Long-Term Monitoring in the Nearshore:
Designing Studies to Detect Change and Assess Cause

Project Number: 02395

Workshop Summaries and Recommendations

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<u>Executive Summary</u>

A series of workshops were conducted to help define essential elements of a nearshore monitoring program in the Gulf of Alaska (GOA). As a first step, a panel of independent scientists was convened in Santa Barbara in November 2001 to develop a conceptual framework. This group recommended three basic elements: 1) synthesis, compilation, and management of both pre-existing and new data; 2) synoptic studies of large spatial scale nearshore oceanographic processes; and 3) monitoring of a limited number of intensive sites and a greater number of extensive sites. Intrinsic to this plan is a nested design in which spatial replicates are hierarchically partitioned and similar protocols are followed throughout the region. The panel also provided preliminary guidance on the types of metrics, number of sampling locations for each, and frequency of sampling. The panel recommended following existing protocols where available and noted the strong similarity in goals between GEM and the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO)

This conceptual framework was presented to Alaska researchers, resource managers, and community stakeholders during a second workshop in Anchorage in January 2002. The goals of the Anchorage workshop were to further develop recommendations for variables to be measured, where they should be measured, and how often. As starting points, the draft GEM Program, National Research Council comments on the nearshore component of GEM, the results of the prior expert panel, and an example of a monitoring program with similar goals (PISCO) were presented to a larger group of stakeholders, researchers, and resource managers. The group was then subdivided into smaller working groups and asked to provide comment on the NGEM plan.

The key results of the Anchorage workshop were that 1) there were no substantive objections to the proposed monitoring design for the Gulf of Alaska, 2) there was general agreement that the approach used by PISCO would also be appropriate for the Gulf of Alaska, and 3) involvement and support of coastal communities in the nearshore program of GEM are essential to its long-term success. The specific issues addressed by the participants are summarized as follows:

<u>What to measure</u>: Essential components of a Gulf-wide monitoring program were identified and prioritized as follows: oceanographic variables, habitat type, benthic community structure, human use, contaminant levels, and abundance of selected marine mammals, birds, and fishes.
<u>Where to measure</u>: The recommendation of the Santa Barbara panel was generally accepted as the best approach for the Gulf of Alaska. This approach utilizes a combination of synoptic, intensive, and extensive sites to monitor the above components at nested scales of space and time. Intensive sites would be used for process oriented studies and to address questions linked to Gulf-wide hypotheses. 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.
When to measure: A program was recommended that matched sampling frequency to the appropriate temporal scale for the ecosystem component of interest. No specific sampling frequencies were identified. It was also suggested that a portion of the sampling effort should be event driven.
Who should be involved: Academic and agency scientists, teams of specialists, and graduate students were identified for studying Gulf-wide intensive sites. Community representatives and stakeholders were identified as critical participants in the extensive study site program, from planning to implementation and information transfer.

The GEM program is an unprecedented opportunity to develop a monitoring program that could transcend our lifetimes and even our grandchildren's lifetimes. Careful thought, therefore, needs to be put into the design so that change in the nearshore ecosystem can be both detected and understood.

Part I

A Conceptual Model for Monitoring Nearshore Habitats in the Gulf of Alaska

Workshop Summary and Recommendations November 9, 2001, Santa Barbara, California

Summary

Five academic and agency scientists along with the three Principal Investigators and GEM scientists met for one day in Santa Barbara to develop a conceptual model for monitoring nearshore habitats in the Gulf of Alaska (GOA). The invited scientists were noted for their experience with large-scale studies across multiple disciplines, and many of the individuals had direct experience with or had designed long term monitoring programs. This group recommended three basic elements: 1) synthesis, compilation, and management of both pre-existing and new data; 2) synoptic studies of large spatial scale nearshore oceanographic processes; and 3) monitoring of a limited number of intensive sites and a greater number of extensive sites. Intrinsic to this plan is a nested design in which spatial replicates are hierarchically partitioned and similar protocols are followed throughout the region. The panel recommended a monitoring program that measured key metrics over several temporal and spatial scales but noted that the scale of sampling should be dictated by the metric. The panel provided preliminary guidance on the types of metrics, number of sampling locations for each, and frequency of sampling. The panel recommended following existing protocols where available and noted the strong similarity in goals between GEM and the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO), a large-scale marine research program that focuses on understanding the nearshore ecosystems of the U.S. West Coast (California, Oregon and Washington). The extension of these research protocols into the GOA would allow an unprecedented opportunity to address research questions of several disciplines over spatial scales heretofore never conceived. The first step noted by the panel was to conduct an inventory of habitat within a region through mapping of habitat and major biological features into a GIS. Specific sites could then be selected based on this analysis with consideration of the potential to detect change given the signal to noise ratio of the habitat, ease of observation in that habitat, site accessibility, and potential for human disturbance.

Introduction

Recent breakthroughs in technology and numerous scientific disciplines have made possible unprecedented large-scale studies of the marine environment. These developments show much promise for enabling significant advances in understanding as well as protecting the oceans. Basic knowledge about several major characteristics of nearshore marine ecosystems is now within reach (e.g. the variation in coastal oceanography, effects of food availability and nearshore oceanography on the dynamics of ecological communities, and connections among ecological communities through larval dispersal). The GEM program is unprecedented in being able to provide long-term funding to monitor the Gulf ecosystem. The problem remains however, that without a commitment from GEM to adopt standardized protocols across the scale of the Gulf for a long term time scale, many of the questions asked by GEM will remain unresolved.

The National Research Council (NRC) in their review of the GEM Science Plan emphasized the need for a broad conceptual framework with a sound scientific basis. A scientific framework will result in data that is useful and ecologically significant. A strong scientific justification will also lend the program the information required to address short term issues of public concern.

The marine ecosystem is subjected to forces of change at many scales of space and time. Changes in the patterns of atmospheric forcing will influence oceanic hydrographics in ways that are not fully understood. Smaller scale changes can come directly or indirectly from human disturbance, such as the destruction of benthic habitats from bottom trawling or indirect effects from leaking septic fields and oil spills. The underlying natural variation in marine systems must be considered when designing a program to detect change due to human activities. Some impacts from human activities will interact with natural cycles at the scale of the entire Gulf of Alaska, while others are likely to have more local impacts. It is difficult to address these multi-scale effects due to logistical costs, political agendas, and the vagaries of funding sources. Thus, our lack of understanding on how large scale processes interact with small scale processes is largely systematic.

Historically, most research has been done locally and within a particular discipline. Technologically, we are poised to begin studying ecosystems at multiple spatial and temporal scales. What we are lacking is the organization to tackle multi-discipline, multi-scale issues. Yet these are the very issues raised by the GEM Science Plan and the recent reviews of that plan from the National Academy of Sciences (National Research Council). A coordinated network of researchers, acting in concert, could augment work being done in the lower 48 so that questions can be addressed at local, regional (GOA), oceanic (North Pacific), and global scales.

In November, 2001 we convened a panel of marine scientists to develop a conceptual model for a nearshore monitoring program in the Gulf of Alaska (Table 1). The panel consisted of academic and agency scientists noted for their experience in large-scale studies across multiple disciplines. The disciplines represented included nearshore oceanography, genetics and molecular biology, invertebrate and algal ecology, fish ecology, avian ecology, mammal ecology, and biostatistics. Many of the individuals had direct experience with or had designed long term monitoring programs. Some of the programs represented by the panel include: GLOBEC, NOPP, PISCO, NSF-LTER, and NOAA NERRS.

The panel recommended developing a conceptual model for a nearshore monitoring program that spans the Gulf of Alaska using standardized protocols to determine processes underlying the dynamics of coastal ecosystems.

Background

The oceans are at risk from a variety of threats including direct and indirect effects of human development compounded by natural climate variation. Nearshore marine ecosystems are the focus of many current conservation efforts, yet we lack the basic knowledge necessary for proper management. Ecological and evolutionary principles derived from studies in terrestrial environments are not easily applied to marine systems. The young of most marine organisms are water-borne for extensive periods of time, so that the connections between distant communities are potentially great, and local production may not correspond to local recruitment. Seawater carries plankton and nutrients as well as young. Thus recruitment, growth, and mortality of many organisms in a coastal marine community are intimately tied to the characteristics of the water bathing the site, and communities even short distances apart can have fundamentally different structures.

Ocean waters, in turn, are variable over immense spatial and temporal scales, and coastal dynamics are the least understood area of oceanography. The primary goal of the nearshore monitoring program in GEM is to understand the interaction of the nearshore oceanographic environment with coastal marine communities over the Gulf of Alaska region. This includes quantifying patterns of distribution, abundance and diversity of the biota in nearshore ecosystems, and determining how ecological and oceanographic processes influence these patterns. We believe that this understanding of both local and biogeographic patterns and processes must span small-to-large spatial scales and short-to-long temporal scales.

A key fact underlying much of marine ecology is that most marine organisms possess a pelagic larval stage that is capable of long-distance dispersal. This two-stage life cycle means that many populations of adults within a given area may disperse their young to other areas, and they in turn may be dependent on distant populations for their own replenishment. For the U.S. West Coast, it is clear that appropriate spatial scales for understanding the ecological dynamics of nearshore ecosystems should range from Alaska to southern California. The northward-flowing Alaska Current and the southward-flowing California Current systems dominate this region and exhibit potentially significant variation from north to south at scales of hundreds of kilometers and on temporal scales of decades. Ecologically significant regional variation in currents, upwelling regime, temperature, El Niño events, climate, zooplankton abundance and transport, and the benthic biota are implicit in recent studies. To date, however, efforts to integrate this knowledge across traditional habitat boundaries and disciplinary boundaries have received limited and sporadic support, at best, from funding agencies.

Many of the testable hypotheses about community processes were first developed and explored in intertidal and subtidal benthic systems. Strong evidence suggests that variation among nearshore benthic communities can depend on recruitment and such bottom-up oceanic influences as phytoplankton productivity and nutrient concentration, all of which vary significantly with currents, upwelling, and other physical oceanographic processes. These broad questions include those identified by the National Research Council as part of their review on the GEM Science Plan:

1. What processes and physical conditions produce larvae?
2. How long do larval stages last, and where do they go?
3. How and why does production vary along the shore?
4. How variable is recruitment in space and time among major groups of planktonic larvae?
5. What are the primary energy and nutrient sources of intertidal and benthic communities?
6. Under what conditions do recruitment, food, space, natural disturbance, temperature, predators, competitors, and disease limit populations?
7. What are the sources and rates of natural disturbance to intertidal and subtidal communities?
8. What are the rates and patterns of recovery?

The Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) is a large-scale marine research program that focuses on understanding the nearshore ecosystems of the U.S. West Coast. They are addressing the same questions posed above with intensive biological sampling of larvae, recruits, and post-settlement individuals in both subtidal and intertidal communities, combined with simultaneous monitoring of nearshore waters using mooring arrays and remote sensing. PISCO, an interdisciplinary collaboration of scientists from four universities, integrates long-term monitoring of ecological and oceanographic processes at dozens of coastal sites with experimental work in the lab and field. PISCO conducts studies of species diversity monitoring, temporal patterns of larval distributions, identification of larval sources and sinks, recruitment rates, growth rates, genetics, physiological responses to stress, biomechanics, and nearshore oceanography. All of these components lend themselves to the questions identified by the NRC in their review of the GEM Science Plan. PISCO's findings are applied to issues of ocean conservation and management and are shared through public outreach and student training programs. A smaller scale version of PISCO could be implemented in the Gulf of Alaska. The extension of these research protocols into the GOA would allow an unprecedented opportunity to address research questions of several disciplines over spatial scales heretofore never conceived.

