Exxon Valdez Oil Spill
Gulf Ecosystem Monitoring and Research Project Final Report

Long-Term Monitoring in the Nearshore Ocean: Designing a Program to Detect Change and Determine Cause

GEM Project 02395
Final Report

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Study History

This is a new project and therefore has no previous study history with EVOS. This project responds to the need for a design to monitor the nearshore marine environment as a means for detecting change in the physical, chemical and biological components of this system and to study the specific mechanisms of change. This final report represents the first published results from this project.

Abstract

A series of workshops were conducted to help define essential elements of a nearshore monitoring program for the Gulf of Alaska. As a first step, a panel of independent scientists was convened to develop a conceptual framework. This group recommended three basic elements: 1) synthesis, compilation, and management of both existing and new data; 2) synoptic studies of large spatial scale 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 standard protocols are followed throughout the region. This conceptual framework was then presented to Alaska researchers, resource managers, and community stakeholders for comments and to develop preliminary recommendations for variables to be measured. The 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 the Partnership for Interdisciplinary Studies of Coastal Oceans would also be appropriate for the Gulf of Alaska, and 3) involvement and support of coastal communities in the nearshore monitoring program are essential to its long-term success.

Key Words

Monitoring, Gulf of Alaska, nearshore marine, nested spatial design, nested statistical design, standard protocols, change detection, patterns of change, processes of change

Project Data

No data were collected as part of this project. Summaries of workgroup findings are presented in text, tables, figures, and appendices contained in this report.

Citation

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EXECUTIVE SUMMARY

The oceans are at risk from a variety of threats including direct and indirect effects of human development compounded by natural climate variation. Recent breakthroughs in technology in 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 on the dynamics of ecological communities, and connections among ecological communities through larval dispersal). The Gulf Ecosystem Monitoring Program (GEM) is unprecedented in being able to provide long-term funding to monitor the Gulf of Alaska ecosystem. The problem remains however, that without a commitment from GEM to adopt standardized protocols across the scale of the Gulf of Alaska for a long term time scale, many of the questions asked by GEM will remain unresolved. The nearshore has been identified as one of four important habitat types of the Gulf of Alaska ecosystem included in the GEM program. For the purposes of this project, the nearshore is defined as the intertidal and shallow subtidal to the 20 meter 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.

Objectives

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.

The objective of this project was to design a conceptual model for a GEM nearshore monitoring program over multiple scales of space and time, develop general recommendations for a nearshore monitoring program based on expert advice from other large scale monitoring programs, and develop consensus on the general recommendation from local stakeholders, and specific recommendation from the local stakeholders on what to monitor and where to monitor.

Methods

A series of workshops were conducted to help define essential elements of a nearshore monitoring program in the Gulf of Alaska. 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 existing and new data; 2) periodic synoptic studies of large spatial scale oceanographic processes; and 3) monitoring a set of nearshore parameters using standard protocols over a limited number of intensive sites and a greater number of extensive sites. 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 the Gulf Ecosystem Monitoring Program and the Partnership for Interdisciplinary Studies of Coastal Oceans.

The resulting 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. To establish the historical context, participants were presented overviews on the draft Gulf Ecosystem Monitoring Program, the National Research Council comments on the nearshore component of the Gulf Ecosystem Monitoring Program, the results of the Santa Barbara expert panel, and an overview of the Partnership for Interdisciplinary Studies of Coastal Oceans were presented. The participants were then subdivided into smaller working groups and asked to provide comments on the plan.

Results

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 the Partnership for Interdisciplinary Studies of Coastal Oceans would also be appropriate for the Gulf of Alaska, and 3) involvement and support of coastal communities in the nearshore program of the Gulf Ecosystem Monitoring Program 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.

Conclusions

To monitor and study processes of the nearshore ocean, we propose a nested sampling design linking standardized 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 fixed transects (benthic and water column), mooring arrays and oceanographic transects. The entire array of these intensive studies would constitute a "Site". Each Site would encompass a spatial scale of 1-10 km 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. 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 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.

LONG-TERM MONITORING IN THE NEARSHORE:
DESIGNING A PROGRAM TO DETECT CHANGE AND DETERMINE CAUSE

INTRODUCTION

The oceans are at risk from a variety of threats including direct and indirect effects of human development compounded by natural climate variation. Recent breakthroughs in technology in 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 Gulf Ecosystem Monitoring Program (GEM) is unprecedented in being able to provide long-term funding to monitor the Gulf of Alaska (GOA) ecosystem. GEM seeks to provide long-term monitoring of changes in the GOA ecosystem. The goals of the 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;

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

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

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. For example, 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. 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. The nearshore has been identified as one of four important habitat types of the GOA ecosystem included in the GEM program. For the purposes of this project, the nearshore is defined as the intertidal and shallow subtidal to the 20 meter 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.

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 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 NRC in their review of 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?

Ocean waters are variable over immense spatial and temporal scales, and coastal dynamics are the least understood area of oceanography. For the North American 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 from funding agencies.

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 shoreline erosion, 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 NRC. 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. The problem remains however, that without a commitment from GEM to adopt standardized protocols across the scale of the GOA for a long-term time scale, many of the questions asked by GEM will remain unresolved.

OBJECTIVES

The primary goal of the nearshore monitoring program in GEM is to understand the interaction of the nearshore oceanographic environment with coastal marine life 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.

Our objectives were to begin defining 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. A key first step was to design a conceptual framework for monitoring in the nearshore ocean. We convened an expert panel to discuss specific recommendation based on the success and failures of other large scale monitoring programs. The results of this workshop were then presented at a second workshop conducted for local stakeholders. The goals of the second workshop were to build consensus for the experts recommendations and further develop recommendations for specific variables to be measured, where they should be measured, and how often.

In this report, we 1) present the conceptual model; 2) summarize the recommendations made by an expert panel; 3) review the deliberations of the local stakeholders regarding the NGEM plan; 4) present the recommendation of the local stakeholders; and 5) summarize remaining tasks necessary to construct a final NGEM plan.

