, and biological variables in coastal watersheds of the GEM region
- Participate with regional partners the development of a strategic plan for use and improvements to remote sensing data acquisition, analysis, and modeling of coastal watersheds of the GEM region

Proposed Actions in FY 07

- Apply models to begin process of developing watershed management products in cooperation with community groups and management agencies

EVOSTC watershed-related projects

In FY 03, complete Kenai River Watershed planning effort FY 04 initiate research efforts to measure basic marine signals in selected watersheds

02612 Detecting and Understanding Marine-Terrestrial Linkages in a Developing Watershed Nutrient Cycling in the Kenai River Watershed – A Mazumder

Status A draft Kenai River Watershed Study Plan has been prepared and is undergoing peer review

02649 Reconstructing Sockeye Populations in the Gulf of Alaska over the Last Several Thousand Years The Natural Background to Future Changes – B Finney

Status Equipment failure has delayed completion of the coring until Spring 2003

Non-EVOSTC projects

Narrative

The monitoring and research efforts of GEM are to be viewed through the complementary data gathering activities, retrospective data sets and models of potential partner agencies in the Coastal Gulf of Alaska Persons submitting proposals, reviewing proposals, and administering ongoing research and monitoring projects should routinely compare proposed and ongoing activities to the list of Non-EVOSTC projects by agency, as a first step toward the coordination and leveraging goals of GEM for all projects When similar items are found, additional information on the projects is available in databases of GEM and other agencies (CIIMMS, PMEL and PICES) through links on the GEM website or directly from the agencies A brief list of the dominant non-EVOSTC data sources for watersheds in the GEM region follows as an entry point to the larger data bases

List by agency

Cook Inlet Keeper Lower Kenai Peninsula Watershed Health Project

ADF&G - Sonar Enumeration of Returning Adult Salmon

ADF&G - Catalog of Waters Important for the Spawning, Rearing, or Migration of Anadromous Fishes

ADF&G - Weirs and Counting Towers for Enumeration of Returning Adult Salmon, Escapement

ADF&G - Aerial / Foot Surveys of Spawning Streams, Salmon Escapement

USDOI - Hydrologic Data Collection and Investigations

Offshore

The offshore program for the foreseeable future will consist of observations on plankton, temperature, salinity and fluorescence collected from ships of opportunity, as described in the Alaska Coastal Current (ACC) habitat The development of the offshore program needs to await further developments of data in the other habitat types and the development of the GEM model

Data Management and Information Transfer

The GEM data management project presents a unique challenge for data-systems development When fully implemented, GEM will be a long- term monitoring program annually producing a large array of datasets which need to be incorporated into a system which provides selective accessibility to the data contained within The GEM system must supply users and other data warehouse systems a transparent view of the data outside of the confines of the individual datasets The system must be highly scalable and flexible but still provide structured descriptors in lookup tables for expediting all inclusive queries Thematic, semantic, and syntactic metadata and geo-referencing must be incorporated as an essential part of the architecture of the system The system must also act as a robust and conciete data archive to ensure integrity and longevity of the data itself

The GEM data management system must address the issues related to the data types supplied by the observational component and the demand placed by the applications component As such, the data management system is positioned between these two components and must develop and maintain an interface to both In addition, modeling and map creation applications will generate new data that will also be archived and delivered by the GEM data system More detailed information on data management and information transfer can be found in Chapter 9 of the GEM Program Document

Primary System Requirements

Flexibility

For the most part, GEM data sets will be non-homogenous, independent, and unique from each other Datasets could consist of physical measurements, taxonomic measurements, in addition to unforeseen types, or combinations of all three The GEM data system must be able to accommodate foreseen data in addition to allowing for the absorption of unknown data and information types The system must be able to absorb all GEM data in structured form associated with descriptive syntactic and thematic meta-data to allow facilitation of queries

Scalability

Due to the nature of the GEM project, its data system must be capable of easily absorbing multiple heterogeneous datasets each year Over the years the number of datasets could rise into the thousands and comprise a data warehouse of a billion or more records The data system must be inherently scalable and capable of easily absorbing new datasets into the system with minimal required maintenance Data incorporation must be simple, automatic and straightforward

