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GEM

Gulf of Alaska Ecosystem Monitoring and Research Program

A program of the *Exxon Valdez* Oil Spill Trustee Council • www.oilspill.state.ak.us

MISSION

The mission of GEM 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.

GEM PROGRAM GOALS

- Detect annual and long-term changes in the marine ecosystem
- Understand the causes of these changes
- Inform the public, resource managers, policymakers and industry about what is happening in the gulf
- Solve problems arising from human activities and help regulators improve resource management
- Predict the status and trends of natural marine resources

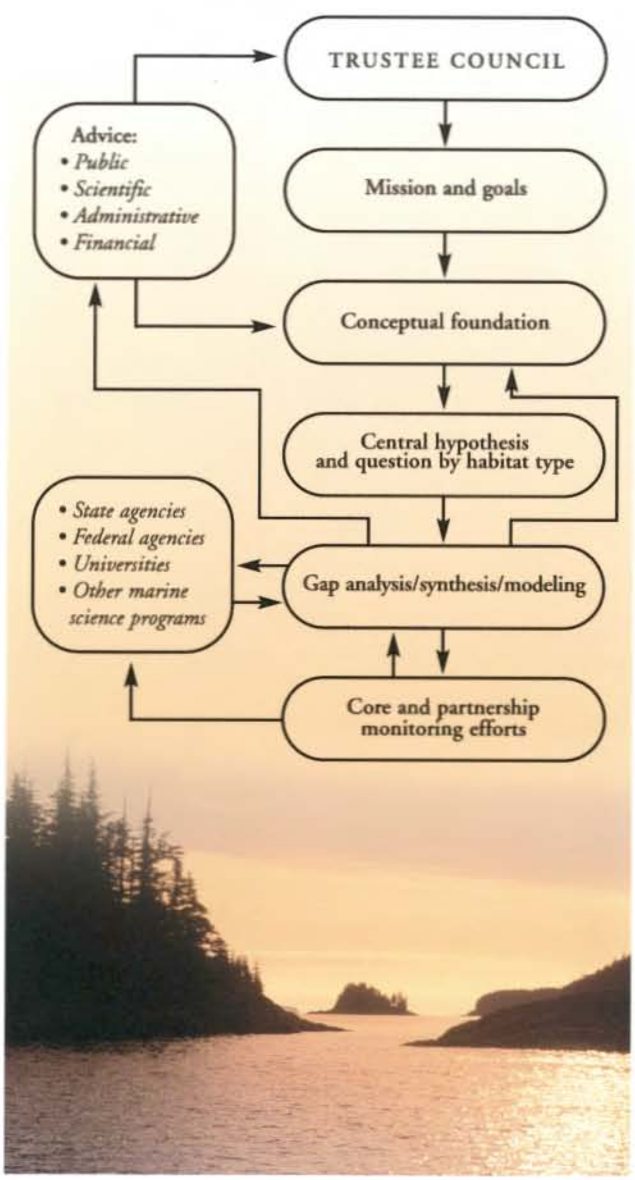
WHAT IS GEM? Imagine a marine research program in one of the world's most productive ecosystems that had indefinite, guaranteed funding. This is the Gulf of Alaska Ecosystem Monitoring and Research (GEM) program, a long-term commitment to gathering information about the physical and biological components that make up a world-renowned marine ecosystem. What makes GEM unique is that it incorporates interagency cooperation and collaboration, public involvement and accessible, informative data and information on the Gulf of Alaska ecosystem. The flagship of the GEM program will be a core monitoring program, which, when combined with the monitoring efforts of other resource agencies and research entities, will help detect environmental change over time and greatly expand understanding of the Gulf of Alaska ecosystems. The program will also include short- and long-term research using the latest technological breakthroughs in marine science. With these, the GEM program will provide a better understanding of the complex processes in the ocean, an understanding that will help us enjoy the great productivity and biodiversity of Alaska's oceans for generations to come.

WHY GEM? The northern Gulf of Alaska is one of the world's most productive ecosystems. Biological production in the gulf provides hundreds of millions of dollars annually in income from the seafood, recreation and tourism industries, as well as the subsistence resources on which many Alaskans depend. The gulf contains 25 species of marine mammals, 26 species of seabirds and 287 known species of fish, and the surrounding area is home to more than half of Alaska's human population. Ultimately, it is our understanding of the Gulf of Alaska and our ability to share information that will determine the future of the gulf ecosystem and the human activities that depend on it. To continue these activities into the future, we must be able to detect environmental change and distinguish between human-caused impacts and natural forces.