METHODS

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 expertise 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: Global Ocean Ecosystems Dynamics (GLOBEC), National Oceanographic Partnership Program (NOPP), Partnership for Interdisciplinary Study of Coastal Oceans (PISCO), National Science Foundation-Long Term Ecological Research (NSF-LTER), the National Estuarine Research Reserve System (NERRS), and California Cooperative Oceanic Fisheries Investigation (CalCOFI).

These 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 GOA. 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. This group then recommended three fundamental elements for the monitoring program: 1) synthesis, compilation, and management of both 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: described below), 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.

PISCO: The Partnership for Interdisciplinary Study of Coastal Oceans

PISCO (www.piscoweb.org) 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 management and conservation efforts. PISCO is a large-scale marine research program that focuses on understanding the nearshore ecosystems of the U.S. West Coast. 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 that 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.

RESULTS

General Recommendations of the Santa Barbara Panel

The preliminary conceptual model developed by the panel is shown on Fig. 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 foundation of the science programs should include three basic elements: 1) synthesis, compilation, and management of both 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).

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.

Spatially nested sampling design: A highly replicated spatially nested sampling design is recommended based on the NRC questions regarding detection of spatial and temporal change, the geographic extent of GEM, and the flow of currents in the Gulf of Alaska (Figs. 2-5). An example of the lowest level of nesting is shown for Kachemak Bay on Fig. 2. At this Site, time series data collected from a nearshore instrument array is linked to integrative measures of biological response at replicate subtidal benthic monitoring sites adjacent to three replicate intertidal benthic sites. Beach seines, bottom trawls, bird counts, and measures of productivity can be incorporated into this level of the design. Replicate samples are aggregated into a Site. Monthly CTD transects measure profiles to monitor water conditions flowing into and out of the Site "box". Sampling could be done annually by local agency or academic staff, or in some cases trained volunteers 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 type selected for monitoring. Replicate Sites are aggregated into the Area level. Figure 3 shows the location of several Sites within the Kachemak Bay Area. The number of Sites sampled within an Area would depend on the statistical power required. Areas could be centered on coastal communities such as Sitka, Yakutat, Cordova, Seward, Homer, and Kodiak (Fig. 4). Thus, within the GOA region, a series of replicate samples within a Site, and multiple Sites within Areas, and multiple Areas within a Region would capture small to large spatial scale environmental variability and the biological response to that variability. Shared protocols with PISCO could lead to merging data sets to assess the biological response to very large scale perturbation of the atmosphere or ocean such as decadal oscillations and global climate change (Fig. 5).

The panel recommended the use of "intensive" vs. "extensive" sample sites. Intensive sampling was thought to best capture the data requirements for the above nested sampling design, while extensive sampling would fulfill the data needs of projects that do not conform well to nested designs. Examples include marine mammal counts, citizen monitoring programs, event-based or spatially limited sampling such as minor oil spills or locally derived contaminants.

Specific Recommendations of the Santa Barbara Panel

Bottom-up and top-down approach: The panel recommended a bottom-up approach for ecosystem monitoring but acknowledged that some effort at monitoring keystone predators is needed to evaluate the effects of top-down processes. A conceptual model of a bottom-up ecosystem monitoring program is shown on Fig. 6. 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.

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 challenge will be to determine the relative levels of effort for each. 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.

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 benthic habitat types, 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

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.

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.

Mechanistic studies: 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:

1. How growth rates of migratory fish change in different water bodies;
2. How physiological traits contribute to ecological patterns on local to geographic scales;
3. How the role of abiotic factors perturb physiological systems;
4. 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.

Graduate student fellowship program: 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.

General comments: The panel expressed concern that the structure of GEM and the funding 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.

Findings of the Anchorage Workshop

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.

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 GOA-wide monitoring program were identified and prioritized as follows 1) oceanographic variables, 2) habitat type, 3) benthic community structure, 4) human use, 5) contaminant levels, and 6) abundance of selected marine mammals, birds, and fishes. 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 mapping - (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 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.

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 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.

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).

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.

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 to monitoring: 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.

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.

DISCUSSION

To monitor patterns and study processes of the nearshore ocean we propose a nested sampling design statistically linking standardized 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 benthic and water column transects, mooring arrays and oceanographic transects as illustrated on Figure 2. The entire array of these intensive studies would constitute a "Site". Each Site would encompass a spatial scale of 1-10 km 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 3. 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 4. 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.

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 what to monitor, who will monitor, and when and where to monitor.

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 such as PISCO have developed protocols for addressing many of the same questions being asked in the Gulf of Alaska. They are addressing these questions 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 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. If the GEM partnerships were to adopt these same protocols, then the spatial extent of our combined studies reach unprecedented scales (Figure 5). 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.

The proposed nested design should be augmented by 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 fieldwork by providing instantaneous synoptic images to allow some generalization of oceanic processes beyond local study sites.

CONCLUSIONS

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:
    a. What specific parameters should be measured
    b. Number and locations of sampling sites for each parameter
    c. Sampling frequency for each metric
    d. Specific sampling protocols
3. Development of a quality assurance and data management plan

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.

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.