Metadata

Data is useless in today's scientific world without its complementary metadata Syntactic, semantic, and thematic metadata must be an integral part of the GEM data system and accessibility to it must exist via simple pathways Syntactic Metadata describes programmatic/computational technical characterization of data and can include but not limited to data type, measurement units, and associated measurement error Semantic metadata can describe contextual information about the individual data and can include descriptions like measurement type and measurement device Thematic metadata can include descriptions which define the context of the study which produced the data and could include information detailing principal investigator, species association, study hypothesis, etc Information describing the context of the measurement, data collection device, units, and spatial temporal relationships are just a few of the descriptive quantities which must be contained within the system The metadata must be standardized and structured (i e , contained in lookup tables chosen for universal usage) to assist in data extraction, data mining, and data formatting functionality Metadata specifications must meet with Federal Government Data Committee (FGDC) requirements

Transparency, Aggregation, and Data Mining

Though the GEM data system will be composed of multiple heterogeneous data sets, useis of the system must interface it as if they are accessing a single dataset The ability to generate subsets of data from both individual and multiple sets is an absolute necessity of the system This ability to aggregate data from independent datasets into a homogenous representation must be a core property of the system Projects will of course produce unique datasets Many measurements of each independent dataset will be of the same semantic type but may very well be represented in differing units and data types Structures must exist within the data system to isolate those semantic homogeneities and format and aggregate those measurements to produce a continuous transparent view of the distributed data Users should be able to data mine the system for information which conforms to their search criteria

Data interchange between other data warehouse systems

A paramount requirement of the GEM data system is that it be able to interact, extract, and contribute to other data systems The facilitation of these tasks will be through the use of middleware products which must be inherently compliant with characteristics of the data system The system should also be capable of interfacing with current oceanographic data sharing protocols such as OPENDAP

GIS and WEB functionality

The system selected for the storage of GEM related data must be both WEB and GIS enabled without the application of extravagant measures to do so Both of these technologies have become primary sources for the representation and dissemination of modern information and having a system which is conducive to the creation of ports to these technologies is a fundamental requirement of any contemporary information system

GEM Data and Meta Data Archive System

The GEM data system must act as a robust and concrete data archiving system to insure backup and integrity of the data contained within it This will include all data, metadata and computational structures

Current Design

The core of the GEM data system lies in the inherent characteristics of the data and metadata archive system The archive system is the programmatic structure which holds the actual numeric values contained within by the various datasets which are supplied by GEM funded projects The system is also responsible for organizing this data through the use of inherent metadata system structures into categories and associations which will be useful in providing gateways to the information to future researchers The archive system is the foundation of the entire GEM data system and, in this sense, requires much care and foresight in its development The capabilities of the GEM data system will draw upon the functionality imbedded in the archive structure, conversely, intrinsic flaws in the archive structure will be perpetuated on every level of the GEM data system

The relational database methodology has been chosen as the framework for the development of the foundational archive system because it can provide the functionality requirements of the GEM data system listed above The methodology for developing data archive structures using the relational design has remained virtually unchanged since its advent in the late 1960s Many software products which facilitate web access, GIS representation, and information dissemination are designed to interface directly with relational database systems In addition, data sharing protocols such as OPENDAP have been ported to relational database systems which ensure interconnectivity with systems such as GOOS, IOOS, and OBIS An inherent characteristic of relational systems is its ability to ensure robust data integrity Below is a diagram portraying the proposed relation design of the archive system for GEM physical oceanographic data