General Recommendations of the Santa Barbara Panel

Conceptual model

The preliminary conceptual model developed by the panel is shown on Figure 1. As outlined by the NRC review of the GEM Science Plan, the need for an effective administrative structure to manage the funds and coordinate a large-scale long term study was identified as the key element of a successful program. Scientific oversight must be provided through a committee made up of academic peer reviewers. At least one GEM staff person would be required to act as the primary administrative contact. The function of this position would be to ensure continuity of the data within each region and compliance with the standard protocols. The centerpiece of the science programs should include three basic elements: 1) synthesis, compilation, and management of both pre-existing and new data; 2) synoptic studies of large spatial scale nearshore oceanographic processes such as ocean temperature, ocean color, carbon budgets, etc.; and 3) intensive monitoring of regional sites and a series of extensive sites among regions.

Synthesis and Data management

One essential component of GEM would be to establish the means to collect and manage historical and new data and serve as a data archive for the Gulf of Alaska. Existing data should not be overlooked, and in fact, a major effort should be undertaken to collect and manage this data. The panel agreed with the NRC review that GEM, through its data management program, could provide a central computing facility and data managers to create this data archive. There are excellent tools for data archiving and models for data management being developed at the National Center for Ecological Analysis and Synthesis (NCEAS).

Causes of change

Table 2 outlines specific hypotheses with respect to agents of change, likely effects, and scales of importance. While it is unlikely we will be able to predict all potential agents of change that might occur over the next century, identifying likely agents will help us to decide on appropriate scales of sampling and to prioritize among sampling schemes. For example, detecting changes that might result from global warming will likely occur over large spatial scales, and would require sampling over those scales. On the other hand, changes that might result from more localized events (e.g. development of a specific watershed) would require sampling on smaller spatial scales. Trying to tease apart causes for changes that will likely occur on several spatial and temporal scales will require a combination of sampling schemes that are carried out over both large and small scales. The trick will be to determine the relative levels of effort for each.

Synoptic studies

The panel recommended that GEM try to partner with short term programs such as GLOBEC and NOPP and with long term programs, such as PISCO, CalCOFI, the NOAA data buoy program (NDBC), NERRS, and others, to develop synoptic data sets for the Gulf of Alaska. At the scale of the Gulf of Alaska, remotely sensed data are available for ocean color, sea surface temperature, and ocean altimetry. NASA is considering a series of ground control sites in the Gulf of Alaska for a variety of satellite platforms. The GEM program should strive to maintain close relationships with the appropriate NOAA and NASA program managers so that collaborations can develop at early stages. For example, studies such as the North American Carbon Budget Program are currently being developed, and steps should be taken to integrate sites in the GOA.

Intensive regional study sites

The geographic extent of GEM should consider the flow of currents in the Gulf of Alaska and the length of time that larvae spend in the plankton. Figure 3 shows the location of several regions that could be considered as part of the intensive regional research network. These sites were chosen for their proximity to the communities of Sitka, Yakutat, Cordova, Seward, Homer, and Kodiak. Within each region (Figure 4), a series of sampling areas can be established to capture smaller spatial scale environmental variability such as gradients in temperature and salinity, wave energy, species diversity, growth rates, etc. Within each area, experimenting and monitoring programs can be established over a series of replicate sample sites. Figure 5 shows an example in Kachemak Bay where a nearshore instrument array is linked to a subtidal monitoring site and three intertidal sites. Sampling of the intensive regional sites could be done annually by local agency or academic staff at relatively low taxonomic resolutions, and every two to five years by a team of taxonomic specialists for a comprehensive species lists for each habitat selected.

Extensive study sites

The proposed network does not preclude individual sites from pursuing areas of research and monitoring that may be of special interest to one or a few regions. These additional efforts could be conducted either within or among the regions of intensive focus, at additional or extensive sites. Extensive sites can be within the regional network or between regions. A minimum number of metrics would be studied at extensive sites. In addition, these extensive sites would be ideal for citizen based monitoring programs.

Metrics

Table 3 list the parameters considered for possible sampling, the possible number of sites sampled, and the possible frequency of sampling. Also given are “priority’ designations. These range from 1 (highest priority) to 3 (lowest priority). These are preliminary designations based on a previously convened panel of experts. The table is arranged in three sections that identify sampling to be conducted at: 1) throughout the GOA, 2) at intensively sampled sites, and 3) at less intensively sampled sites.

Bottom-up approach

PISCO is collecting data that suggests variation among nearshore benthic communities can depend on recruitment and such bottom-up oceanic influences as phytoplankton productivity and nutrient concentration, all of which vary significantly with currents, upwelling, and other physical oceanographic processes. In particular, this research emphasizes that the scale of study is crucial. Bottom-up influences were previously missed largely because most prior research was conducted at scales in space and time that were too small or too short to detect potential variation due to variation in oceanic processes. These results on the West Coast, suggest that variation among coastal sites will be fully understood only when we enlarge the spatial and temporal scales of our research to those appropriate to ocean-related scales of variation.

The panel acknowledged that a bottom-up approach is the most appropriate model to adopt for ecosystem monitoring. Figure 6 shows a conceptual model of a bottom-up ecosystem monitoring program. The focus early on would be to fund and develop an appropriate array of weather and oceanographic instruments to begin understanding the physical forcing mechanisms driving the dynamics of the nearshore ecosystem. These data would help us identify the atmospheric and oceanic patterns forcing primary productivity. A key component linking the variability of the ocean and that of the nearshore biota is habitat type. Thus, developing adequate habitat maps is a prerequisite to understanding habitat dynamics and the spatial and temporal variability of nearshore biota. Studies of the frequency and magnitude of primary productivity would lead to monitoring recruitment and growth rates of benthic fauna and flora. A number of research and monitoring components can be incorporated into this program as shown in Table 2. But the key to successfully implementing this large scale network is adopting a standard protocol for each of the research components.

Oceanographic sampling

The panel identified the need to study nearshore oceanography in order to understand natural variation in population and community dynamics in nearshore organisms. Nearshore oceanographic sampling needs to occur at a higher spatial frequency than offshore oceanographic sampling because the scales of sampling biota in the nearshore are necessarily small, and understanding those scales will rely on understanding the oceanic variability at the same scales. The simplest and most economical approach is to measure temperature with low cost temperature loggers bolted to shoreline rocks. But shallow water instrument arrays (in depths less than 20 m) have been developed and successfully deployed by the PISCO program and in Kachemak Bay to measure a more complex array of abiotic and biotic variables including: nearshore salinity, temperature, pH, D.O., turbidity, chlorophyll fluorescence, and photosynthetically available radiation (PAR). PAR is highly recommended as a parameter to measure in addition to chlorophyll in order to relate the pigment response to light in the wavelengths of 400-700 nm. These parameters are relatively inexpensive to monitor and provide the basic information necessary to begin understanding the relationship between physical cycles and biological responses. Additional measurements for nutrient concentrations and suspended matter, particularly the concentrations of organically bound carbon and nitrogen (POC, PON), would help resolve issues related to the North Pacific carbon and nitrogen budgets. In terms of the movement of pelagic larvae, measurements of current speed and direction in the nearshore ocean would greatly benefit our understanding of recruitment in populations of fishes, invertebrates and algae. PISCO is seasonally deploying bottom mounted ADCP's to measure water velocity profiles and nearshore currents that may affect the distance larvae travel along the shore before recruitment. A nutrient sampling program would need to be developed for nitrates and phosphates or automated nutrient samplers could be deployed along with the instrument arrays. Farther offshore, a deep water mooring should be deployed adjacent to each nearshore region to suspend instrument arrays, with a minimum array consisting of temperature and salinity loggers, and preferably with an ADCP and a fluorometer. As with the nearshore array, the latest technology makes possible continuous profilers that allow instruments to sense the entire water column at pre-set intervals. The nearshore monitoring program should be dynamic enough to adapt to new technologies as they become accepted in the field of study. The panel pointed out however, that when new technologies are adopted, both the old and the new method should overlap for a period to compare and correlate values and to ensure consistency of results before and after the transition.

Habitat mapping

Most research groups, management agencies, local governments, and conservation advocates could benefit from a comprehensive, high resolution database of shoreline and nearshore habitats, and from information on the physical changes seen through time. At present, no such detailed database or monitoring program exists within the Gulf of Alaska. The NOAA Environmental Sensitivity Index (ESI) maps, developed for oil spill response planning, do not contain the data necessary for resolving small spatial scale features of the shoreline needed in ecological studies where biophysical linkages often occur at scales of less than one meter. The panel regarded habitat mapping as the foundation for developing a monitoring program to detect changes in nearshore communities resulting from shifts in watershed and marine processes. The proposed method relies on a nested hierarchical nearshore classification based on the physics of the environment. The habitat inventory should occur at two resolutions. Aerial surveys by geomorphologists and marine biologists are augmented with low altitude videography to generate spatially comprehensive inventories and maps of physical and biological features. Initial work should focus on habitats within the intensive study regions, and later among regions to include extensive sites. The second step is to increase the resolution of this product within regions by quantifying the physical structure of shoreline habitats. This will entail detailed on-the-ground surveys of selected areas within each region or of the entire region. These data would be entered into a GIS to create a powerful database tool that can be used to compare habitat types within and among regions over multiple spatial scales. Queries of this database will yield locations of replicate habitats that can be assessed as candidates for long term monitoring sites. This method has been successfully adopted along the North American West Coast (British Columbia, Washington, and portions of Oregon and California) in a cost-effective yet detailed manner. The method of using a high resolution physical habitat classification scheme to aid in site selection of replicate habitats has been adopted by PISCO along the entire U.S. West Coast, and by groups including the Olympic Coast National Marine Sanctuary, the State of Washington, and the Cook Inlet Regional Citizens Advisory Council. Extending this habitat inventory into the Gulf of Alaska, by using the established protocols, would create a comprehensive database of unprecedented scale and utility to scientists and managers far beyond the interests of GEM.

Site selection

It should be acknowledged that not every habitat can be monitored everywhere. The panel identified the following criteria to be used in selecting habitats to be monitored:

1. The signal to noise ratio should be high enough to detect a change
2. Ease of manipulation/observation
3. Need to be replicated in space, so that at least 3 transects represent each area, and three areas represent each region
4. Ease of access

Habitat should be as consistent as possible across all intensive sites. For quantifying the effects of environmental change on community structure, rocky shores are the preferred habitat type for long term monitoring in both the intertidal and subtidal because they meet the above criteria. Organisms on rocky shores are easily observed, identified, manipulated, and quantified compared to organisms on sediment shores. Sediment shores could be monitored at extensive sites (which could be adjacent to rocky shores if the effect of habitat is to be investigated).

Diversity Monitoring

Knowledge of species abundance and how these vary across different spatial and temporal scales are necessary to accurately assess both short and long-term changes in local and biogeographic distributions. Coordinated quantitative assessments of community patterns to establish baseline estimates and changes through time of benthic nearshore populations and communities were considered a high priority by the panel. Variation in community structure can result from both recruitment and post-recruitment processes. To quantify the ecological and oceanographic processes that influence the patterns of community structure in the subtidal and intertidal, the panel suggested investigations of recruitment, larval abundance, phytoplankton concentration, nutrients, currents, growth, and species interactions at each site.