Communities of the northern Gulf of Alaska

HOW WILL GEM WORK? Beginning with the mission and goals developed by the Trustee Council for the GEM program, a working concept about how the Gulf of Alaska ecosystem works is developed. Specific key questions about the working concept, or central hypothesis, will be addressed in each of four habitat types through research and monitoring. The first tool for answering these questions is synthesis, which pulls together existing information on a specific question. Synthesis serves a process called "gap analysis" which involves identifying missing information and locating institutional partners for research, and evaluation and analysis of current scientific knowledge. A database also serves the gap analysis as a tool to identify the projects that are already in place.

HOW GEM COMPONENTS FIT TOGETHER



GEM AT A GLANCE

- The 1989 *Exxon Valdez* oil spill led to a record $900 million settlement to restore the public's natural resources injured by the spill.
- GEM program is the ultimate legacy of the oil spill restoration program.
- GEM is funded with $120 million endowment from the remaining *Exxon Valdez* oil spill settlement funds.
- Annual budget: approximately $5-6 million.

Another important component of the GEM program is the use of computer models, which can:

- represent and examine complex relationships;
- distinguish variability from actual patterns;
- prioritize the most important factors in a system; and
- predict the likely course of future events.

The synthesis, gap analysis and modeling processes will be the primary tasks in the early implementation phase of the GEM program. To prepare for long-term monitoring, short-term research projects will help determine how to answer the most important questions at the lowest cost. Short-term research will also help reveal the core variables, locations and methodology to use in long-term environmental monitoring. Other research will focus on food web dynamics, plankton dynamics, weather, nutrient transport and human impacts.

Monitoring will provide multi-decadal data sets for scientists, resource managers, conservation groups and the public. Given the complexity and size of the Gulf of Alaska, GEM monitoring will include core monitoring done by GEM scientists and partnership monitoring with other organizations A multi-purpose website will provide raw data, maps, diagrams and graphs.

COMMUNITY INVOLVEMENT. Extensive community involvement will be central to the GEM program. Citizen volunteers will assist in observations and data gathering and Alaska Natives will be consulted for traditional ecological knowledge. Strong community involvement will permit the program to compile a more extensive and expansive database.

GULF OF ALASKA FACTS

- Steep mountains along the coast of the eastern Gulf of Alaska catch significant rainfall.
- The Gulf of Alaska region is still tectonically active, creating and altering habitats.
- The Aleutian Low Pressure system dominates the Gulf of Alaska climate, influencing storm tracks, air temperature, wind velocities and ocean currents.
- Clouds cover the ocean 60 percent of the time.
- Glaciers cover 20 percent of the gulf watersheds, forming the third largest ice field in the world.

GEM SCIENCE. The GEM approach recognizes that science-based management of marine resources requires an ecosystem-wide approach that takes into account complex processes and dynamic relationships. This can best be accomplished through long-term monitoring and studies repeated over time.

NATURAL CHANGES. It is becoming increasingly clear that climate and oceanography play major roles in controlling biological processes and populations of fish and wildlife important to humans. The set of climatic conditions – also known as the "regime" – at any given time is determined by several processes occurring simultaneously, but on different time scales. Most of these have to do with astrophysical cycles such as variability of the earth's orbit around the sun, the tilt of the earth and the amount of solar radiation entering the atmosphere. They include the El Niño/La Niña Southern Oscillation, the Pacific Decadal Oscillation and global warming, all of which operate on different time scales. The cycle works this way:

1) Large-scale physical processes change the heat content of the atmosphere and ocean, thereby
2) altering currents and climate, which in turn
3) change populations of fish, birds and mammals.
Understanding the relationships among these processes will provide a context for evaluating the potential impacts of human activities.