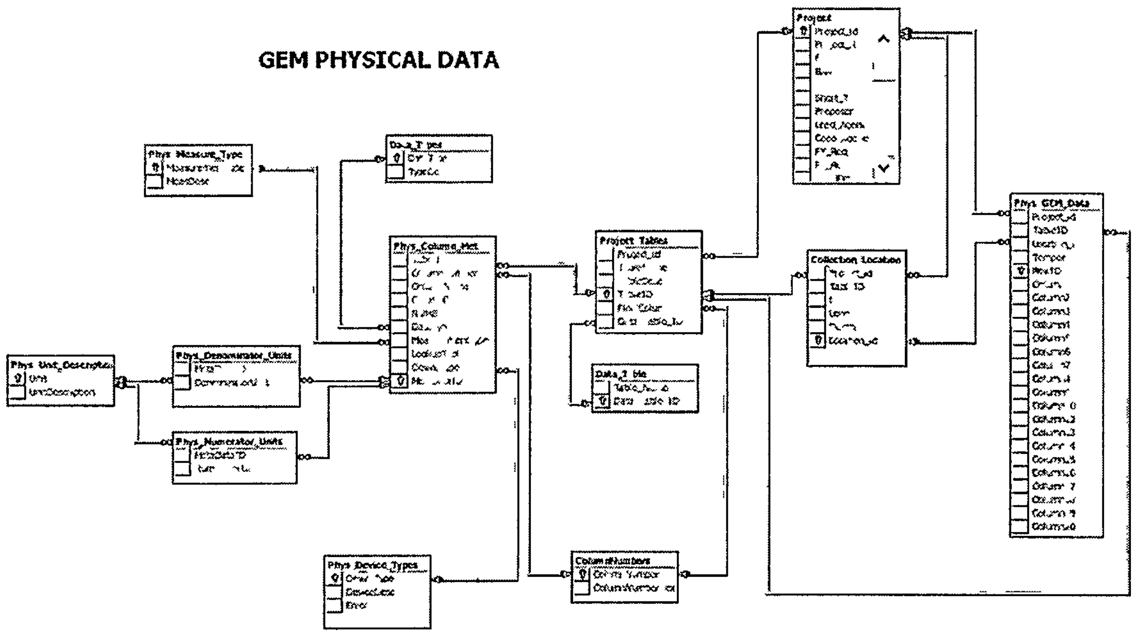

Figure DMIT-1 GEM physical oceanographic relational database topology

The above topological database diagram displays the interaction between individual tables describing thematic, syntactic, and semantic metadata characteristics of physical GEM datasets All table structures are normalized according E F Codd's rules of normalization and predicate logic Topologies for the absorption of species specific and general taxonomic study data are currently under development and will have topological structures analogous to the structure shown above

Due to the data archive system's adherence to the relational model, the system can be queried, sorted, and filtered by any of the fields contained within it Of course this also includes the ability to perform compound queries (i e , searching by multiple fields) and more sophisticated drill down queries (i e , selecting subsets from previously queried subsets)

GEM Data System Plan

Once the GEM data archive system has been developed, tested, and implemented, it will be possible to start building the secondary and tertiary structures on top of the foundational components These components will allow the actual dissemination of information from the archive system to the user In addition, a component to interface with other data systems, such as OBIS, GOOS, and IOOS, will be developed to share data using OPENDAP or other middleware products Although development of these components is projected to occur in FY 05 and beyond, we can ensure a certain level of system functionality with the use of current computer technology The following is a rough template of basic core functionality components which will be provided by the GEM data system, and is expected to be modified by both user need and future technological innovation

Web Interface

Data stored in the GEM data-system will be available for download over the internet The internet application will be dynamic in nature and data driven to accommodate issues of scalability The web interface will accommodate complex query requests and create a friendly intuitive interface for users to process their requests Query functionality will exist on the individual record level allowing users to create subsets of individual datasets Downloads will be available in a multitude of formats (i e comma delimited, tab delimited, excel spreadsheet, etc) Downloads will also include a metadata document generated from relevant entries in the relational database This metadata document will contain the data type, units, sampling device (when relevant) for every field in the dataset download, and any known quantitative errors associated with the sampling device The document will also contain information specific to the inclusive dataset (i e , principal investigator, description of project which generated report, table description as documented by PI, field description as documented by PI, and directions on how to find more information on the project itself) The web interface will be written in Cold Fusion and NET web services

Spatial/Temporal Geo-referencing

All data will be spatially and temporally documented as defined by the GEM data policy This will include latitude, longitude, depth, and time when relevant The spatial fields will be interfaced through a Geographic Information System (GIS) and indexed appropriately using Spatial Data Engine (SDE) or Oracle Spatial depending upon the backend database platform Current development is occurring on SQL Server 2000 and would therefore use SDE A GIS query interface will of course be integrated into the web interface to facilitate spatial query, aggregation, and analysis functions

ODBC Client Connectivity

Certain users will require direct connectivity to the system via their client side software analysis packages Users will be able to connect analysis packages such as matlab, arcview, and SPS directly to the database via Ordinary Database Connections (ODBC)

Large Scale System Data Sharing

A critical component of the GEM data system is its ability to communicate, disseminate/ absorb information, and interoperate with other scientific data storage systems This process will be facilitated through the implementation of OPENDAP and other middleware products

The following page displays a template for the technological structure of the future GEM data system as it is seen now by the Data Management section

GEM Data Management and Information Transfer Needs and Schedule

<u>Actions in FY 03</u>

- Define primary system level requirements (staff)
- Initiate development of data archive system (staff)