<u>Mechanistic Studies</u>
Intertidal and subtidal surveys and experiments, along with moored and large-scale oceanography observations, will provide a comprehensive picture of how local oceanography interacts with community ecology. These observations will allow us to interpret patterns and changes emerging from large-scale yearly biodiversity surveys. For these findings to be most useful to planners and managers, we need to know the mechanisms that connect coastal biological communities together. One promising approach to this problem lies in the use and interpretation of environmental markers, where analysis of hard parts of organisms can indicate past residence in different water masses or coastal environments as larvae. Other potential areas of academic study include:

- How growth rates of migratory fish change in different water bodies,
- How physiological traits contribute to ecological patterns on local to geographic scales,
- How the role of abiotic factors perturb physiological systems,
- How much change in an abiotic factor such as temperature is sufficient to perturb a system enough to detect a change at the organismal, population, and community levels.

<u>Graduate student fellowship program</u>
One very cost effective way to have monitoring data used in scientific studies is to fund graduate student research that will utilize data produced from GEM. Such a fellowship program could be viewed as serving the missions of outreach and education, as well as research.

<u>General comments</u>
The panel expressed concern that the structure of GEM and the process may be too politically motivated to accomplish valid scientific goals. GEM needs to focus on establishing a process to ensure the longevity of a core monitoring program, one that transcends management and individual agency agendas and ensures a scientifically credible program.

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Table 2. Possible agents of change in nearshore systems of the Gulf of Alaska over the next century, their physical effects, biological effects, and temporal and spatial scales on which impacts are likely to occur.

Agents of Change	Physical Effect	Biological Effect	Temporal/spatial scale[1]
Natural			
Climate			
ENSO - El Nino	Temperature increase Decreased upwelling Increase storm activity	Decrease in primary production Northerly range extension of southern species Increase in some diseases	Years/Region
ENSO – La Nina	Temperature decrease Increased upwelling	Southerly range extension of northern species Increase in primary production	Years/Region
PDO	(In warm cycle) Temperature increase Decreased upwelling	Decrease in primary production Northerly range extension of southern species Increase in some diseases	Decades/Region
Weather			
Extreme cold events	Freezing in intertidal Extreme cold air temp	Death of Inverts/algae and some vertebrates	Days (though effects may last years) /Area (with greater effects in northerly exposures)
Extreme heat events	Heat/dessication in intertidal (especially if coincident with spring tide)	Death of inverts/algae	Days (though effects may last years) /Area (with greater effects in southerly exposures)
Storms	Waves/debris increase Salinity decrease	Death of inverts/algae and some vertebrates	Days (though effects may last years) /Area (with greater effects in more exposed locations, locations with movable substratum, or nearer stream mouths)
Disease		Increased death rate or reduced reproductive rate	Largely unknown
Geologic events			
Earthquakes	Uplift or downthrust/sediment shifting/shifting of stream mouths	Killing of inverts and algae	Minutes/Hours (though effects may last years) /Area (with greater effects in

			areas of greatest uplift/downthrust
Volcanoes	Increased sedimentation in intertidal	Smothering of inverts and algae	Minutes/Hours (though effects may last years) /Area (with greater effects in areas most exposed to ash
Glacial activity	Increased / decreased sedimentation and calving	Smothering of inverts and algae (on advance) or increase in exposed bottom/intertidal inverts and algae and decreased glacial feeding by birds (on retreat)	Decades/Location or Sites
Anthropogenic			
Global warming	Increased temperature, increased UV radiation, reduced salinity	Northerly shift in species distribution, reduced photosynthesis of kelp, reduction in marine stenohaline spp.	Years/Region
Introduction of exotic spp.	None	Reduction in abundance of competitors/prey	Years/Area
Fishing	None	Reduction in targeted stocks, reduction in predators of those stocks, possible habitat destruction	Years/Area or Location
Aquaculture (especially intertidal clam)	None	Intertidal habitat loss, reducition in intertidal inverts/algae with possible reduction in their predators	Years/Area or Location
Coastal development	Increased sedimentation and eutrophication, introduction of contaminants	Reduction in fish spawning habitat, reduction in inverts and algae intolerant to stress, increases in stress tolerant spp., increased contaminant levels in animals and increased death rate or reduced reproductive rate especially in higher trophic levels.	Years/Sites
Recreational use	None	Disturbance to mammals/birds, entanglement of	Years/Sites

		birds/mammals with trash, reduction in intertidal inverts/algae due to trampling	
Watershed development	Increased sedimentation and eutrophication, introduction of contaminants	Reduction in fish spawning habitat, reduction in inverts and algae intolerant to stress, increases in stress tolerant spp., increased contaminant levels in animals and increased death rate or reduced reproductive rate especially in higher trophic levels.	Years/Sites (especially at stream or river mouths)
Contamination from distant sources	Increased levels of metals and other chemicals	Increased contaminant levels in animals and increased death rate or reduced reproductive rate especially in higher trophic levels.	Years/Region or Areas
Logging activity	Increased sedimentation and eutrophication, introduction of contaminants	Reduction in fish spawning habitat, reduction in inverts and algae intolerant to stress, increases in stress tolerant spp., increased contaminant levels in animals and increased death rate or reduced reproductive rate especially in higher trophic levels.	Years/Sites
Oil or chemical spills	Increased levels of contamination	Reduction in inverts and algae intolerant to stress, increases in stress tolerant spp., increased contaminant levels in animals and increased death rate or reduced reproductive rate especially in higher trophic levels.	Days (although impacts may last years or decades) /locations or sites

[1] Definition of spatial scales (with approximate shoreline extents)
Region – Gulf of Alaska (1,000 plus km)
Area – Southeast, Yakutat/Prince William Sound, Cook Inlet/Kenai, Kodiak/AK

peninsula) – (200 km)
Location – Subareas on the order of Western Prince William Sound 50-100 km
Site - Eg. Herring Bay, Orca Inlet, Jakalof Bay,,Etc.(5-10 km)
Spot – 10s to 100s of m

Table 3. Possible physical, chemical, biological, components to measure as indicators of change and identify associated causative agents. Possible metrics and spatial/temporal scales of measurement are also given.

Entire Region

Metric	Sites per region	Frequency	Priority	Comments
Synoptic ocean color, temperature, altimetry	N/A	Continuous	1	Develop algorithms for nearshore corrections
Habitat maps	N/A	Once / decade?	1	
Human Use maps	N/A	Once per decade?	2	
Special Use maps (e.g. fish take)	N/A	Annual	2	
Event documentation (E.G. earthquake activity)	N/A	As they occur	2	

Intensively sampled sites

Metric	Sites per region	Frequency	Priority	Comments
Physical - chemical				
Substrate Composition	All	Once/5-10 yr	1	
Slope	All	Once/5-10 yr	1	
Exposure	All	Once/5 10 yr	1	
Data Loggers				
Temperature	1-3	Continuous (C)	1	Profiles or near surface and near bottom
Salinity	1-3	C	1	"
DO	1-3	C	1	“
PH	1-3	C	1	“
Turbidity	1-3	C	1	“
Chlorophyll	1-3	C	1	“
PAR	1-3	C	1	"
Nutrients				
Nitrate, Nitrite, Ammonium, Phosphate	1-3	C	2	Profiles or near surface and near bottom
POC	1-3	Monthly	2	“
PON	1-3	Monthly	2	“
DOM	1-3	Monthly	2	“
Wave energy	1-3	C	2	“
Current speed/direction	1-3	C	2	“
Habitat Characteristics				
Biological				
Kelp and eelgrass mapping	All	Once / yr.	1	
Abundance - sea otters	Entire area	Once / yr	1	Aerial surveys
Mortality rate – sea otters	Entire area	Once / yr	2	Based on recovered skulls/carcasses
Diet – sea otters	3-4	Once / yr	2	

Disease – sea otters	All	Once / yr	2	Based on recovered carcasses
Contaminant levels – sea otters (POPs, PAHs?)	All	Once / yr	2	Possible archival of samples
Abundance – selected birds (Oyster catchers, goldeneye, scooters, harlequin ducks)	All	Once / yr	2	
Abundance - All birds	All	Once / 5 yr?	2	
Abundance – selected fishes	All	Once / yr	2	Diver surveys
Body burden of comtaminants in selected fish (e.g greenling)	All	Once / yr	2	Possible archival of samples
Intertidal – hard substrate				
Abundance - all macro inverts and algae	All	Once / yr	1	
Distribution - selected inverts and algae (Fucus, mussels, kelp)	All	Once / yr	1	
Temperature	All	C	2	High and low intertidal;
Size distribution – selected inverts (mussles, stars, ?)	All	Once / yr	2	
Recruitment – selected inverts and algae	All	Once / yr	2	
Growth – selected inverts and algae	All	Once / yr	2	
Condition – selected inverts/algae	All	Once / yr	3	
Body burdens of metals, PAHs, and other contaminants in mussles	All	Rotating subset once per year	2	Possible archival of samples
Intertidal – soft substrate				
Abundance – Protothaca and selected clams., crabs	All	Once / yr	2	
Body burdens of metals, PAHs, and other contaminants in clams (Protothaca)	All	Rotating subset once per year	2	Possible archival of samples

Less intensively sampled sites

Metric	Sites per region	Frequency	Priority	Comments
Physical – chemical				
Temperature?	All	C	2	High and low intertidal;
Salinity?	All	C	2	Low intertidal
Substrate Composition	All	Once/5-10 yr	1-2?	
Slope	All	Once/5-10 yr	1-2?	
Exposure	All	Once/5 10 yr	1-2?	
Biological				
Body burden of comtaminants in selected fish (e.g greenling)?	All	Rotating subset once per year	1-2?	Possible archival of samples
Kelp and eelgrass mapping?	All	Rotating subset once	1-2?	

		per year		
Intertidal – hard substrate				
Abundance - Selected macro inverts and algae (Fudus, mussels, limpets, stars)	All	Rotating subset once per year	1-2?	
Distribution - selected inverts and algae (Fucus, mussels, ?)	All	Rotating subset once per year	1-2?	
Size distribution – selected inverts (mussles, stars, ?)	All	Rotating subset once per year	1-2?	
Body burdens of metals, PAHs, and other contaminants in mussles?	All	Rotating subset once per year	1-2?	Possible archival of samples
Intertidal – soft substrate				
Abundance – Protothaca and selected clams., crabs	All	Rotating subset once per year	1-2?	
Body burdens of metals, PAHs, and other contaminants in clams (Protothaca)?	All	Rotating subset once per year	1-2?	Possible archival of samples

Part II

Presentation of a Conceptual Model For Monitoring Nearshore Habitats in the Gulf of Alaska

Workshop Summary and Recommendations January 24, 2002 Anchorage, Alaska

Summary

A conceptual framework for nearshore monitoring in the Gulf of Alaska was presented to Alaska researchers, resource managers, and community stakeholders during a second workshop in Anchorage in January 2002. The goals of the Anchorage workshop were to further develop recommendations for variables to be measured, where they should be measured, and how often. As starting points, the draft GEM Program, National Research Council comments on the nearshore component of GEM, the results of the prior expert panel, and an example of a monitoring program with similar goals (PISCO) were presented to a larger group of stakeholders, researchers, and resource managers. The group was then subdivided into smaller working groups and asked to provide comment on the NGEM plan.