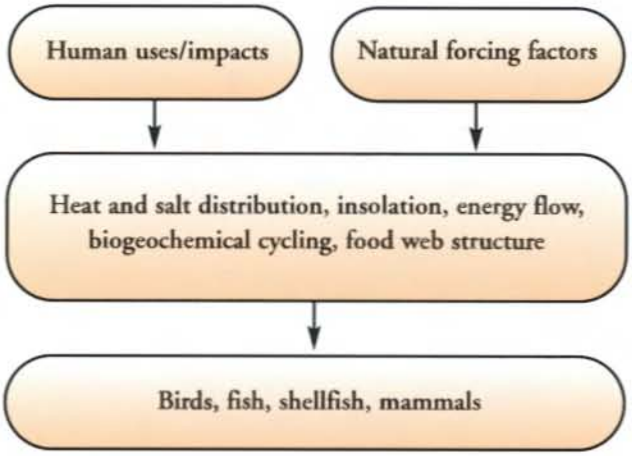
POTENTIAL IMPACTS OF HUMAN ACTIVITIES. Human activities play a prominent role in the Gulf of Alaska and may have unintended consequences on the overall ecosystem dynamics. Fishing may deplete nutrients and fish stocks, alter sea floor habitat and even affect non-commercial species such as the natural predators of these fish. Tourism may disturb wildlife and add sewage and gray water to marine habitats. Oil spills and chronic leaks occur frequently on a small scale, putting harmful contaminants in the water. Subsistence puts pressure on populations of marine mammals. The pressure may be insignificant when populations are large, but have a substantial effect when populations decline. The goal is not to stop people from these activities, but rather, to help resource managers set reasonable standards that ensure these activities are sustainable.

PHYTOPLANKTON FEED THE SEA

Phytoplankton are the foundation of all life in the sea as we know it. Phytoplankton are microscopic floating plants that convert ocean nutrients and solar energy into a food source that supports the entire ecosystem. As larger organisms eat the plankton, they are in turn eaten by still larger animals such as salmon, seabirds and killer whales.

Phytoplankon require a balance of mixing between ocean layers – so nutrients get to the sunlit layers – and stability to keep them in the sunlight. Each spring, the ocean is stratified into layers of different densities and salinities, providing ideal conditions for annual plankton blooms. GEM research will investigate the conditions that cause these blooms and the efficiency with which higher organisms can integrate this explosion of food into the food web.

HABITATS COVERED BY GEM. The GEM program will take place in watersheds, the intertidal and subtidal zones, the Alaska Coastal Current and offshore habitats. These systems are highly interdependent.



Relationships are everything. *The marine ecosystem in the northern Gulf of Alaska depends on the nature of connections between heat and salt distribution, insolation, energy flow, biogeochemical cycling and food web structure. Natural forces and human activities bring about changes in the populations of birds, fish, shellfish and mammals by altering these connections.*

CHANGING POPULATION LEVELS

Some species in the Gulf of Alaska appear to be doing well, while others have declined and still others have almost disappeared:

Population declines

- Shrimp
- Red king crab
- Black-legged kittiwakes
- Common and thick-billed murres
- Cormorants
- Sea lions
- Harbor seals
- Fur seals
- Beluga whales
- Common loon
- Some salmon populations

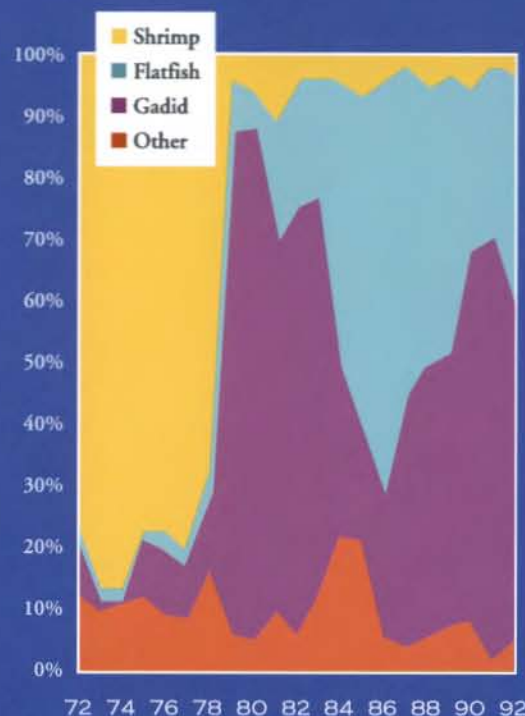
Population increases

- Most salmon populations
- Cod
- Pollock
- Flatfish (arrowtooth flounder)
- Sea otters (not on Aleutians)
- River otters
- Bald eagles
- Sea urchins
- Sharks

WHEN CLIMATE REGIMES SHIFT

Trawl surveys 1970-1976

Trawl surveys 1981-1996



Shrimp populations have decreased dramatically since about 1977-78, while cod and pollock (gadids) and flatfish such as arrowtooth flounder now dominate much of the Gulf of Alaska. The '77-'78 shift mirrors a warming trend within a cycle of cold and warm periods known as the Pacific Decadal Oscillation (PDO). Scientists hypothesize that each cold or warm climate regime favors certain species and harms others. Weather patterns may help explain some biological trends. When weather-related changes can be ruled out, the focus turns to human causes. Scientists now think we may currently be experiencing another regime shift back to cooler ocean conditions, with apparent increases in shrimp and some crab species.