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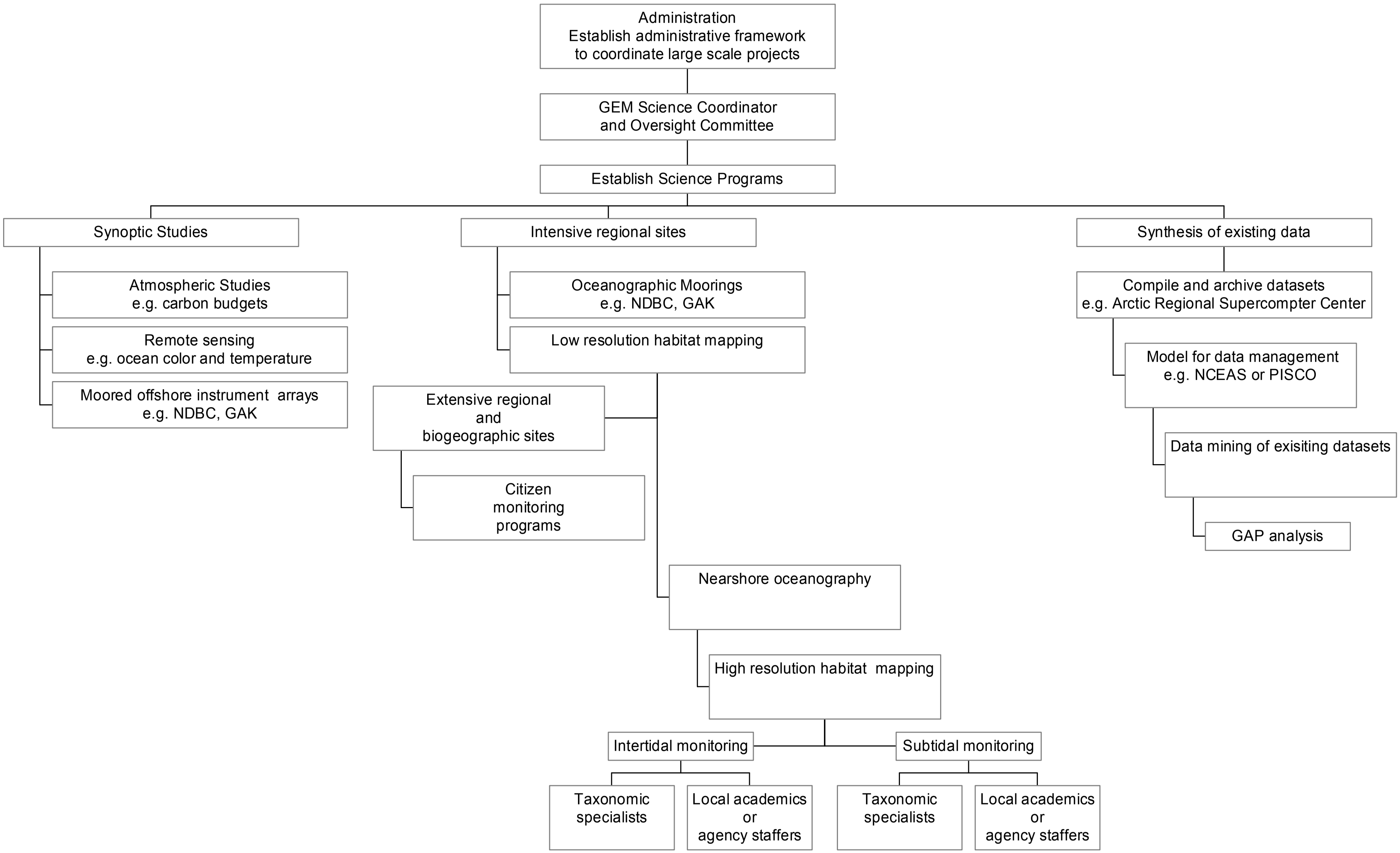

Figure 1. Proposed conceptual model for a Gulf of Alaska nearshore monitoring program