The key results of the Anchorage workshop were that 1) there were no substantive objections to the proposed monitoring design for the Gulf of Alaska, 2) there was general agreement that the approach used by PISCO would also be appropriate for the Gulf of Alaska, and 3) involvement and support of coastal communities in the nearshore program of GEM are essential to its long-term success. The specific issues addressed by the participants are summarized as follows:

What to measure: Essential components of a Gulf-wide monitoring program were identified and prioritized as follows: oceanographic variables, habitat type, benthic community structure, human use, contaminant levels, and abundance of selected marine mammals, birds, and fishes.
Where to measure: The recommendation of the Santa Barbara panel was generally accepted as the best approach for the Gulf of Alaska. This approach utilizes a combination of synoptic, intensive, and extensive sites to monitor the above components at nested scales of space and time. Intensive sites would be used for process oriented studies and to address questions linked to Gulf-wide hypotheses. 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.
When to measure: A program was recommended that matched sampling frequency to the appropriate temporal scale for the ecosystem component of

interest. No specific sampling frequencies were identified. It was also suggested that a portion of the sampling effort should be event driven.
Who should be involved: Academic and agency scientists, teams of specialists, and graduate students were identified for studying Gulf-wide intensive sites. Community representatives and stakeholders were identified as critical participants in the extensive study site program, from planning to implementation and information transfer.

Several remaining issues of importance were identified. These included:

1. A process to include community members and stakeholders in plan development needs to be determined and implemented.
2. Specific details of the monitoring plan (e.g. specific metrics to sample, the number and location of sampling sites) need to be determined.

We recommend a process for plan development that includes selected representatives from communities, stakeholder groups, resource managers, and researchers. We also provide guidance on the steps necessary to further develop details of a nearshore GEM plan.

Introduction

The Gulf Ecosystem Monitoring Program (GEM) seeks to provide long-term monitoring of changes in the Gulf of Alaska ecosystem. The goals of the GEM program as outlined in the GEM Science Plan (http://www.oilspill.state.ak.us/gem/index.html) are:

DETECT: Serve as a sentinel (early warning) system by detecting annual and long-term changes in the marine ecosystem, from coastal watersheds to the central gulf;
UNDERSTAND: Identify causes of change in the marine ecosystem, including natural variation, human influences, and their interaction;
INFORM: Provide integrated and synthesized information to the public, resource managers, industry and policy makers in order for them to respond to changes in natural resources; and
SOLVE: Develop tools, technologies, and information that can help resource managers and regulators improve management of marine resources and address problems that may arise from human activities;
PREDICT: Develop the capacity to predict the status and trends of natural resources for use by resource managers and consumers.

The nearshore has been identified as one of four important habitat types of the Gulf of Alaska (GOA) ecosystem included in the GEM program. The nearshore is loosely defined as the intertidal and nearshore subtidal to the 20m depth contour, and it includes the physical and chemical environment and resident plant and animal species. It also includes important transient species of fish, birds, marine mammals, and humans that depend on the nearshore for food and shelter. The nearshore is likely to be one of the areas in the GEM program that is most impacted by humans.

Over the past several months, two workshops were conducted to help to define essential elements of a nearshore monitoring program (hereafter referred to as the Nearshore GEM program, or NGEM) and to identify elements that should be given high priority for future funding. As an initial first step in the process of developing a nearshore GEM program, a panel of independent scientists was convened in Santa Barbara in November 2001 to help provide a conceptual framework for monitoring in the nearshore. The results of this workshop were then presented at a second workshop conducted in Anchorage on 24 January 2002. The goals of the Anchorage workshop were to further develop recommendations for variables to be measured, where they should be measured, and how often. As starting points, the draft GEM Program, National Research Council comments on the nearshore component of GEM, the results of the prior expert panel, and an example of a monitoring program with similar goals (PISCO) were presented to a larger group of stakeholders, researchers, and resource managers. The group was then subdivided into smaller working groups and asked to provide comment on the NGEM plan.

In this report, we 1) summarize the recommendations made by the Santa Barbara panel; 2) present the conceptual model or monitoring framework that was based on the Santa Barbara panel recommendations; 3) review the questions asked of the working groups at the Anchorage workshop regarding the NGEM plan; 3) present the findings of the working groups; and 4) summarize remaining tasks necessary to construct a final NGEM plan.

<u>Findings of the Santa Barbara Panel</u>

The findings of the panel of independent scientists convened in Santa Barbara in November 2001 are detailed in a report to the EVOS Trustee Council submitted in January 2002 (Part I). In summary, the panel recommended that the monitoring program be focused on detecting changes at several spatial and temporal scales by using a sampling design that includes:

1) Sampling of some synoptic measures, such as ocean surface temperature and habitat type, over the entire GOA,
2) Sampling a variety of physical and biological measurements (e.g. nearshore oceanography; species diversity; growth and recruitment rates for selected invertebrate and plant species, abundance patterns for selected fishes, birds, and marine mammals) at “intensively” studied sites within a few (three to six) regional study centers. These studies would provide for detection of large-scale changes within the system (e.g. shifts in species distribution due to climate change) and would help to identify mechanisms of change.

3) Sampling of a limited number of physical, chemical and biological measurements at a larger number of "extensively" sampled sites. These would be more widely distributed throughout the GOA. The metrics would include a subset of those sampled within the intensive sampling sites (e.g. abundance patterns for a few selected algal or invertebrate species). The data from the extensively sampled sites would provide a means of detecting changes that might occur on a more localized scale, and especially changes that might result from anthropogenic effects (e.g. destruction of nearshore habitat due to shoreline development).

The panel also provided some preliminary recommendations for variables to be measured, where they should be measured, and how often (see Table 2 of Part I for details). They also provided some preliminary guidance on which elements would be most essential to an effective nearshore monitoring program.

Proposed GEM Nearshore Monitoring Framework

The National Research Council (NRC) in their review of the GEM Science Plan emphasized the need for a broad conceptual framework with a sound scientific basis. A scientific framework will result in data being collected that is more useful and ecologically significant. A strong scientific justification will also lend the program the information required to address short term issues of public concern. Many of the testable hypotheses about community processes were first developed and explored in intertidal and subtidal benthic systems. Strong evidence suggests that variation among nearshore benthic communities can depend on recruitment and such bottom-up oceanic influences as phytoplankton productivity and nutrient concentration, all of which vary significantly with currents, upwelling, and other physical oceanographic processes. These broad questions include those identified by the National Research Council as part of their review on the GEM Science Plan:

1. What processes and physical conditions produce larvae?
2. How long do larval stages last, and where do they go?
3. How and why does production vary along the shore?
4. How variable is recruitment in space and time among major groups of planktonic larvae?
5. What are the primary energy and nutrient sources of intertidal and benthic communities?
6. Under what conditions do recruitment, food, space, natural disturbance, temperature, predators, competitors, and disease limit populations?
7. What are the sources and rates of natural disturbance to intertidal and subtidal communities?
8. What are the rates and patterns of recovery?

But while the NRC recommendations are based on the strength of the scientific approach, this approach does not address issues of concern for many of the coastal communities in the Gulf of Alaska. These issues include (but are not limited to): increased sedimentation, increased fresh water runoff, increased community development, pollution (oil, metals, isotopes, etc.), fishing, aquaculture, tourism, and coastal erosion.

The purpose of monitoring is to detect change over time. Data collected by biological monitoring programs are often confounded by low statistical power due to high natural variation in the populations being monitored. Biota in the nearshore ocean are largely dependent on physical processes that “force” food production and dispersal such as currents, upwelling, surface mixing, etc. that operate over different scales of space and time. Biota are also dependent on the availability of food, nutrient concentrations, phytoplankton productivity, and larval recruitment from the plankton.

Coastal communities have been at the forefront of developing citizen monitoring programs on both the east and west coasts of North America. Examples of community based monitoring programs include: vessels of opportunity, water quality monitoring, fish diversity counts, biotic/abiotic shoreline surveys, coast-walk, and beach cleanups. With a long time series, these data are useful for identifying historical trends and patterns. Observed patterns can help direct “process” oriented studies requiring specialized equipment and technical skills. Observation programs can be designed to validate process oriented research over large spatial scales. Process oriented studies are useful for understanding why patterns occur such as: atmospheric carbon and nitrogen budgets, oceanic mixing, stratification, primary productivity, nearshore wave dynamics, sediment transport, invasive species identification, larval recruitment dynamics, post-recruitment processes, fine mesh fish trawls, otolith micro-chemistry, heat-shock proteins, population genetics, harmful algal blooms, and kelp bed community interactions
Our proposed monitoring program seeks to combine “intensive” process-oriented research to understand the mechanisms driving observed patterns with “extensive” data to address community issues and involve citizens in observational studies to augment the intensive programs.

To monitor and study processes of the nearshore ocean, we propose a nested sampling design linking monitoring programs conducted from the coastal communities in Southeast, Southcentral and the Southwest Gulf of Alaska. The nested design consists of a highly replicated series of onshore transects, with adjacent subtidal transects, mooring arrays and oceanographic transects as illustrated on Figure 5. The entire array of these intensive studies would constitute a “Site”. Each Site would encompass a spatial scale of 1-10km where the data would help characterize patterns and processes operating locally. A Site would have at a minimum one moored nearshore oceanographic instrument, one oceanographic transect, three replicate subtidal transects, and 9 (three sets of three replicate) intertidal transects. The next larger spatial scale consists of an aggregation of at least three Sites. This aggregation of Sites is an "Area" encompassing a spatial scale of 10-100 km as shown on Figure 4. Studies within an Area will help us understand patterns and processes at larger scales without sacrificing the smaller scale resolution. Areas can then be aggregated into the Gulf of Alaska "Region" to help us understand Gulf-wide patterns and processes without compromising Area or Site scale studies as shown on Figure 3.

At the Anchorage workshop we specifically requested that this monitoring framework be adopted by participating stakeholders and the GEM administration as the first step towards developing a nearshore monitoring program. For this to work the monitoring programs will have to adopt standardized sampling protocols over every scale of spatial replication. Other large scale studies have developed protocols for addressing many of the same questions being asked in the Gulf of Alaska. One such program is the Partnership of Interdisciplinary Study of Coastal Oceans (PISCO) which is described below. If the GEM partnerships were to adopt these same protocols, then the spatial extent of our combined studies reach unprecedented scales (Figure 2). The scale of this data set would allow scientists to simultaneously study, for the first time, the effect of large scale ocean phenomena on large and small scale populations.

This nested design should be augmented by continuous analysis of satellite remote imagery. The Santa Barbara workshop recommended synoptic studies of the Gulf of Alaska to continually monitor sea surface temperature, ocean color, altimetry, currents, and eddies. Studying these large scale features will help smaller scale studies understand the context of oceanic variability measured by a network of coastal ocean instruments and by local monitoring programs. Satellite imagery is data that can be acquired continuously for the entire Gulf of Alaska, while on-the-ground programs will always have limited geographic coverage, and for the most part will usually be seasonal efforts, albeit at higher resolution. The remotely sensed imagery will augment the field work by providing instantaneous synoptic images to allow some generalization of oceanic processes beyond local study sites.