THE GEM CONCEPTUAL FOUNDATION. *While the northern Gulf of Alaska ecosystem is extremely complex and much remains to be learned, scientists have already compiled an in-depth understanding of the region. The adjacent graphic illustrates the dynamic interface in the Gulf of Alaska between forces on land and at sea. This conceptual foundation serves as a working hypothesis for how the ecosystem works. It will be tested and subsequently updated through GEM monitoring and research projects.*

OCEANOGRAPHY AND CLIMATE. *The boundary mountains on land catch precipitation and airborne contaminants from the Aleutian Low Pressure system. Freshwater runoff strengthens the Alaska Coastal Current and carries runoff and contaminants from the watersheds. Meanwhile, weak seasonal upwelling and perhaps lunar forcing bring nutrients and old carbon upwards through the photic boundary where wind-driven mixing and surface currents bring them to where there is enough sunlight for phytoplankton to use the nutrients in photosynthesis. This often occurs where there are underwater structures called "sills" that push currents toward the surface. Winds from the Aleutian Low Pressure system create two counteracting forces. Turbulence keeps nutrients in the photic zone, while shoreward transport causes downwelling, which carries nutrients and plankton out of the photic zone.*

THE FOOD WEB. *Zooplankton link this primary productivity to the production of forage fish, which are the basis for production of larger fish, birds, marine mammals and humans. As surface animals die, they become the detritus that sinks to the ocean floor to feed species in benthic, or bottom-dwelling, communities. Throughout their lifecycle, salmon(shown in pink) link different parts of this ecosystem, migrating as fry from the watersheds all the way to the far offshore region and then back again to spawn as adults.*

HUMAN ACTIVITIES. *Meanwhile, human activities such as tourism, recreation, commercial and sport fishing, and subsistence all depend on these systems and processes occurring in the gulf. At the same time, these activities affect these processes by removing marine organisms, altering coastal habitat, changing animal behavior and depositing waste and contaminants into the marine environment.*

Gulf of Alaska Ecosystem

Watersheds

DESCRIPTION. Watersheds are freshwater and terrestrial habitats from the mountains to the extent of a river's plume. Links between watersheds and marine areas have been recognized for a long time, but new discoveries are heightening awareness of how strong these links are. The Alaska Coastal Current, for example, is completely dependent on incoming freshwater from rivers, streams and non-point runoff in the gulf.

CONNECTIONS. Watersheds provide rearing habitat for anadromous fish and seabirds such as murrelets and their rivers are pathways for nutrient exchange between terrestrial and marine ecosystems. Woody debris and vegetation from land are also imported to the marine environment, providing a carbon source and habitat for some species. Rivers also deposit iron, sediments and sometimes pollution and contaminants, all of which have varying effects on the sea life downstream. As rocks are worn down by glaciers and weathering, rivers carry minerals and silt to the ocean. Development and clear cut logging can affect watersheds by removing vegetation and increasing soil erosion. Contaminants found in watersheds may be of local origin, and indeed, most contaminated watersheds are located near towns and cities. However, contaminants also are brought by atmospheric processes from as far away as Asia. So far, contaminants from far-away sources have been detected only at very low levels.

SALMON - A VITAL LINK BETWEEN WATERSHEDS AND OCEANS

After salmon return to watersheds to spawn, their carcasses deposit significant amounts of marine nitrogen into river ecosystems. Nitrogen is a limiting factor for plant growth in many of these systems, so the health of riparian habitats may depend on the salmon returning to spawn. What happens to riparian habitats if salmon numbers change?