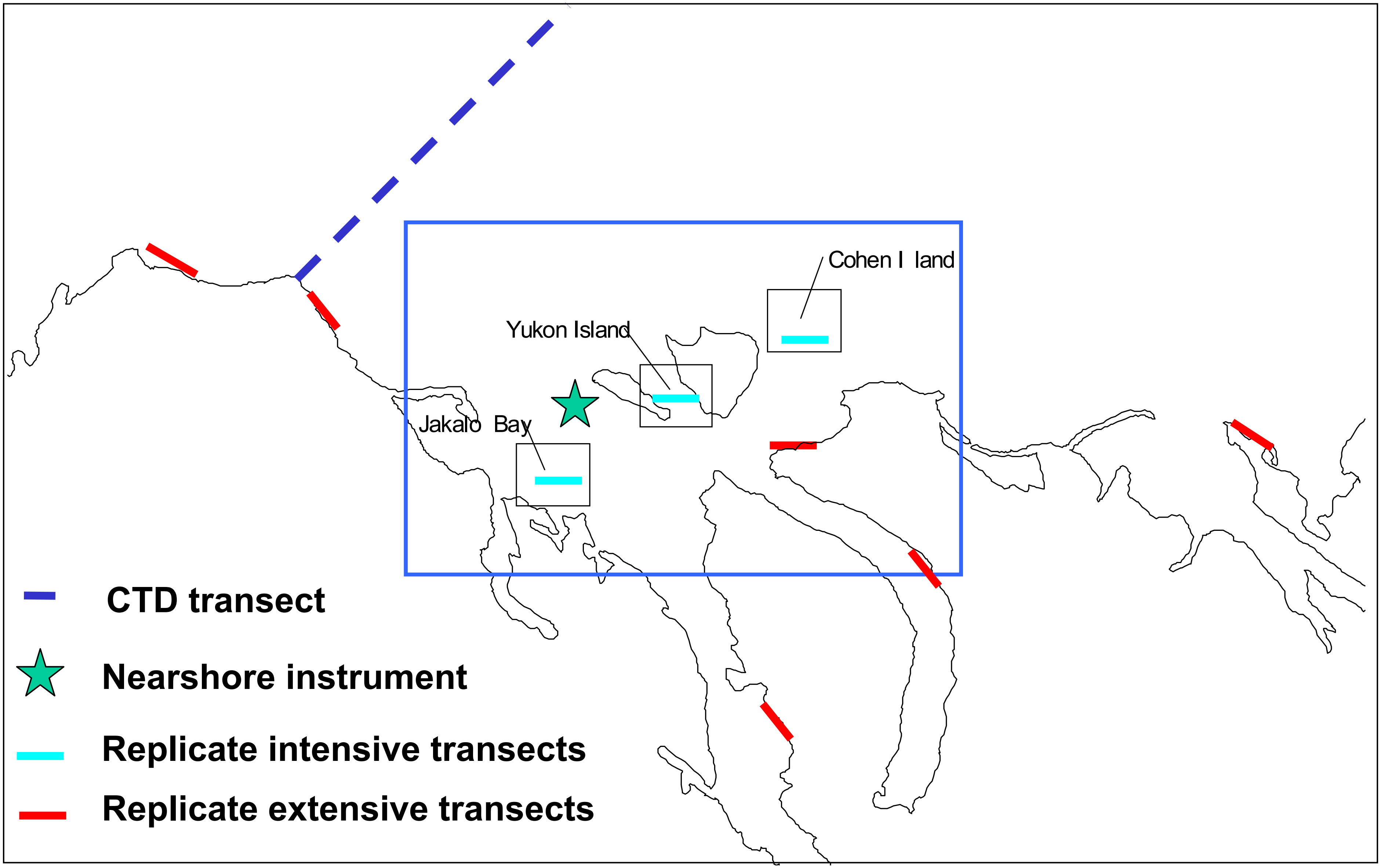

Figure 2. Example of a Site in Kachemak Bay with benthic intertidal and subtidal transects, oceanographic instruments, beach seines as potential monitoring