A networked nearshore monitoring program will rely heavily on the mutual cooperation of adjoining Areas to develop and accept new methods or the existing PISCO protocols. If the concept of standardized protocols, for at least one monitoring component, can be accepted within all Sites, all Areas, and the Region, then we can proceed with deliberating the details of <u>what</u> to monitor, <u>who</u> will monitor, and <u>when</u> and <u>where</u> to monitor.

<u>PISCO: The Partnership for Interdisciplinary Study of Coastal Oceans</u>

Carol Blanchette, Science Coordinator of the Partnership for the Interdisciplinary Study of Coastal Oceans (PISCO) presented an overview of this program, their goals, and their activities. PISCO is a consortium of 4 universities, Oregon State University, University of California at Santa Cruz, Stanford University, and University of California at Santa Barbara, funded by the Packard Foundation to study nearshore ecology and oceanography to better inform conservation. The goals of PISCO's monitoring program are very similar to the goals of GEM and include: 1) tracking natural changes within and among communities over a large spatial scale, 2) assessing anthropogenic impacts, 3) linking ecological mechanisms (e.g. settlement, oceanographic features) to population and community measures, and 4) developing a long-term, spatially extensive, feasible and funded program. PISCO's approach is to use a coordinated monitoring and experimental network to track ecological patterns and processes along 2,000 km of coastline (Washington to California). Nearshore oceanographic moorings which monitor temperature, salinity, nutrients, chlorophyll, larval supply and currents are combined with biological monitoring of community structure and recruitment. Subtidal community structure is annually monitored using a nested design where replicate transects are conducted within each of 3 zones at 2 sites within 22 areas. Intertidal community structure is annually monitored using a similar nested design where replicate transects are conducted at each of 3 zones at 3 sites within 16 areas. Permanent photoplots and spatially explicit grid sampling are also conducted at some intertidal sites to examine within site dynamics. For all community structure surveys, voucher specimens are collected and maintained to verify species identifications. Their monitoring program has detected shifts in species distributions, tracked disease outbreaks over a large spatial extent, studied anthropogenic impacts, and documented underlying natural variability. Their monitoring is also used to direct other process-oriented and experimental studies, such as predation in the intertidal and microchemistry of fish otoliths to study dispersal and connectivity among populations. PISCO recommends that any monitoring program consider the following: scientific merit, inclusion of key species or habitats, trophic linkages, cost, statistical power, community involvement and partnerships, and data quality, longevity, and accessibility. Participants at the Anchorage meeting voiced general support of adopting the PISCO approach for the nearshore component of GEM.

Anchorage Workshop Findings

The goals of the Anchorage workshop were to further develop recommendations for variables to be measured, where they should be measured, and how often in the GEM nearshore monitoring plan. As starting points, the draft GEM Program, the National Research Council comments on the GEM Science Plan, the results of the prior expert panel, the proposed nearshore monitoring program, and the PISCO program were presented. These were followed by smaller working groups formed to discuss and prioritize the details of the plan.

Each workgroup was asked to:

1. Identify what should be monitored.
2. Identify where monitoring should occur (i.e. how many sampling localities and at what spatial density).
3. Identify how often the variable is monitored.
4. Prioritize the above tasks (high medium or low). Especially, identify which tasks, locations, and sampling frequencies are essential elements of an effective monitoring program.

Then, if time permitted, each workgroup was asked to:

5. Identify human and infrastructure resources available to make measurements.
6. Identify techniques or technologies that should be used to take the measurements.
7. Approximate costs for each of the above.

A designated person from each subgroup was asked to summarize the findings of the group and to focus on 5 tasks that were identified by the workgroup as essential elements of the NGEM plan.

The following is a compilation of the findings and recommendations of the working groups that are organized with respect to the above questions.

What variables to measure?

Each working group identified variables that they thought were essential to the NGEM program. These are presented below in order of most to least often identified. The number of groups that identified each measure as critical is given in parentheses.

1. Selected physical and chemical variables - (7 of 8). Ocean temperature and salinity were most often identified as variables of importance, but variables mentioned also included currents, wind, rainfall, and chlorophyll.

2. Habitat - (5 of 8). Critical habitat features to be mapped included shoreline geomorphology (intertidal and subtidal) and important biological habitats (e.g. mussel, eelgrass and kelp beds). These habitat maps might also include biological “hotspots” that are areas of high production or serve as important nursery and feeding areas for birds and mammals.

3. Benthic community – (5 of 8). Monitoring and analysis of structure of communities of intertidal and nearshore subtidal invertebrates and algae. Several groups (3 of 8) specifically indicated that both hard and

soft substrate communities should be evaluated. Some groups included specific recommendations. For example they recommended measuring diversity; abundance, and recruitment of selected species like clams, mussels, limpets, and chitons; the abundance of selected "keystone" predators like starfish; and the growth of clams and macrophytes. The occurrence of invasive or introduced species was also mentioned.

4. Contaminants - (5 of 8). Contaminants most often mentioned as being of concern were oil, persistent organic pollutants (e.g. PCBs), and heavy metals. Of particular concern were contaminants that might impact human health. Contaminant levels in mussels and clams were identified as potential key indicators.

5. Human use - (5 of 8). Maps should include uses such as fishing pressure, subsistence use, shoreline development, and recreational use.

6. Selected birds and mammals - (4 of 8). The abundance of marine mammals, especially sea otters and sea lions were identified as important to monitor. Bird species considered included harlequin ducks, oyster catchers, and pigeon guillemots. Sea birds were identified as potentially useful indicators of change in the environment.

7. Forage fish and salmon. - (3 of 8). Forage fish, especially herring that spawn in the intertidal and nearshore subtidal, and salmon were indicated as important components of the nearshore system that should be monitored.

Where to monitor?

Two groups specifically indicated that it was important to consider spatial scales in monitoring and that different spatial scales would be appropriate for different variables. All groups concurred, either explicitly or implicitly, with the approach of using a combination of Gulf-wide monitoring for some synoptic variables like sea surface temperature, intensive sampling of a few selected sites, and less intensive sampling of smaller suite of key indicator variables at a larger number of "extensive" sites.

Several groups gave guidance as to how sites should be selected. Three groups suggested that sites not be randomly selected, but focused on "hotspots". Intensively sampled sites should be focused on areas of special biological significance (areas of high productivity, nursery grounds, etc.) and should be located in areas where localized human disturbance (e.g. shoreline development or logging) is unlikely to have a significant impact in the foreseeable future. Extensive sites on the other hand might be focused in areas of likely human impact. Other recommendations included the consideration of safety in selecting sites (2 groups), that sites be accessible (2 groups), and that sites where there are historical data be given preference (1 group). One group also suggested that high-energy sites along open coasts should be excluded because they are physically disturbed on a regular basis and therefore were unlikely be effective indicators of change.

One group suggested that a GIS database be established and used in selecting sites. This database might identify habitat types, biological hotspots, human use, and sites where historical data of specific types are available. Sites could then be selected based on the co-occurrence of specific attributes. For example, desired attributes for intensive sites might include biological hotspots where there is little human disturbance, where there has been some historical data collected, and that are in close proximity to research support facilities.

When to monitor?

Several groups indicated that the temporal scale of monitoring be should depend on the variable of interest and on the important scales of inherent temporal variability for that variable. For example, temperature and salinity that are highly variable on several temporal scales would require frequent (perhaps continuous) monitoring. On the other hand, the level of contaminants in the tissues of clams or mussels might be measured only once every several years.

Three groups also indicated that the NGEM program should have a component that is event driven and can respond rapidly to sample at times or locations of special significance (e.g. an earthquake, chemical spill, or unexplained die off of animals).

Only one group had sufficient time to identify time scales of measurement for specific variables of interest. As a result, we do not report these.

Who should monitor?

Five groups identified community involvement as a key element of a successful monitoring program. It was recognized that community representatives should be involved in the entire process, from planning to implementation. Several specific suggestions were made regarding how communities might be involved in sampling. These included conducting bird counts (similar to the Christmas bird count program), estimating the abundance of sea otters, seals, and sea lions, measurement of temperature and salinity, collection of organisms or sediments for the evaluation of contaminant levels, and photo documentation of benthic communities. One group indicated that community members might be particularly valuable assisting with sampling at “extensive” sites.

Outreach and education was also indicated (2 groups) as an important component of the NGEM program. One group suggested establishing a web-based hotline where community members could input observations and data could be shared among researchers and community members. It was also suggested that local schools be involved in the process.

Two groups specifically mentioned that establishing partnerships with other research programs would be an important way of leveraging the value of the NGEM program.

<u>How should monitoring should be conducted?</u>

Three groups suggested that establishing strict quality assurance measures were critical and that standard sampling and data reporting protocols be established as a part of a QA program. Two groups also indicated that data management plans be established and strictly adhered to.

One group suggested that a protocol be established to advise and get approval of communities prior to establishing sampling locations and conducting studies in the vicinity of each community. This would help ensure that sampling effort did not conflict with other uses (e.g. subsistence harvest) and help to improve communication and cooperation between researchers and community members.

Two groups pointed to the use of historical data and retrospective analyses of existing data as an important component of the NGEM program. These types of analyses might be used to establish background conditions (for contaminant levels or growth rates of clams for example), to aid in the selection of sampling sites, or to determine the appropriate frequency of sampling.

Remaining Questions and Recommendations

As a result of the workshops conducted to date, a general framework has been developed for a nearshore monitoring program. At the Anchorage workshop there was general agreement to adopt the proposed design for monitoring the Gulf of Alaska using synoptic, intensively, and extensively sampled sites at nested spatial scales. However, several important issues need to be resolved prior to finalizing a nearshore GEM plan. The most critical are:

1. How to include community representatives in the process of planning the specific monitoring programs
2. Details of the plan including:
   - What specific parameters should be measured
   - Number and locations of sampling sites for each parameter
   - Sampling frequency for each metric
   - Specific sampling protocols
3. Development of a quality assurance and data management plan

We recommend using GEM funding and a competitive scientifically peer-reviewed proposal process to solicit ideas for developing the specific details of the synoptic, intensive and extensive sampling. The intensive sampling should be strongly coordinated or initiated by a single group to ensure standardization of protocols throughout the monitoring region. Intensive sampling plans should reflect heavily on existing protocols such as those developed by PISCO. Guidelines should be developed to help the proposing parties develop a program that is aligned with the findings of this report (i.e. nested sampling design, standardized monitoring protocols, recommended parameters, community involvement, etc). Since the nested design was agreed upon at the Anchorage workshop, we suggest that interested communities work with specialists, consultants, and academics of their choice to develop proposals to pilot community monitoring programs at extensive sites with the objective of building model programs that can be exported to other communities.