Examples of watershed monitoring topics:

- Two-way nutrient and contaminant flow between watersheds and ocean
- Variation in precipitation and stream flow in Gulf of Alaska watersheds
- System-wide effects of physical variables on aquatic and marine organisms

Nearshore

DESCRIPTION. Intertidal and subtidal areas of the nearshore habitat are brackish and salt-water coastal habitats which extend offshore to 20 meters in depth. These shallow areas are some of the most productive habitats in the Gulf of Alaska and may be the most threatened. These habitats were the most severely affected by the *Exxon Valdez* oil spill and many still harbor oil. In general, these areas have abundant invertebrates such as barnacles, crabs and shellfish and juveniles of many species.

SIGNIFICANCE. Nearshore habitats provide important feeding grounds for larger animals. Terrestrial and aquatic birds, mammals, invertebrates, large fish and even humans depend on food from these rich meeting places of sea and river nutrients. In addition to their importance as feeding grounds, these areas provide nurseries for young marine organisms, unique habitats for specialized animals and are major sources of seaweed production. At the same time, contaminants such as persistent organic pollutants (POPs) may be found in high concentrations in several invertebrate species of the inter- and subtidal zones, providing pathways and potential threats to wildlife and human health. For research purposes, some invertebrate species make excellent biological pollution indicators.

Examples of nearshore monitoring topics:

- Species abundance and composition over time
- How larvae of intertidal animals use currents to disperse throughout the intertidal and subtidal
- Origin and fate of contaminants in shellfish and other invertebrates

MARINE MAMMALS IN THE HABITATS OF THE GULF OF ALASKA

Each species of marine mammal uses the Gulf of Alaska habitats differently. Sea otters and harbor seals are important predators in the intertidal and subtidal habitats, while Steller sea lions occupy the Alaska Coastal Current. Killer whales and Beluga whales move throughout the intertidal, subtidal and offshore regions. Some species of marine mammals are permanent residents of the northern Gulf of Alaska, while others migrate extensively throughout the year. For example, harbor seals, which stay year round, are possibly more affected by climatic and prey changes because they depend solely on this region for their food. Populations may be declining because the current warming regime has changed the abundant prey sources to species that are less nutritious.

Sea otters play a crucial role in maintaining biodiversity in the nearshore habitats. Sea otters prey on sea urchins which, when uncontrolled, sharply reduce nearshore marine plants such as kelp. By keeping the sea urchin populations in check, sea otters control the distribution of many plant and animal species.

Alaska Coastal Current

DESCRIPTION. Just beyond the subtidal zone up to about 30 miles offshore flows the Alaska Coastal Current. This low-salinity channel extends from the mouth of the Columbia River to the end of the Alaska Peninsula. The current is shaped by the tremendous influx of freshwater from the glaciers and thousands of streams flowing into the gulf. Because it is fed in part by ice melt, the current flows at its maximum in late summer and at its minimum in winter. The Alaska Coastal Current is an ever-changing part of the gulf that plays many important ecological roles. For example, it supplies plankton to Prince William Sound and carries fish and invertebrate eggs from one place to another. However, the same coastal flow that benefits so many species may also distribute marine pollutants as seen in the *Exxon Valdez* oil spill. A future toxic spill could be spread across the entire gulf by this current.

A KEY HABITAT. The success of many species depends on the specific shape of the current, which is influenced by climate, season and sea-floor topography. Juvenile pollock are kept in areas rich in food supply by eddies, circular side currents formed as larger currents move around land masses. Oceanographic features can have a major influence on biological production in the water column, so understanding how they work provides an important piece of the ecological puzzle.

Examples of coastal current monitoring topics:

- Variability of its physical attributes over different time scales
- Effects of climate on current shape and behavior
- Nutrient supply to the photic zone where phytoplankton may uptake them
- Effects of current behavior on productivity
- Effects of current behavior throughout the food web
- Populations and feeding behavior of fish, seabirds and marine mammals

