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

Alternative Sampling Designs for Nearshore Monitoring

GEM Project 040687
Final Report

James Bodkin
US Geological Survey
1011 East Tudor Road
Anchorage, AK 99503
Phone: (907) 786-3550
Email: james_bodkin@usgs.gov

Thomas A. Dean
Coastal Resources Associates, Inc.
5674 El Camino Real, Suite M
Carlsbad, CA 92008
Phone: (760) 603-0612
Email: coastal_resources@sbcglobal.net

December 2003

The *Exxon Valdez* Oil Spill Trustee Council conducts all programs and activities free from discrimination, consistent with the Americans with Disabilities Act. This publication is available in alternative communication formats upon request. Please contact the Restoration Office to make any necessary arrangements. Any person who believes she or he has been discriminated against should write to: EVOS Trustee Council, 645 G Street, Suite 401, Anchorage, Alaska 99501; or O.E.O. U.S. Department of the Interior, Washington D.C. 20240.

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

Alternative Sampling Designs for Nearshore Monitoring

GEM Project 040687
Final Report

James Bodkin
US Geological Survey
1011 East Tudor Road
Anchorage, AK 99503
Phone: (907) 786-3550
Email: james_bodkin@usgs.gov

Thomas A. Dean
Coastal Resources Associates, Inc.
5674 El Camino Real, Suite M
Carlsbad, CA 92008
Phone: (760) 603-0612
Email: coastal_resources@sbcglobal.net

December 2003

Alternative Sampling Designs for Nearshore Monitoring

GEM Project 040687
Final Report

Study History: This project was initiated in December of 2002 with approval of funding by the *Exxon Valdez* Oil Spill (EVOS) Trustee Council. Early in 2003 we hired staff and began research and compilation of references to be included into a historic metadata base. The reference collection would include prior and current studies of a select assemblage of marine taxa, including alga, invertebrates, fishes, birds, and mammals that occupy nearshore habitats of the Gulf of Alaska. Concurrently we implemented a process to provide input into the selection of resources (biological taxa and physical attributes) and metrics to be included in our metadata. By 15 September of 2003 we concluded compilation of references and began finalizing inclusion of references in hand into the data set and began developing a GIS (ArcView themes) dataset that would eventually allow geographic representation of the metadata. Concurrently with the development of the metadata, we began conceptualizing and developing sampling alternatives for the nearshore habitats in the Gulf of Alaska for consideration of inclusion within the GEM program. The sampling alternatives included those physical and biological resources identified in the development of the metadata project as important to the GOA nearshore ecosystem.

Abstract: Over the past several years a series of workshops were convened to help develop a monitoring plan for the nearshore. In these workshops it was recognized that changes are likely to occur in the Gulf of Alaska over the next 100 years, and that these are likely to result from a number of different causal agents (e.g. global climate change, shoreline development and associated inputs of pollutants). It was also recognized that changes are likely to occur over varying temporal and spatial scales. For example, global climate change may result in a gradual change in the nearshore community that occurs over decades and has impacts over the entire GOA. On the other hand, impacts from shoreline development will likely be more episodic and more local. Thus, one challenge of designing a monitoring program was to detect changes occurring over these widely varying scales of space and time. To this end, a conceptual framework for monitoring was designed that had the following elements:

1) Synoptic sampling of specified physical and biological parameters (e.g. shoreline geomorphology and eelgrass cover) over the entire GOA
2) Intensive sampling of a variety of specified biological and physical parameters (e.g. abundance and growth of intertidal organisms, abundance of selected birds and marine mammals) within a few specified areas spread throughout the GOA.
3) Sampling of a smaller suite of selected biological and physical parameters (e.g. the abundance, growth, and contaminant levels in mussels and clams) at a larger number of less intensively studied sites stretching across the GOA. These are referred to as extensive sites.

4) Conduct of shorter-term studies aimed at identifying important processes regulating or causing changes within a given system or subsystem.

Intensive sampling was designed to detect larger spatial scale changes while extensive sampling was aimed at evaluating potential impacts from more localized sources, and especially those resulting from human activities. Process studies were to focus on determining causes for observed changes. While the workshops provided a valuable conceptual framework, they did not give necessary details (e.g. what to sample, where to sample, when to sample and at how many sites). In this report we provide those details in the form of three alternative sampling designs for the nearshore-monitoring program.