Proposed Actions in FY 04

- Construct a database of meta-data describing marine-related databases from the northern Gulf of Alaska relevant to GEM (project)
- Develop pilot project to apply OBIS within the GEM region (project)
- Finish development and test the GEM data system architecture for primary level functionality (staff)
- Define metadata descriptors for use in defining various current GEM datasets (staff)
- Research technology for higher order data system functionality (staff)

Proposed Actions in FY 05 and beyond

- Isolate secondary and tertiary requirements and ensure that higher order system functionality (i e presentation and analysis of data) be incorporated into the growing data system

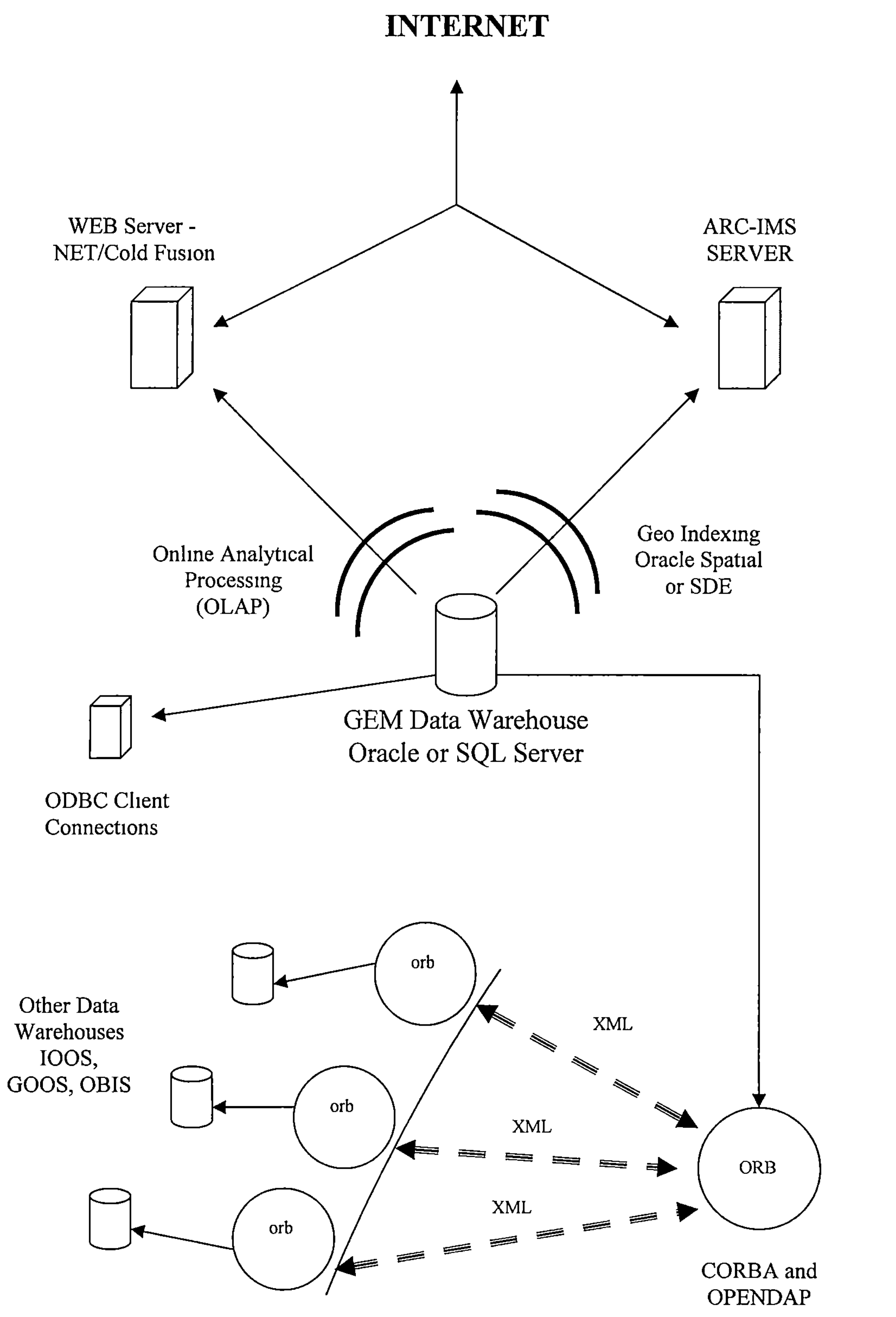

Figure DMIT-2 Technological structure of GEM data system and communication components

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