SEABIRDS IN THE INTERTIDAL, SUBTIDAL AND ALASKA COASTAL CURRENT

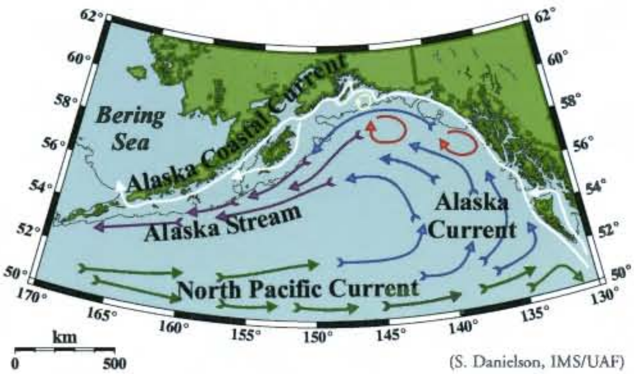
Marbled Murrelet

For several decades scientists have noticed a broad-scale decline in seabird abundance in the gulf, although there are notable exceptions in some localities. Population declines have been noted especially in loons, cormorants, mergansers, puffins, gulls, kittiwakes, terns and auklets. Species such as kittiwakes and murres can be useful indicators of regional marine productivity because their food supply also feeds many other birds, mammals and fish. By assessing the type and quality of food eaten by indicator species, scientists can glean information about the region's overall marine productivity. GEM may contribute to understanding the origins of differences in diet between bird species as well as the effects of variability in prey abundance on seabird breeding biology and population dynamics.

Black-legged Kittiwakes

Common Murre

Offshore



As the North Pacific Current moves east toward the coast, much of it becomes the northward-flowing Alaska Current which flows west along the continental shelf break toward the Aleutian Islands.

DESCRIPTION. The offshore region refers to the continental shelf break and the Alaska gyre, a large-scale counterclockwise circulation off the coast. Most large animals of the outer continental shelf and deep sea are fish, the most common being flounder, ocean perch, pollock, halibut and cod. Salmon also use this habitat before they return to the watersheds to spawn. One of the most important processes in this part of the gulf is upwelling, which occurs slowly in the middle of the gyre and at a higher rate in the summer over the shelf break. This upward lift pulls rich deep-sea nutrients to the surface where they can be used by photosynthetic phytoplankton, the primary producers of the marine ecosystem. This process is mediated by climate, especially the Pacific Decadal Oscillation, which can slow down or speed up the wind-driven transport (and perhaps the supply) of deep water nutrients across the shelf to support inshore production. Offshore currents may also carry pollutants originating from as far away as Asia or from deep-ocean dumping and accidents at sea.

Offshore research and monitoring are more difficult due to distance from shore. However, instruments located on ferries, tankers and cruise ships may be useful to obtain offshore data on temperature, salinity, detritus and ocean nutrients. Collected over the long-term, this type of data can put together a big picture of the oceanographic characteristics of the Alaska gyre and the way it changes. A clearer picture of the gyre will permit better understanding of how offshore changes might affect productivity throughout the gulf ecosystem.

Examples of offshore monitoring topics:

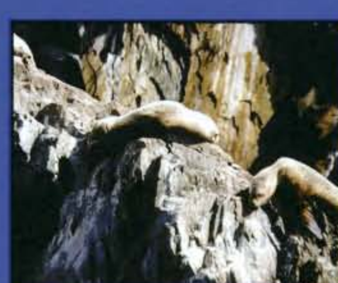
- The effect of climate on nutrients
- How plankton abundance changes over time
- Shoreward flow of carbon produced by plankton
- Variability of the shape and strength of the Alaska gyre
- Variability of offshore temperature, nutrients, salinity and detritus

FOOD WEB INTERMEDIATES

Macrozooplankton such as krill serve as intermediate links in the marine food web between primary producers and higher-level consumers. Forage fish – usually the smaller, less commercially important species – convert the krill into a food source that larger fish, birds and marine mammals can eat. Baleen whales skip this step, feeding directly on the macrozooplankton. GEM is interested in these tiny creatures, barely visible to the naked eye, because their role in the ecosystem is still only vaguely understood.

Macrozooplankton

Forage fish (salmon fry)



Sea lions

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GEM SCHEDULE

- March 1999: Trustee Council decides to endow GEM program.
- 2000: Draft GEM program developed.
- 2000-2002: Intensive review by public, resource agencies, user groups, scientists and the National Research Council.
- Fall 2002: GEM program officially begins, focusing on synthesis of existing data.
- 2003: Pilot monitoring projects begin.
- 2003-2007: Components added until program fully implemented.

ADMINISTRATION

GEM is administered by the staff of the *Exxon Valdez* Oil Spill Trustee Council with funding approved by the Trustee Council. Trustees are:

- U.S. Department of the Interior
- U.S. Department of Agriculture
- National Oceanic and Atmospheric Administration
- Alaska Department of Fish and Game
- Alaska Department of Environmental Conservation
- Alaska Department of Law

GEM is a program of the *Exxon Valdez* Oil Spill Trustee Council
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