Conceptual Monitoring Program for the Gulf of Alaska

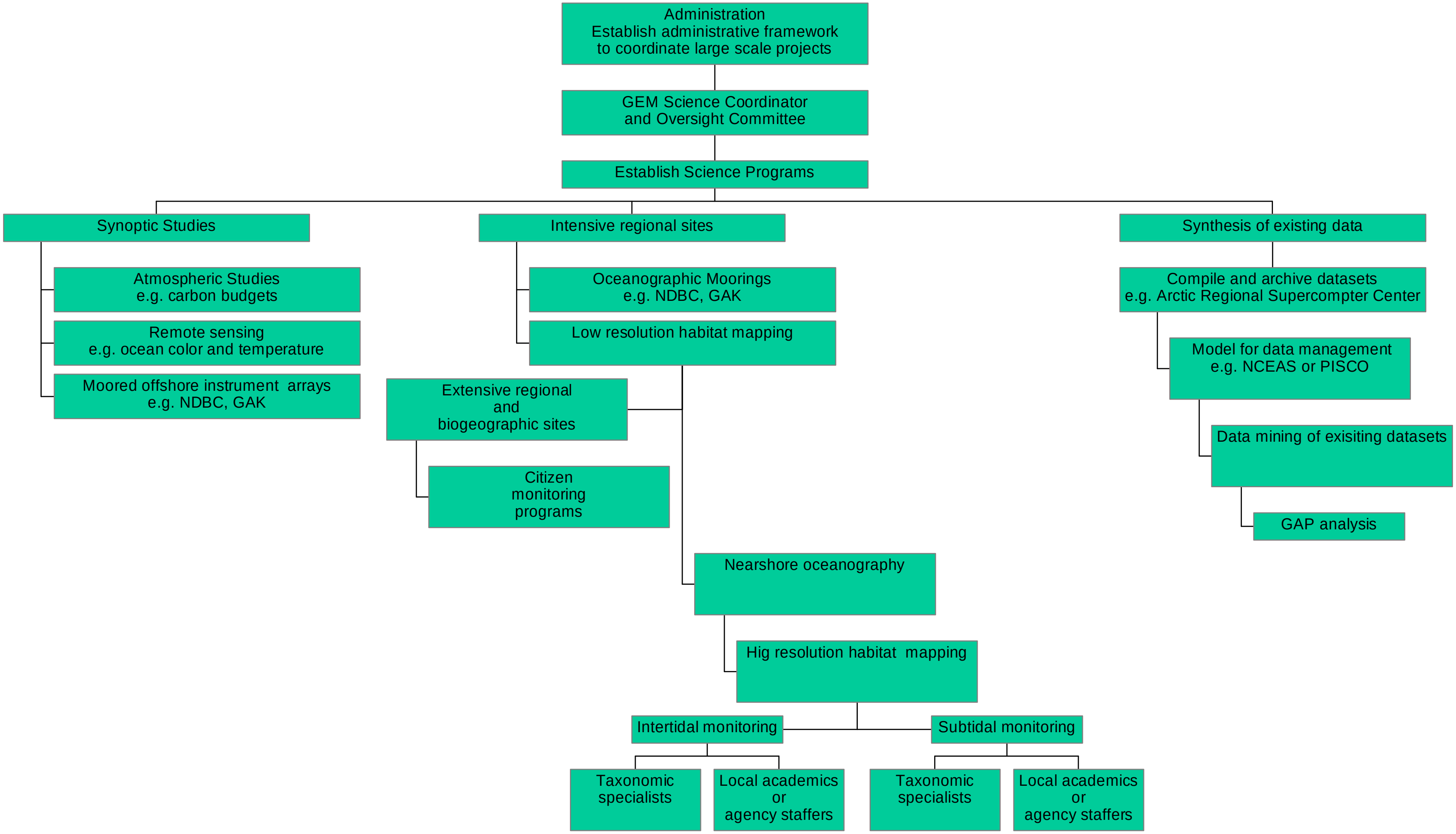
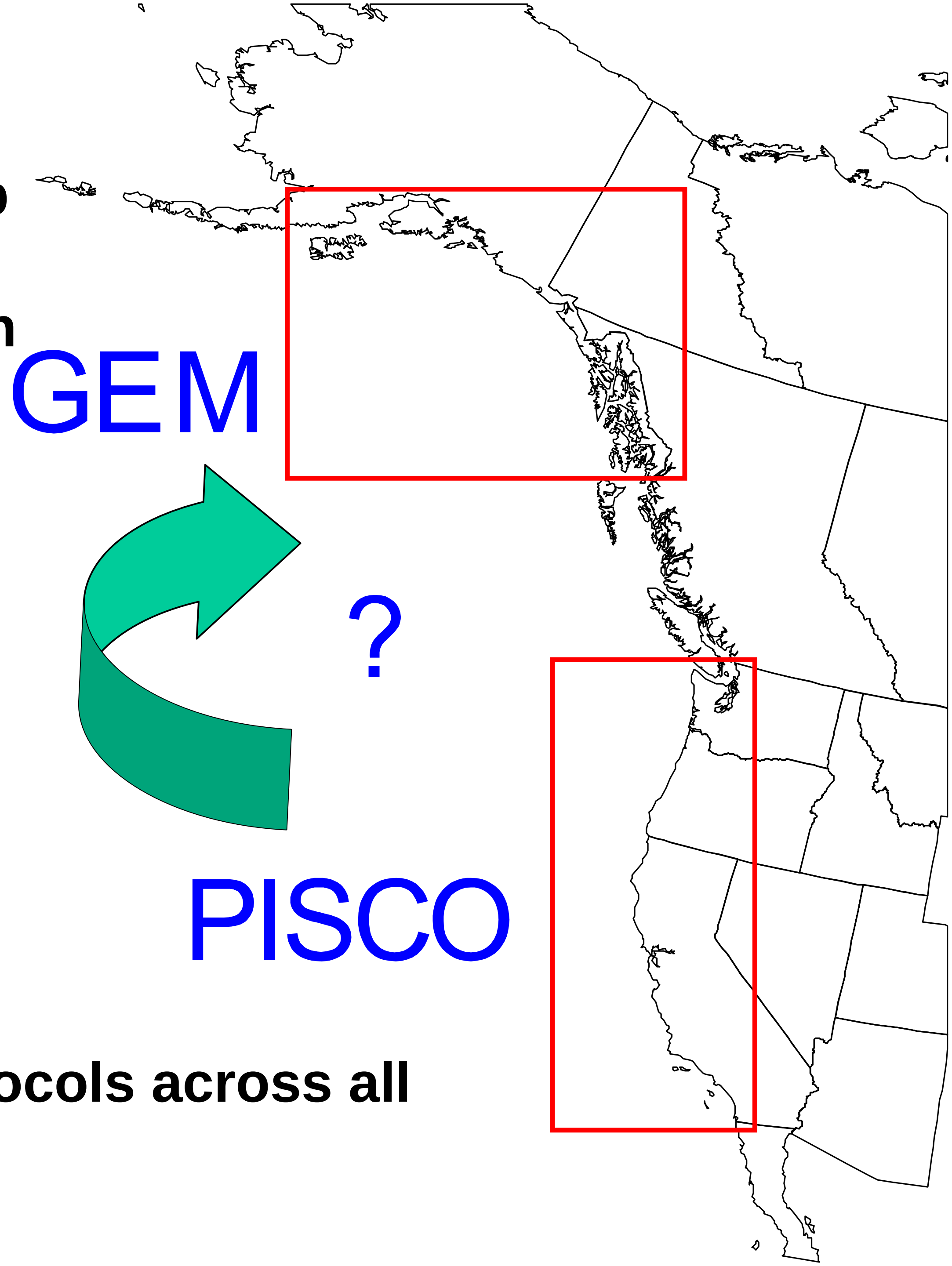


Figure 1

Figure 2.Scaling up Regions: North Pacific Ocean



(using consistent protocols across all Regions)

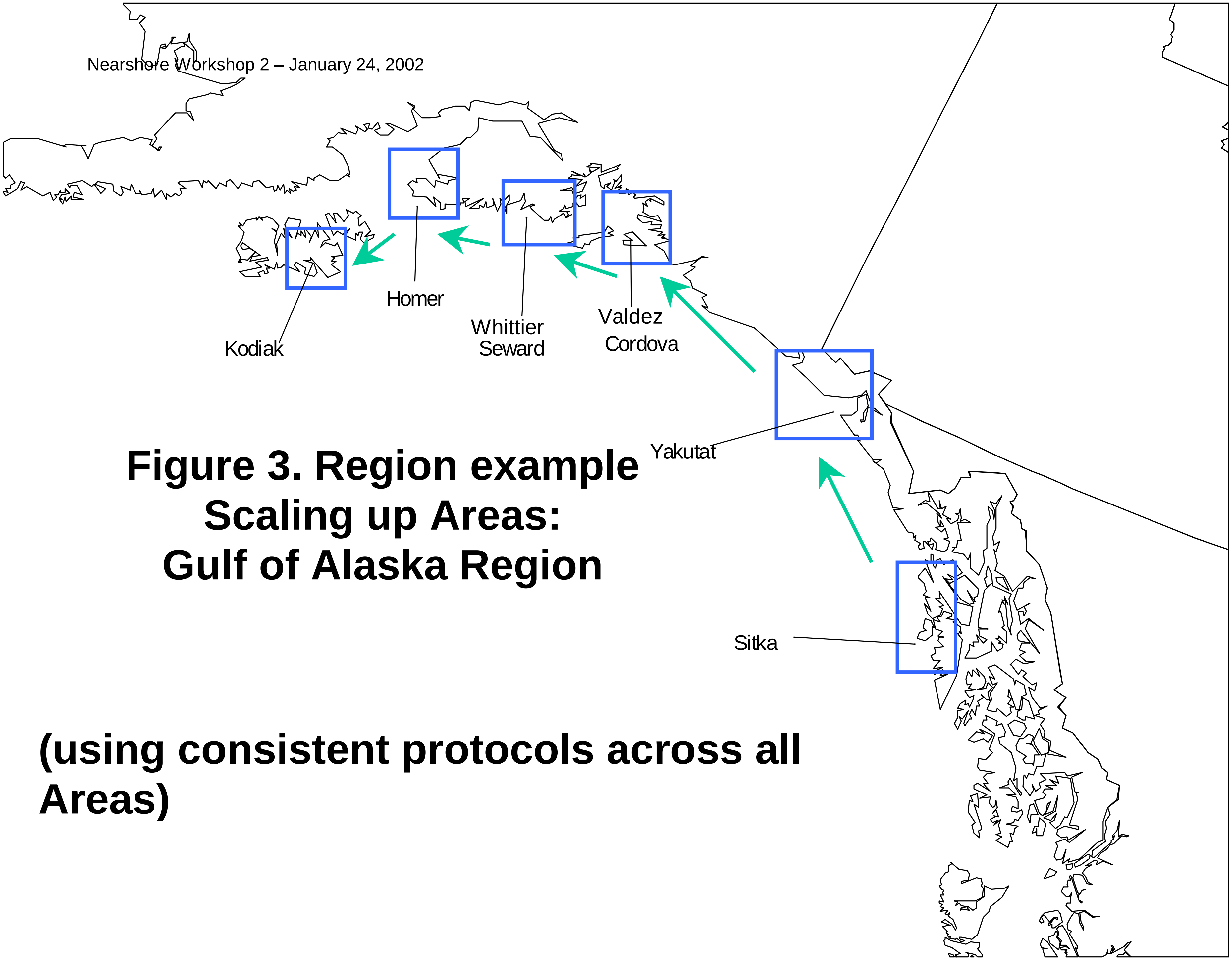


Figure 3. Region example
Scaling up Areas:
Gulf of Alaska Region

(using consistent protocols across all Areas)