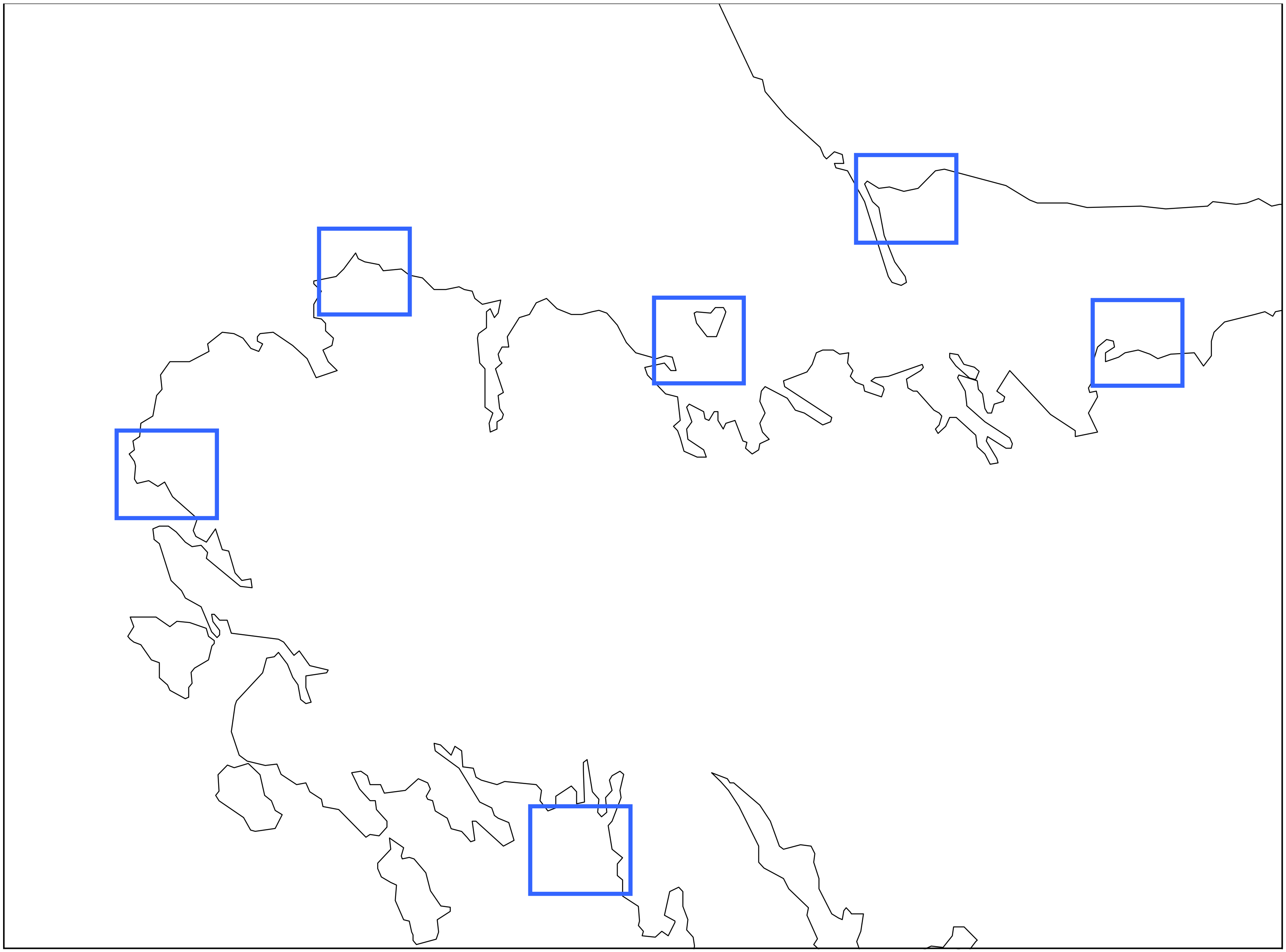

Figure 3. Area example for scaling up Sites: Kachemak Bay/Lower Cook Inlet Area

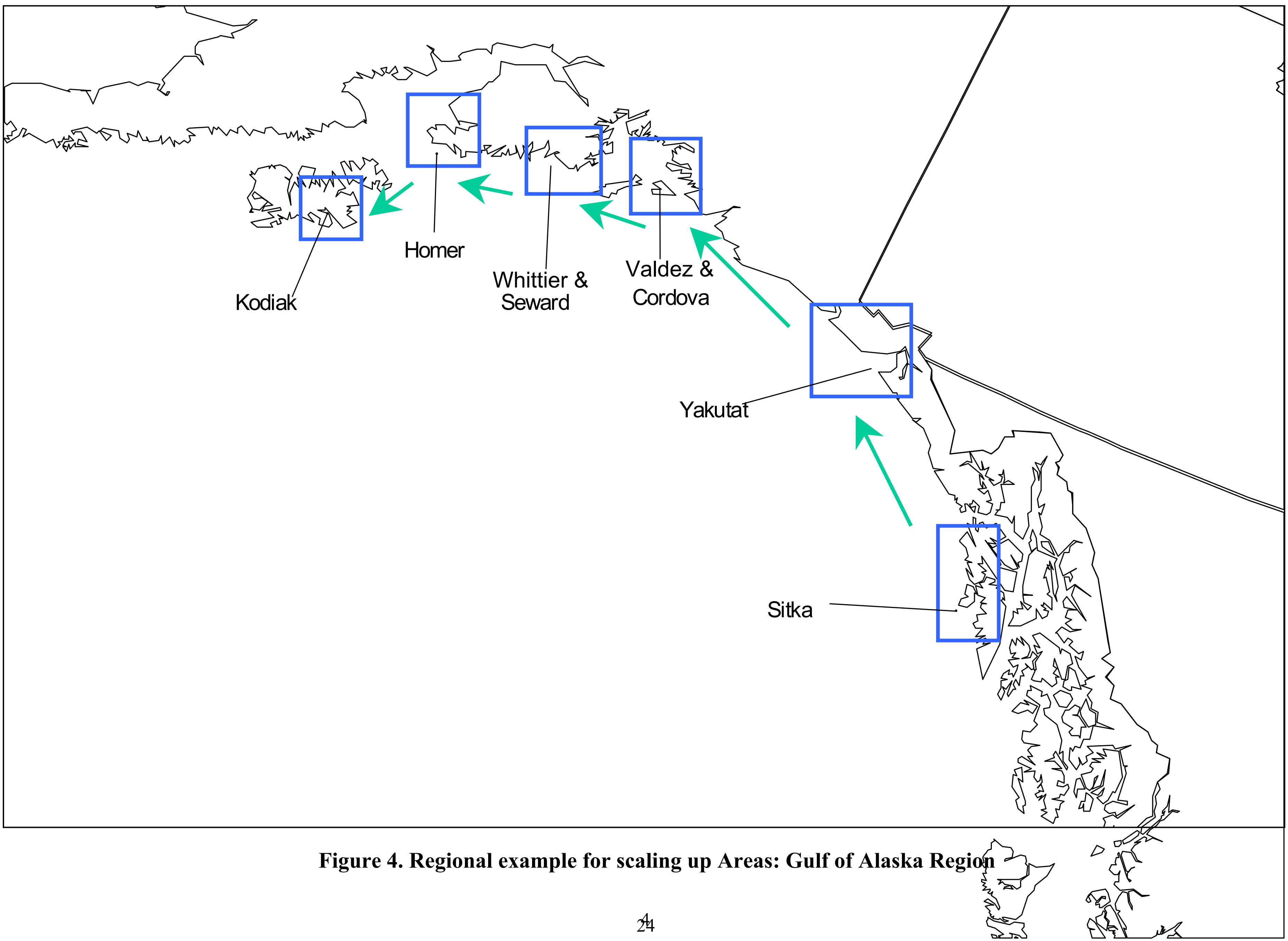

Figure 4. Regional example for scaling up Areas: Gulf of Alaska Region

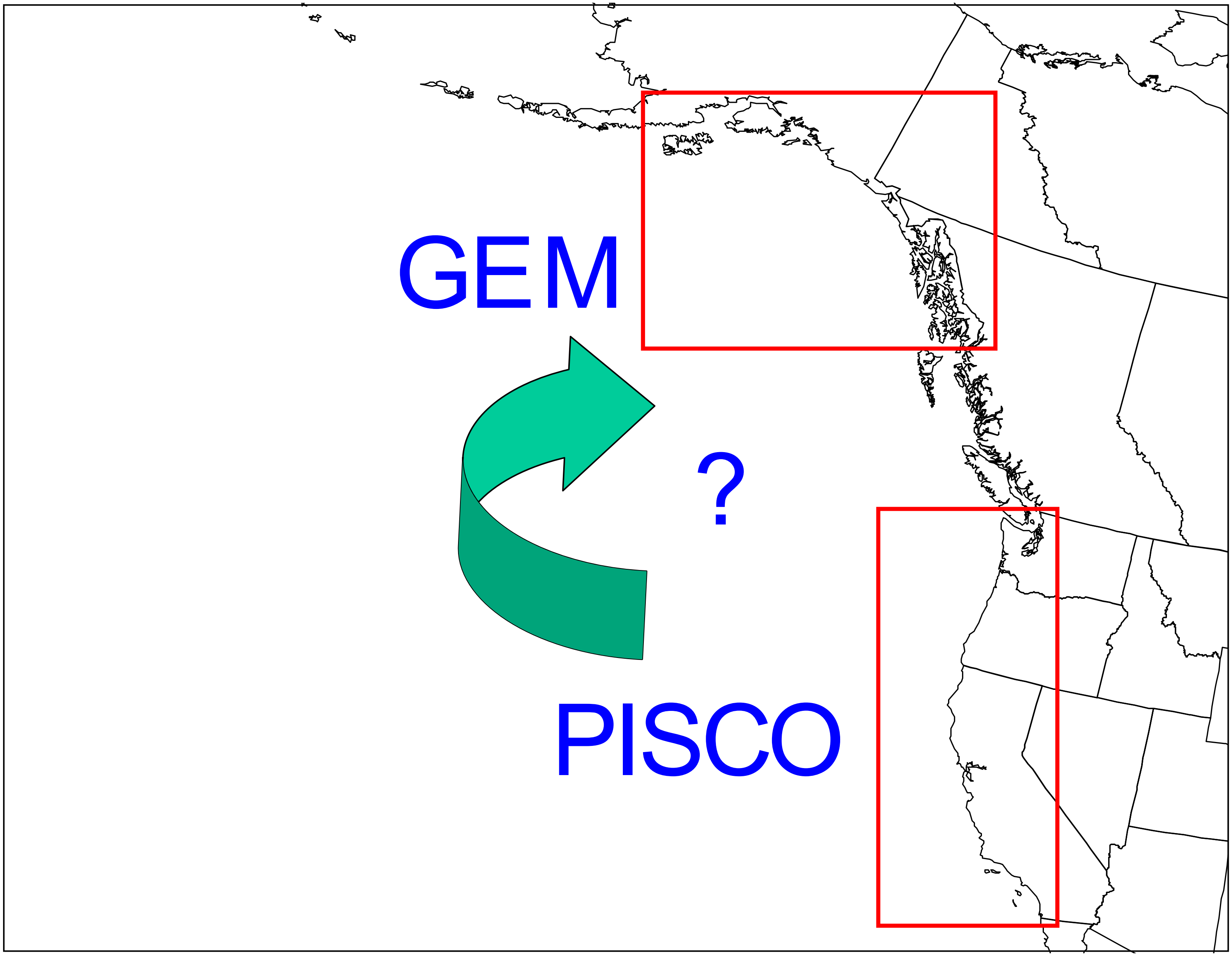

Figure 5. Scaling up Regions: North Pacific Ocean

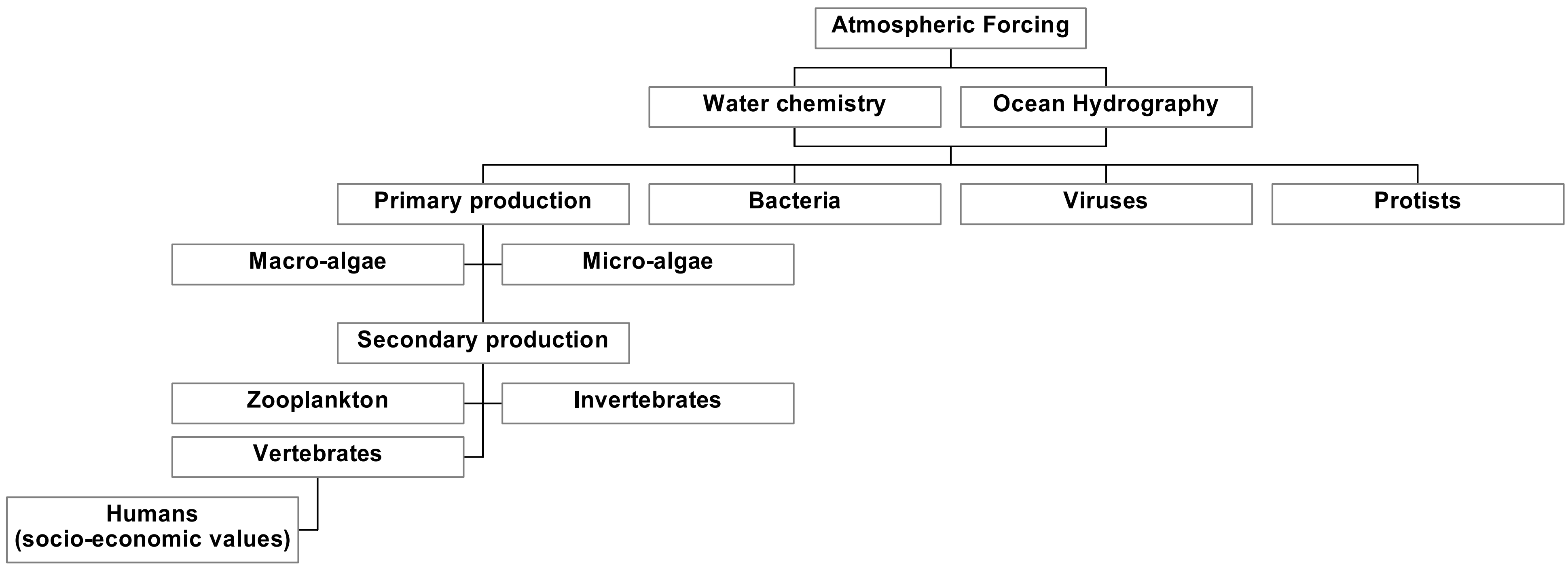

Figure 6. Bottom-up perspective of ecosystem forcing

Table 1. Experts Panel

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Table 2. Possible agents of change in nearshore systems of the Gulf of Alaska.

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/desiccation 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	Years/Area or Location

		habitat destruction	
Aquaculture (especially intertidal clam)	None	Intertidal habitat loss, reduction 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 birds/mammals with trash, reduction in intertidal inverts/algae due to trampling	Years/Sites
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	Increased levels of	Increased	Years/Region or

from distant sources	metals and other chemicals	contaminant levels in animals and increased death rate or reduced reproductive rate especially in higher trophic levels.	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's km)
Domain – Southeast, Southcentral, Southwest GOA (100's km)
Area – Shelikof Strait, Cook Inlet, Kenai Fjords, Prince William Sound, etc (10's km)
Site - Herring Bay, Orca Inlet, Jakalof Bay, etc. (1000's meters)
Sample – (<1 to 100's meters)

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 / 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 contaminants 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 (mussels, 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,	All	Rotating	2	Possible archival of

PAHs, and other contaminants in mussels		subset once per year		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 contaminants 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 per year	1-2?	
Intertidal – hard substrate				
Abundance - Selected macro inverts and algae (Fucus, 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 (mussels, stars, ?)	All	Rotating subset once per year	1-2?	
Body burdens of metals, PAHs, and other contaminants in mussels?	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

Appendix A. Workgroup Summary and Group Recommendations from EVOS annual meeting in January, 2002.

The following provides a summary of the recommendations made by workgroups during the January 18, 2002 workshop on nearshore monitoring. Note that suggested "high priority" items are not ordered.