All of the proposed alternatives restrict sampling to the central GOA region between Kodiak and Cordova. Also, all alternatives include sampling of intertidal invertebrates and algae, selected vertebrate predators closely tied to the nearshore (e.g. sea otters and black oystercatchers), selected physical variables (e.g. temperature and salinity), and contaminant concentrations in the animal tissue. Sampling of intertidal invertebrates and algae is restricted to sheltered rocky and gravel / mixed sand-gravel habitats. All alternatives have an estimated average annual budget of approximately $900,000.

The three design alternatives differ primarily with respect to emphasis on intensive vs. extensive sampling effort. Alternative 1 provides a balanced approach, with relatively equal emphasis on detecting changes that may occur over both small and large spatial scales. Approximate equal weight was given to intensive sampling at a few widely scattered sites, and extensive sampling of a smaller suite of variables at a larger number of sites. Alternative 2 gave greater emphasis to detecting smaller scale changes and was more heavily weighted toward sampling at extensive sites. In particular, this alternative prescribed sampling at a greater number of extensive sites, a higher frequency of sampling at those sites, and greater emphasis on sampling of contaminants. The third alternative was focused more at detecting larger scale changes and on examining possible mechanism of change. Sampling effort was increased at intensive sites, especially with respect to physical factors that may help explain biological changes. The number of extensive sites, the sampling frequency, and the level of effort for contaminant studies were reduced in this alternative. Detailed sampling plans, including number and location of sampling sites, a list of metrics to be sampled, sampling frequency, and cost estimates are supplied for each alternative.

As part of the design effort, we also provided a comprehensive historical perspective of locations and types of past studies conducted in the nearshore marine communities within Gulf of Alaska in the form of a geographical information system database. This database provides a visual means of assisting in site selection based (in part) on the locations for which historical data of interest are available.

Key words: ArcView, GIS, Gulf of Alaska, intertidal, metadata, monitoring, nearshore, sampling.

Project Data: Data are maintained in digital format (ArcView 3.3, Excel 2002, and Procite) at the Alaska Science Center, USGS in Anchorage, Alaska.

Citation: Bodkin, J. L., and T. Dean. 2003. Alternative sampling designs for nearshore monitoring, Exxon Valdez Oil Spill Gulf Ecosystem Monitoring and Research Project (GEM Project 040687), US Geological Survey, Alaska Science Center, Anchorage, Alaska.

TABLE OF CONTENTS

LIST OF TABLES ix
LIST OF FIGURES x
INTRODUCTION 11
  Background and Project History 11
  The GEM planning process 12
OBJECTIVES 13
  Definitions, geographic and habitat constraints 13
  Purpose and Nearshore Monitoring Goals 15
    Detecting change-- 15
    Assigning Cause-- 17
    Predicting change-- 18
    Informing stakeholders and resource managers-- 18
    Providing tools for solving problems-- 18
OVERVIEW AND REPORT ORGANIZATION 18
  General Design Considerations 19
    Selection of metrics-- 19
    Selection of sampling sites-- 21
    Sampling frequency-- 22
    Adaptive management-- 23
ALTERNATIVE SAMPLING DESIGNS 23
  Alternative 1. Balanced between intensive and extensive sampling efforts. 24
    Synoptic sampling-- 24
    Intensive sampling-- 24
    Extensive sampling-- 26
    Sampling of contaminants in subsistence food-- 28
    Process studies-- 28
  Alternative 2. Sampling weighted toward extensive sampling. 28
    Synoptic sampling-- 29
    Intensive sampling-- 29
    Extensive sampling-- 29
    Sampling of contaminants in subsistence food-- 29
    Process studies-- 29
  Alternative 3. Sampling weighted toward intensive sampling. 29
    Synoptic sampling-- 30
    Intensive sampling-- 30
    Extensive sampling-- 30
    Sampling of contaminants in subsistence food-- 30
    Process studies-- 30
COST ESTIMATES 30
ANALYSIS OF MONITORING DATA 31
  Analyses to Detect Change 31
  Analyses to assign cause 33
MANAGEMENT STRUCTURE 33
COMMUNITY INVOLVEMENT 34
ACKNOWLEDGEMENTS 34
LITERATURE CITED 35
APPENDIX A. Geographical Information System database of the availability of historical data in the nearshore zone of the Gulf of Alaska 54
  Introduction 55
  Methods 56
  Results 57
    Excel Database 57
    GIS ArcView 3.3 Near GEM project 60