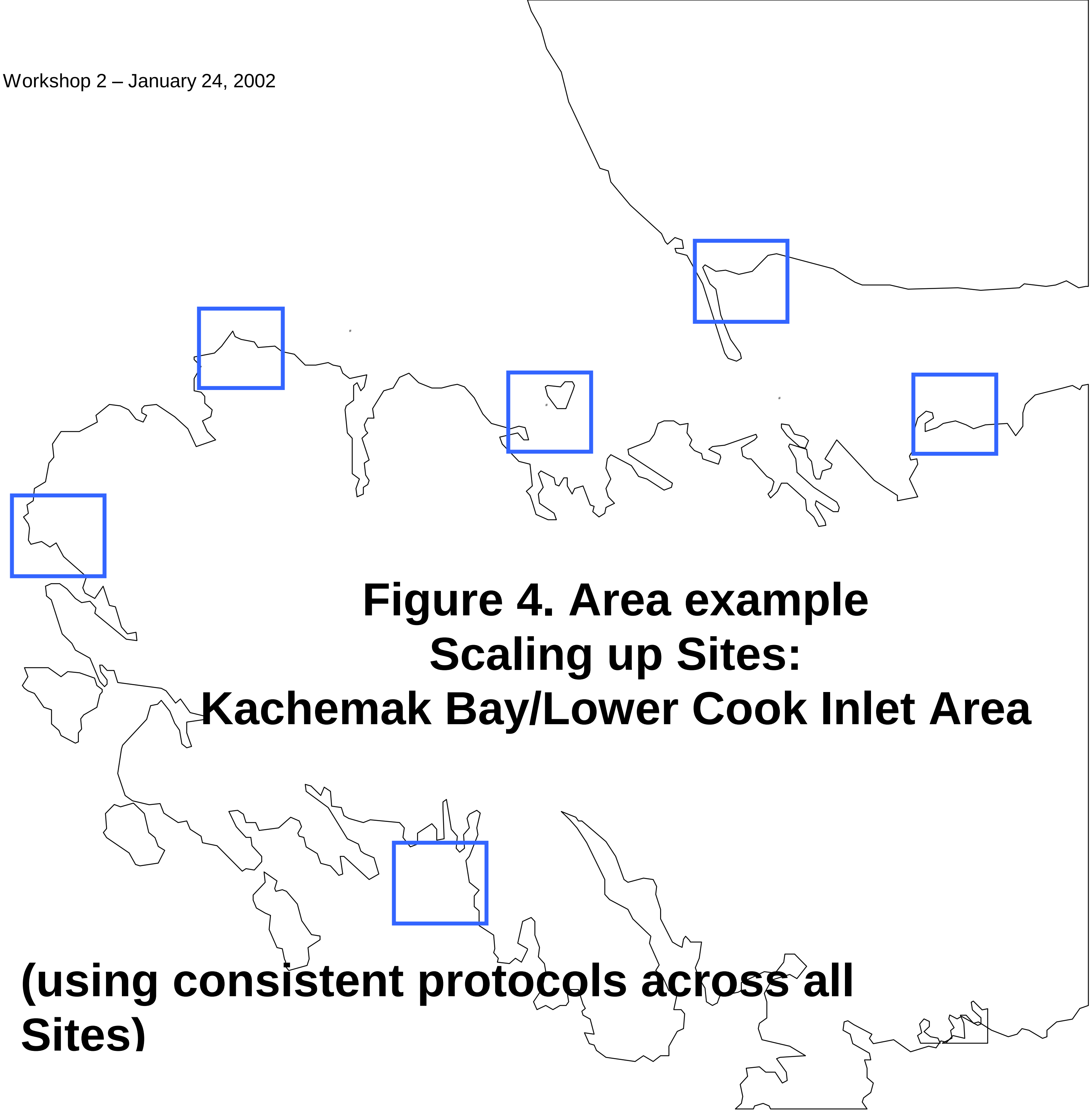
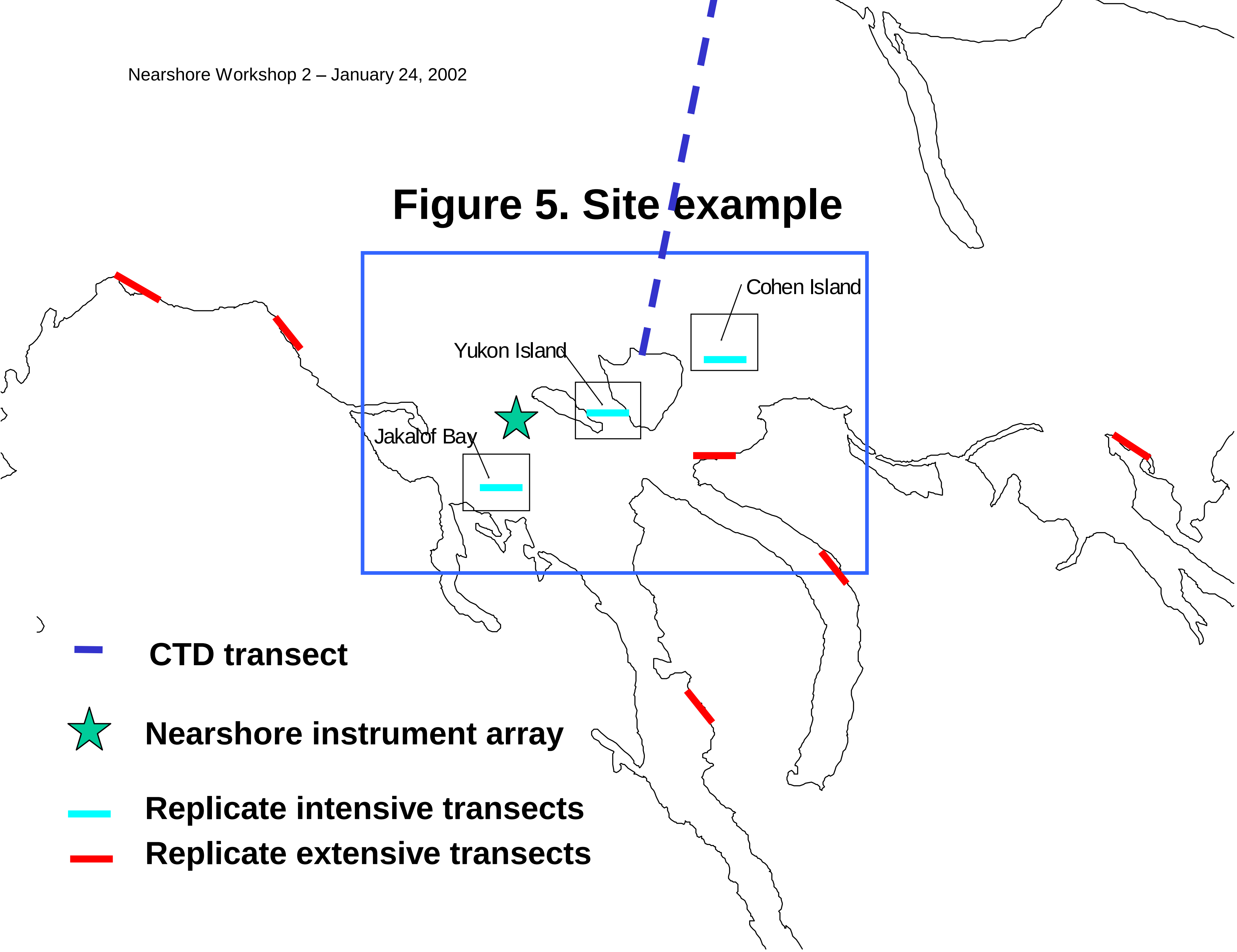


Figure 4. Area example
Scaling up Sites:
Kachemak Bay/Lower Cook Inlet Area

(using consistent protocols across all Sites)

Figure 5. Site example



Appendix 1. Anchorage Workshop Findings

The goals of the Anchorage workshop were to further develop recommendations for variables to be measured, where they should be measured, and how often, in the GEM nearshore monitoring plan. As starting points, the draft GEM Program, National Research Council comments on the nearshore in GEM, and the results of the prior expert panel were presented before convening smaller working groups to discuss and formulate recommendations for the details of the plan.

Each workgroup was asked to:

1. Identify what should be monitored.
2. Identify where monitoring should occur (i.e. how many sampling localities at what
spatial density).
3. Identify how often the variable is monitored.
4. Prioritize the above tasks (high medium or low). Especially, identify which tasks, locations, and sampling frequencies are <u>essential</u> elements of an effective monitoring program.

If time permitted, work groups were asked to:

5. Identify human and infrastructure resources available to make measurements.
6. Identify techniques or technologies that should be used to take the measurements.
7. Approximate costs for each of the above.

A designated person from each subgroup was asked to summarize the findings of the group and to focus on identification of 5 tasks that were seen as essential elements of the NGEM plan.

The following is a compilation of the findings and recommendations of the working groups that are organized with respect to the above questions.

<u>What variables to measure?</u>

Each working group identified variables that they thought were essential to the NGEM program. These are presented below in order of most to least often identified. The number of groups that identified each measure as critical is given in parentheses.

8. <u>Selected physical and chemical variables</u> - (7 of 8). Ocean temperature and salinity were most often identified as variables of importance, but variables mentioned also included currents, wind, rainfall, and chlorophyll.

9. Contaminants - (5 of 8). Contaminants most often mentioned as being of concern were oil, persistent organic pollutants (e.g. PCB), and heavy metals. Of particular concern were contaminants that might impact human health. Contaminant levels in mussels and clams were identified as potential key indicators.
10. Habitat - (5 of 8). Critical habitat features to be mapped included geomorphological features and important biological habitats (e.g. eelgrass and kelp beds). These habitat maps might also include biological “hotspots” that are areas of high production or serve as important nursery and feeding areas for birds and mammals.
11. Human use - (5 of 8). Maps should include uses such as fishing pressure, subsistence use, shoreline development, and recreational use.
12. Benthic community – (5 of 8). Analysis of structure of communities of intertidal and nearshore subtidal invertebrates and algae were identified. Several groups (3 of 8) specifically indicated that both hard and soft substrate communities should be evaluated. Some groups included specific recommendations for several metrics that should be measured. These included diversity; abundance, and recruitment of selected species like clams, mussels, limpets, and chitons; the abundance of selected “keystone” predators like starfish; and the growth of clams and macrophytes. The occurrence of invasive or introduced species was also mentioned.
13. Selected birds and mammals - (4 of 8). The abundance of marine mammals, especially sea otters and sea lions were identified as important to monitor. Bird species considered included harlequin ducks, oyster catchers, and pigeon guillemots. Sea birds were identified as potentially useful indicators of changes in the environment.
14. Forage fish and salmon. - (3 of 8). Forage fish, especially herring that spawn in the intertidal and nearshore subtidal, and salmon were indicated as important components of the nearshore system that should be monitored.

Where to monitor?

Two groups specifically indicated that it was important to consider spatial scales in monitoring and that different spatial scales would be appropriate for different variables. All groups concurred, either explicitly or implicitly, that the approach of using a combination of Gulf-wide monitoring for some synoptic variables like sea surface temperature, intensive sampling of a few selected sites, and less intensive sampling of smaller suite of key indicator variables at a larger number of “extensive” sites.

Several groups gave guidance as to how sites should be selected. Three groups suggested that sites not be randomly selected, but focused on “hotspots”.