Group 1. Moderator - Sue Saupe, Recorder-Bonita Nelson

Priorities in sampling

Physical Chemical monitoring - Sample temperature and salinity at both intensive and extensive sites. Other metrics (dissolved oxygen, chlorophyll, irradiance, nutrients, currents, other factors) at both intensive and extensive sites. All to be measured continuously. Satellite imagery to be evaluated for sea surface temperature over the entire GOA.

Intertidal monitoring - Sample in both hard and soft bottom communities. Measure diversity and abundance at both intensive and extensive sites, at least yearly. Sample size-distribution, growth, and condition of selected invertebrates at intensive sites. Examine contaminants in selected long-lived species at extensive sites, with focus on the soft-bottom habitat. Contaminant sampling can be done annually to establish a baseline and then every 3 to 5 years thereafter.

Subtidal monitoring – kelp, eelgrass, fishes and macroinvertebrate abundance at intensive and extensive sites, but for a reduced suite of species at extensive sites.

Marine mammals and birds – Abundance throughout the GOA area with diet, condition, and contaminant levels at intensive and extensive sites. Focus should be on sites monitored by US Fish and Wildlife Service.

Habitat mapping – Substrate, geomorphology, biota, and human use throughout the GOA. Establish a baseline and then infrequently thereafter.

Notes

Overlap among programs – There is clear overlap among the GEM programs. A process needs to be identified whereby programs are coordinated and overlap eliminated.

Contaminants- A contaminant baseline needs to be established

Mapping of shorelines – Needed for selection of intensive sites.

Local involvement – Local citizens can be utilized to monitor temperature and salinity. Community based sampling efforts similar to "Christmas bird counts" could be utilized. A hotline should be established so citizens can find out about local research and perhaps update local conditions or events of importance to the nearshore. A protocol should be established for whereby GEM scientists could inform local citizens as to research plans and then report results on a timely basis. Also, selection of potential research sites should be reviewed by community representatives as a part of the protocol.

Site selection – Extensive sites should focus on both sites likely to be developed as well as those far from communities and therefore unlikely to be developed.

Habitat selection – Decisions need to be made as to the number and type of habitats sampled and the relative effort used in sampling each. Soft bottom habitats should not be of secondary concern.

Biotic metrics – Growth and productivity of macrophytes need to be considered.

Human Use – Need to be quantified over time. For example, need to know who is fishing where, for what, and this changes with time.

Group 2. Moderator – Evelyn Brown, Recorder-Stacy Studebaker

Priorities in sampling

Physical Chemical monitoring - Sample temperature, light (PAR), nutrients, turbidity, dissolved oxygen, at both intensive and extensive sites. Transport (via low level ADCP measurement of currents and waves) to be measured at a few selected sites. Measurement of wind speed and direction is important for transport modeling. Sample and archive sediment cores for historical perspective.

Intertidal monitoring - Sample in both hard and soft bottom communities. Count invertebrates, measure cover by algae, and determine community structure.

Habitat and human use mapping – Substrate, geomorphology, biota, and human use throughout the GOA. Establish a baseline and then once every 5 to 10 years or after catastrophic events. Do broad-scale evaluation using remote sensing over the entire GOA, and finer scale estimates at intensive sites.

Contaminant monitoring – Monitoring of contaminants in invertebrates, especially in subsistence foods like octopus, chitons, and clams. Use existing "mussel watch" data where possible.

Notes

Community involvement – GEM should fund and get in place outreach personnel to act as intermediaries between scientists and communities.

Retrospective analysis – A retrospective analysis needs to be carried out to collate and analysis existing data from EVOS, OCEP studies, etc. to aid in program development (e.g. site selection, determination of sampling frequency).

Protected sites – Consider setting aside sites preserved for local community use.

Site selection – Prioritize sites based on: 1. Sites with historical data and/or sites important to communities, 2. Biological hotspots like the Northern Montague Island and Copper River Delta. 3. Safety considerations. The sites should be allocated to four general areas, Southeast Alaska, Prince William Sound/Yakutat, Kenai/Cook Inlet, and Kodiak.

Sampling frequency – Sampling of various metrics should be scaled appropriately. The frequency and spatial intensity should be based on scales in variation. Sampling frequency should coincide with peaks in variation.

Interrelation with other GEM programs - The nearshore should be studied in the larger context of the system as a whole and links between systems considered.

Group 3. Moderator – Dave Musgrave, Recorder-Marilyn Sigman

Priorities in sampling

Physical Chemical monitoring - Sample temperature, salinity, currents at both intensive and extensive sites. Also monitor rainfall. Also monitor substrate characteristics and slope at intensive and extensive sampling sites.

Biodiversity and abundance – Sample selected species of interest including herring and other forage fishes, juvenile salmon, plankton dynamics, intertidal assemblages, birds, and mammals.

Habitat mapping – Mapping of change in habitats of interest including areas of historical human use, near communities, biological “hot spots”, and in areas where human impacts are likely.

Contaminant monitoring – Monitoring of persistent organic pollutants in harvest areas and areas of human use. Sample every 3 to 5 years or more frequently if high concentrations are observed.

Human use – Monitor harvests of subsistence and commercial harvests of sport fish and intertidal invertebrates. Also monitor timber harvests and other terrestrial events that may impact the nearshore.

Notes

Selection of metrics – focus on: 1. Species used by humans including salmon, herring. 2. Species of ecological significance such as sea stars, 3. Predators and important food resources for 1 and 2 above.

Community involvement – Build in support for community outreach and education.

Sampling protocols – Coordinate with existing sampling programs and standardize protocols.

Links to other GEM programs – Link nearshore programs with offshore.

Sampling design – Use an adaptive sampling approach.

Group 4. Moderator – Peter Armato, Recorder-Gail Irvine

Priorities in sampling

Physical Chemical monitoring - Sample temperature and salinity as high priority items. Also monitor rainfall. Also consider monitoring color, nutrients.