Intensively sampled sites should be focused on areas of special biological significance (areas of high productivity, nursery grounds, etc.) and should be located in areas where localized human disturbance (e.g. shoreline development or logging) is unlikely to have a significant impact in the foreseeable future. Extensive sites on the other hand might be focused in areas of likely human impact. Other recommendations included the consideration of safety in selecting sites (2 groups), that sites be accessible (2 groups), and that sites where there are historical data be given preference (1 group). One group also suggested that high-energy sites along open coasts should be excluded because they are physically disturbed on a regular basis and therefore were unlikely be effective indicators of change.

One group suggested that a GIS database be established and used in selecting sites. This database might identify habitat types, biological hotspots, human use, and sites where historical data of specific types are available. Sites could then be selected based on the co-occurrence of specific attributes. For example, desired attributes for intensive sites might include biological hotspots where there is little human disturbance, where there has been some historical data collected, and that are in close proximity to research support facilities.

When to monitor? Several groups indicated that the temporal scale of monitoring be should depend on the variable of interest and on the important scales of inherent temporal variability for that variable. For example, temperature and salinity that are highly variable on several temporal scales would require frequent (perhaps continuos) monitoring. On the other hand, the level of contaminants in the tissues of clams or mussels might be measured only once every several years.

Three groups also indicated that the NGEM program should have a component that is event driven and can respond rapidly to sample at times or locations of special significance (e.g. an earthquake, chemical spill, or unexplained die off of animals).

Only one group had sufficient time to identify time scales of measurement for specific variables of interest. As a result, we do not report these.

Who should monitor?

Five groups identified community involvement as a key element of a successful monitoring program. It was recognized that community representatives should be involved in the entire process, from planning to implementation. Several specific suggestions were made regarding how communities might be involved in sampling. These included conducting bird counts (similar to the Christmas bird count program), estimating the abundance of sea otters, seals, and sea lions, measurement of temperature and salinity, collection of organisms or sediments for the evaluation of contaminant levels, and photo documentation of benthic communities. One group indicated that community members might be particularly valuable assisting with sampling at “extensive” sites.

Outreach and education was also indicated (2 groups) as an important component of the NGEM program. One group suggested establishing a web-based hotline where community members could input observations and data could be shared among researchers and community members. It was also suggested that local schools be involved in the process.

Two groups specifically mentioned that establishing partnerships with other research programs would be an important way of leveraging the value of the NGEM program.

How should monitoring should be conducted?

Three groups suggested that establishing strict quality assurance measures were critical and that standard sampling and data reporting protocols be established as a part of a QA program. Two groups also indicated that data management plans be established and strictly adhered to.

One group suggested that a protocol be established to advise and get approval of communities prior to establishing sampling locations and conducting studies in the vicinity of each community. This would help ensure that sampling effort did not conflict with other uses (e.g. subsistence harvest) and help to improve communication and cooperation between researchers and community members.

Two groups pointed to the use of historical data and retrospective analyses of existing data as an important component of the NGEM program. These types of analyses might be used to establish background conditions (for contaminant levels or growth rates of clams for example), to aid in the selection of sampling sites, or to determine the appropriate frequency of sampling.

Remaining Questions and Recommendations

Overview

As a result of the workshops conducted to date, there is a general framework being developed for a NGEM plan. It is generally agreed that a design be developed that employs measurement of selected metrics at some combination of synoptic, intensively, and extensively sampled sites. The critical metrics of selected physical/chemical variables (e.g. temperature and salinity); contaminant levels; habitat characteristics; human use; benthic community structure; and abundance of selected birds, marine mammals, and fishes have been identified. However, several important issues need to be resolved prior to finalizing a nearshore GEM plan. The most critical are:

3. How to include the community representatives in the planning process
4. Details of the plan including:
   - What specific metrics to measure
   - Number and locations of sampling sites for each metric
   - Sampling frequency for each metric
   - Specific sampling protocols
3. Development of a quality assurance and data management plan

Community Representation

Community representation in the planning process is critical. We recommend that:

1. Specific communities, stakeholder interest groups, and resource agencies be identified and that representatives of these be selected to assist in the planning process.
2. Specific researchers, representing expertise with respect to key elements, be identified to help develop a plan.
3. A formal process and timeline be established whereby smaller subgroups of researchers, community, stakeholder, and resource agency representatives can develop a plan and then present this to the EVOS Trustee Council.

Plan Details

We recommend that plan details be further developed by researcher, community, resource manager, and stakeholder representatives through the following process:

1. Make a preliminary list of potential metrics to measure, number and location of sampling sites, and frequency of sampling.
2. Identify kinds of data analyses or representations that are needed to preliminarily determine appropriate metrics, the number of sites, location of sites, and frequency of sampling. For example, establishment of a GIS database in which habitat types, locations of historical data, existing human use, and biological hotspots are identified might be a necessary precursor to site selection.
3. Establish a protocol for site selection and select potential sites.
4. Prioritize among different metrics, numbers of sites sampled, and frequency of sampling.
5. Make preliminary cost determinations.
6. Select essential elements of a core sampling program based on priorities and costs established. This core program is one that can be fully sustained based on monies received from the EVOS Trustee Council.
7. Identify and conduct preliminary studies that may be needed to finalize metric, site selection, or sampling frequency determination. For example, additional habitat mapping may be required.

8. Make final determination of metrics, sampling sites, and sampling frequency selections.
9. Make preliminary evaluations of potential sampling protocols for each core element. Identify sampling methods, sampling unit sizes, number of samples, etc.
10. Identify analyses of existing data or preliminary sampling necessary to refine protocols.
11. Develop final protocols for a core sampling program.
12. Identify potential partnering agreements for “non-core” elements and develop these.
13. Develop a data management system and quality assurance/quality control procedures prior to sampling.

Appendix 2: Registrants for the Nearshore workshop at the annual EVOS meeting in January, 2002.

Name	Affiliation
Jim Adams	National Wildlife Federation
Ken Adams	Cordova Commercial Fisherman
Virginia Aleck	Community Facilitator
Peter Armato	National Park Service
Torie Baker	PAG member
Brenda Ballachey	
Sonia Batten	Sir Alister Hardy Foundation for Ocean Science
William Bechtol	ADF&G
Alan Bennett	
Catherine Berg	USFWS
Daniel Bevington	Kenai Peninsula Borough Coastal Management
Chris Blackburn	
Arny Blanchard	
Carol Blanchette	University of California, Santa Barbara
Keith Boggs	AK Natural Heritage Program, ENRI, UAA
Dede Bohn	
James Brady	ADF&G
Evelyn Brown	
Valerie Brown	
Mason Bryant	
Joni Bryant	
C. Loren Buck	University of Alaska, Fairbanks, FITC
Richard Cannon	
Tom Chapple	ADEC
Robert Clark	ADF&G
Sue Cogswell	PWS Economic Development District
Linda Comerci	
Joel Cooper	Cook Inlet Keeper
Matt Cronin	LGL Alaska Research Associates Inc.
Joel Cusick	National Park Service
Randall Davis	Texas A&M University
Robert Day	
Tom Dean	Coastal Resources Associates, Inc.
Tony DeGange	
Robert DeVelice	USDA Forest Service, Chugach National Forest
Matthew Eagleton	National Marine Fisheries Service
Ginny Eckert	University of Alaska
Laura Eldred	
Lillian Elvsaas	
Dave Erickson	
Dan Esler	Simon Fraser University, Centre for Wildlife Ecology
Gary Fandrei	
Carmen Field	Kachemak Bay Research Reserve
Bruce Finney	Institute of Marine Science, UAF
Randy Fleharty	
Nora R. Foster	University of Alaska
Robert J. Foy	UAF
Carol Fries	ADNR
Joy Geiselman	USGS
Ben Greene	Trout Unlimited
Gerry Guay	
Peter Hagen	

Bill Hanson	ADF&G Division of Habitat & Restoration
Jeanne Hanson	National Marine Fisheries Service
Scott Hatch	
Bill Hauser	ADF&G
Ron Heintz	
Robert Henrichs	
Jeff Hetrick	
Ray Highsmith	
Nancy Hillstrand	
Ken Holbrook	
Brett Huber	PAG member
Eleanor Huffines	
Charlie Hughey	Valdez Native Tribe
Henry Huntington	Chuguach Regional Resources Commission
David Irons	USFWS
Gail Irvine	USGS
Jon Isaacs	
Lianna Jack	The Alaksa Sea Otter & Steller Sea Lion Commission
David Janka	Auklet Charter Services
Scott Johnson	
Lisa Ka'aihue	Prince William Sound Regional Citizens' Advisory Council
Lynn Kent	ADEC
Susan Kesti	
Arthur Kettle	
Jim King	EVOS PAG
Ron Klein	ADEC
Steve Klein	
Tom Kline	PWSSC
Kim Kloecker	
Eric Knudsen	USGS
Gary Kompkoff	
Pete Kompkoff,	
Brenda Konar	UAF-NURP
Jan Konigsberg	
Kathy Kuletz	
Matthew LaCroix	
Micheal Lambert	Native Village of Eyak
Barat LaPorte	
Pat Lavin	National Wildlife Federation
Mandy Lindeberg	
Bill Lorenz	Alaska Region, Forest Service
Alan Maki	ExxonMobil
Gary Marty	University of California, Davis
Sue Mauger	
Mary McBurney	National Park Service
Paul McCollum	
Chuck Meacham	PAG member
Riley Meganack	
K.J. Metcalf	
Pete Mickelson	
Steve Moffit	
Ross Mullins	
Bonita Nelson	Auke Bay Lab
Gordon Nelson	
Matt Nemeth	
Jennifer Nielsen	USGS

Patrick Norman	
John Olson	National Marine Fisheries Service
Joe Orsi	ABL
Ted Otis	ADF&G
Walter Parker	Prince William Sound Science Center
Kent Patrick-Riley	ADEC
Jennifer Pendergraft	
Caroline C. Powell	SE Sustainable Salmon
John Reft	
Dr. James B. Reynolds	UAF School of Fisheries and Ocean Sciences
Bud Rice	National Park Service
Jeep Rice	
Martin Robards	
Ted Rockwell	
Gilbert Roetman	North Star Media Institute
Dan Rosenberg	ADF&G
David Roseneau	
Deborah Rudis	USFWS
Robert Ruffner	
Gerry Sanger	PAG member
Susan Saupe	CIRCAC
Teri Schneider	Kodiak Island Borough School District
Carl Schoch	Kachemak Bay Research Reserve
Patricia Schwalenberg	
Bill Seitz	
Stan Senner	PAG member
Lewis Sharman	
Bob Shavelson	
Whit Sheard	
Jeff Short	Auke Bay Laboratory
Marilyn Sigman	Center for Alaskan Coastal Studies
Amy Skilbred	ADF&G
Brad Smith	National Marine Fisheries Service
Dr. Robert B. Spies	Applied Marine Sciences, Inc.
Alan Springer	FALCO
Hank Statscewich	
Diana Stram	
Stacy Studebaker	PAG Member
Joe Sullivan	
Paula Terrel	Alaska Marine Conservation Council
John Thedinga	
Jules Tileston	
Tom Van	
Shari Vaughan	Prince William Sound Science Center
Martha Vlasoff	
Sabrina Volstad	
Susan Walker	National Marine Fisheries Service
Frank Wallis	
Marty Waters	
Tom Weingartner	Institute of Marine Science, UAF
Donna Willoya	The Alaksa Sea Otter & Steller Sea Lion Commission
Kent Wohl	
Nancy Yeaton	