Diversity and abundance – Sample selected species of interest including salmon, sentinel species such as sea ducks or forage fish, invasive species, and species important for subsistence.

Habitat mapping – Map sensitive areas and change in habitats of interest including areas of human activity.

Contaminant monitoring – Monitor persistent oil especially in subsistence resources.

Human use – Monitor and map human use.

Notes
Community involvement – Communities should have their own monitoring program, especially for contaminants. Education and information transfer programs should be established.

Sampling protocols –Standardize of protocols is essential. Portions of the PISCO approach might be useful, but habitats other than sheltered rocky should be considered.

Links to other GEM programs – Link nearshore programs with watershed, especially via hydrology.

Group 5. Moderator – Brenda Konar, Recorder-Carmen Field

Priorities in sampling

Habitat mapping – Map entire GOA, especially with respect to substrate type, slope, and exposure. Use existing maps if possible and then do more detailed work at selected sites. Do an initial set and then only following major events. Mapping of kelp and eelgrass beds should be done as a part of this effort.

Physical Chemical monitoring - Sample temperature (highest priority), salinity, and primary productivity as high priority items. Sample synoptic temperature over the entire GOA using satellite. Sample other physical parameters at intensive sampling sites. Some variables might be just as easily monitored continuously vs. seasonally.

Diversity and abundance – Conduct a biological inventory and monitor with focus on keystone or indicator species. Species might include pigeon guillemots, harlequin ducks, mussels, herring, capelin, sandlance, barnacles, urchins, chitons, and limpets.

Human use – Monitor and map human use. Coordinate with communities to assist in map preparation. Also look to permit offices for existing maps.

Event monitoring – Monitor and record important events including both natural and anthropogenic.

Notes
General comment – Need to do a few things very well. Also need to establish partnerships where possible.

Sampling design – Need to standardize of protocols. Also, need to sample in various habitats and use a stratified sampling design, with unequal sampling effort in different habitats.

Group 6. Moderator – Carol Blanchette, Recorder – Diana Stram

Priorities in sampling

Habitat mapping – Map entire GOA. Start with large-scale maps and then focus on sampling sites. Use community members to assist in mapping

Physical Chemical monitoring - Sample temperature and salinity continuously at extensive sites using low-tech methods. Measure temperature, salinity, currents, and nutrients continuously at intensive sites.

Community structure – Conduct bi-annual sampling of algae, invertebrates, marine mammals, birds, and other key species at both intensive and extensive sites.

Contaminants – Sample water and selected animal tissues annually at intensive sites. Monitor and map human use. Coordinate with communities to assist in map preparation. Also look to permit offices for existing maps.

Notes
Sampling design – Both rocky and soft substrate habitats need to be included. Native knowledge of key species, including salmon, plankton, herring, chitons, clams, seals, and sea lions should be utilized. Both intensive and extensive sampling are required for a successful program.

Community involvement – Use communities in the program. There is a need for infrastructure support of community program including training to be conducted within existing tribal government systems.

Rapid response – some funds should be set aside for rapid response issues.

QA/QC – QA/QC program needs to be built into the program. Need protocols for training, data collection, data integrity, and analysis. Start with a small scale program and expand. Protocols for sampling need to be established.

Group 7. Moderator – Randall Davis, Recorder – Keith Boggs

Priorities in sampling

Physical Chemical monitoring - Sample temperature, salinity, light, and currents at intensive and extensive sites at least seasonally. Measure geomorphology (slope, substrate type, aspect, shore processes) every decade or following events such as earthquakes, major storms, or volcanoes.

Productivity – Measure continuously at intensive sites using moorings , and using satellite imagery over entire GOA. Measure secondary productivity of upper trophic groups including birds and forage fish every five to ten years at both intensive and extensive sites.

Contaminants – Sample clams and mussels at intensive and extensive sites annually or following events.

Human use – Map human use including harvested resources, subsistence activity, sport fishing, commercial fishing, and recreational use.

Notes
Community involvement – Scoping within communities is essential.

Group 8. Moderator – Ted Otis, Recorder – Sue Mauger

Priorities in sampling

Physical Chemical monitoring - Sample temperature, salinity, chlorophyll, wind, nutrients, and sea level continuously over the entire GOA.

Contaminants – Measure at extensive sites annually (or less frequently) at extensive sites.

Intertidal / subtidal monitoring – Measure biodiversity and recruitment at intensive sites annually (or less frequently depending on costs).

Forage fish – Measure biodiversity and recruitment at intensive sites annually (or less frequently depending on costs).

Marine birds

Human use – map every 5 years or following events.

Notes
Site selection – focus should be on spill-affected area.

Community involvement – Contaminant sampling should offer an opportunity for community involvement.

Appendix B. 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	USGS
Sonia Batten	Sir Alister Hardy Foundation for Ocean Science
William Bechtol	ADF&G
Alan Bennett	NPS
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	USGS
James Brady	ADF&G
Evelyn Brown	UAF
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	UAF
Nancy Hillstrand	Coal Point Packing
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	USFWS
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	NMFS
Bill Lorenz	Alaska Region, Forest Service
Alan Maki	ExxonMobil
Gary Marty	University of California, Davis
Sue Mauger	Cook Inlet Keeper
Mary McBurney	National Park Service
Paul McCollum	Sound Fisheries
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	Port Graham
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	NMFS
Martin Robards	Ocean Conservancy
Ted Rockwell	
Gilbert Roetman	North Star Media Institute
Dan Rosenberg	ADF&G
David Roseneau	USFWS
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	Glacier Bay NPS
Bob Shavelson	Cook Inlet Keeper
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	UAF
Diana Stram	KBRR
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	Seldovia
Susan Walker	National Marine Fisheries Service
Frank Wallis	ADF&G
Marty Waters	
Tom Weingartner	Institute of Marine Science, UAF
Donna Willoya	The Alaksa Sea Otter & Steller Sea Lion Commission
Kent Wohl	
Violet Yeaton	Port Graham