ProCite Database 64
Discussion 65
Literature Cited..65
Attachment A1. GEM Nearshore Metadata Project letter of inquiry including definition of nearshore marine communities and potential resources for inclusion into metadata set. 71
Attachment A2. GEM Nearshore Metadata Project form mailed to prospective individuals, agencies, or organizations, 2003...74
APPENDIX B. Cost estimates for alternative designs for the nearshore sampling program. 77
APPENDIX C. CD-ROM...89

LIST OF TABLES

Table 1. 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. 37
Table 2. 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. Priorities, as derived from prior workshops, are also given (1 = highest). 40
Table 3. List of metrics to be sampled for each task. Lists of intertidal plant and invertebrate species to be counted are tentative and will be finalized after an initial sampling.. 42
Table 4. Summary of sampling design alternatives indicating the number of sampling locations and frequency of sampling for each task. Metrics associated with each task are given in Table 3 436
Table 5. Cost summaries for each Alternative sampling design proposed. Budget details are given in Appendix B....48
Table A1. The 15 **r**esources (biological and physical) used in the GEM Nearshore Metadata Set (Excel) and viewable as themes in the ArcView 3.3 database. Resources are **bolded,** further taxonomic discrimination is provided in the fields *class1* and *class2*, that usually refer to genus and species....67
Table A2. Metrics used by researchers in the Gulf of Alaska between the years 1896 to 2003 as entered in the GEM Nearshore Metadata Set Excel database to describe how resources (Table 1) were evaluated. The metric field can be used in ArcView queries to display and view specific types of studies (e.g. age or size for biological resources, and salinity for a physical resource) or metrics used to evaluate resources. All metrics are not applicable to all resources. 68
Table A3. Data collection methods in the Gulf of Alaska between the years 1896 to 2003 as entered in the GEM Nearshore Metadata Set Excel database to describe how measurements of a specific metric were obtained. The method field can be used in ArcView queries to display and view specific types of methods (e.g. body weight for size) used to acquire data related to specific metrics or resources. All methods are not applicable to all metrics....69

LIST OF FIGURES

Figure 1. Representation of the change of spatial extent of impact over time for different types of impacts that may occur within the nearshore zone. 49
Figure 2. The proposed sampling areas to be used in the nearshore monitoring program are indicated by the blocks outlined in red. Blocks 3, 4, and 8 are designated for intensive sampling. 50
Figure 3. Map showing the number and approximate distribution of sampling locations for different types of sampling as prescribed in Alternative 1. 51
Figure 4. Map showing the number and approximate distribution of sampling locations for different types of sampling as prescribed in Alternative 2. 52
Figure 5. Map showing the number and approximate distribution of sampling locations for different types of sampling as prescribed in Alternative 3. 53
Figure A1. Examples of ProCite #, Resource, Reference, Review Level, Region, Area, Site/Area, and Inference Scale in the GEM Nearshore Metadata Excel database and viewable in ArcView tables. 58
Figure A2. Examples of Inference Scale, Actual, Lat, Long, Classification Level, Class 1, Class 2, Depth, Metric, Start Year, and End Year in the GEM Nearshore Metadata Excel database and viewable in ArcView tables. 59
Figure A3. Examples of Season, Sample Years, Method, and Notes in the GEM Nearshore Metadata Excel database and viewable in ArcView tables. 59
Figure A4. Viewing a Near GEM ArcView theme by checking a box and highlighting a bar. In this example sea otter and algal species studies are displayed on the Alaska shoreline theme. 61
Figure A5. The query box, displaying a query of invertebrate species where only records where “area” equals “Bay of Isles” will be displayed. 62
Figure A6. Creating a new theme from features selected though the “query”. The highlighted records will be included into the new theme. 63
Figure A7. Dropdown menu for converting the results of a query into a new theme (shapefile). 63
Figure A8. Results of the procedure to view records through the “identify” process described above. Selected points will result in the inset view. 64
Map A1. GEM Nearshore Metadata Project study area of the Gulf of Alaska between Chignik and Yakutat, Alaska, 2003. 66

INTRODUCTION

Background and Project History

The Gulf Ecosystem Monitoring (GEM) program has five major programmatic goals:

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

The GEM plan divides the Gulf of Alaska (GOA) into four habitats: Watershed, the nearshore, the Alaska Coastal Current, and the shelf. As an initial step in developing a sampling design to detect change in the nearshore habitat, the EVOS Trustee Council conducted a series of workshops in 2001 and 2002 (Project 02395). In these workshops it was recognized that the changes are likely to occur in the GOA over the next 100 years, and that these are likely to result from a number of different causal agents (e.g. global climate change, shoreline development and associated inputs of pollutants) (Table 1). It was also recognized that changes are likely to occur over varying temporal and spatial scales. For example, global climate change may result in a gradual change in the nearshore community that occurs over decades and has impacts over the entire GOA, and beyond. On the other hand, impacts from shoreline development will likely be more episodic and more local. Thus, one challenge of designing a monitoring program is to detect changes occurring over widely varying scales of space and time. In response to this challenge, the conceptual design for monitoring in the nearshore was developed (Schoch et al. 2002). It called for a multi-pronged approach consisting of the following:

1) Synoptic sampling of specified physical and biological parameters (e.g. weather, sea surface temperature) over the entire GOA
2) Intensive sampling of a variety of specified biological and physical parameters (e.g. abundance and growth of intertidal organisms, abundance of selected birds and marine mammals) within a few specified areas spread throughout the GOA.
3) Sampling of a smaller suite of selected biological and physical parameters (e.g. the abundance, growth, and contaminant levels in mussels and clams) at a larger number of less intensively studied sites stretching across the GOA. These are referred to as extensive sites.

4) Conduct of shorter-term studies aimed at identifying important processes regulating or causing changes within a given system or subsystem.

Sampling at intensive sites was aimed at detecting large-scale changes (e.g. those due to global climate change) while sampling at extensive sites was focused on detecting changes that might occur as a result of more localized events, and especially those anthropogenic disturbances. A long list of potential parameters to be measured was developed (Table 2) and priorities were given for each of these within the synoptic, intensive, and extensive components.

The workshops resulted in the development of a reasonable framework for development of a nearshore GEM program, but specifics as to the parameters to be measured, the number of sites to be sampled, and the location of sampling sites were not determined. Furthermore, no specific cost estimates were provided and no determination was made as to the appropriate allocation of effort (and costs) among the various components (synoptic, intensive, extensive and process studies). This report provides these details and gives alternative sampling designs to be considered by the Trustee Council for implementation.

The GEM planning process

We envision that the development of a final nearshore GEM sampling design will be finalized using the following process:

1) Based on preliminary recommendations resulting from workshops conducted over the past several years, list potential metrics to measure, number and location of sampling sites, and frequency of sampling.
2) Provide the data analyses and representations needed to determine appropriate metrics, the number of sites, location of sites, and frequency of sampling. These will include establishment of a GIS database in which habitat types, locations of historical data, types of historical data available from each site, existing human use, and biological hotspots are identified and presented.
3) Establish a protocol for site selection and select potential sites. We envision that the selection protocol will have the following elements. Intensive sites will be selected that are spread sufficiently throughout the GOA so large-scale geographic trends can be detected. These sites will be selected based on similarity of habitat, proximity to logistical support facilities, availability of appropriate historical data, and a lack of local anthropogenic disturbance. Extensive sites will be selected so that they are systematically distributed throughout the study area, are in areas that are susceptible to human impacts, or are heavily utilized by humans for their resources.
4) Make preliminary cost determinations and based on these, select alternative sampling designs that can be conducted within the preliminary budget. These are to be “core” sampling design alternatives that can be fully sustained based on support received from the EVOS Trustee Council. Alternatives will provide differing emphases with respect to effort afforded to synoptic, intensive, extensive, and process studies. Each

alternative would include number and location of specific sites to be sampled, the frequency of sampling, and the metrics to be sampled at each site.

5) 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 to finalize sites selection, and preliminary sampling may be necessary in order to estimate the number or sizes of sampling units needed to detect change with reasonable power.
6) Make final determination of metrics, sampling sites, and sampling frequency selections based on the above and develop final protocols for a core sampling program.
7) Identify potential partnering agreements for "non-core" elements and develop these.
8) Develop a data management system and quality assurance/quality control procedures prior to sampling.

OBJECTIVES

In this project, we focus on numbers 2 through 4 above. Specifically, we

- Established a GIS database that identifies habitat types, locations of historical data, and types of historical data available from each site, existing human use, and biological hotspots.
- Provide alternative sampling designs that can detect change, over varying scales of space and time, with reasonable certainty and can be conducted within imposed budgetary constraints. As part of the design, make a preliminary list of potential sites and metrics to be evaluated at each site.
- Estimate costs for each of the above.

The GIS database of historical information is presented in detail in Appendix A. Here, we provide details on development of alternative sampling designs.

Definitions, geographic and habitat constraints

The GEM plan defines the nearshore zone as that portion of the GOA that stretches from the high tide line to approximately 20-m depth. The intertidal and subtidal areas of the nearshore habitat are brackish and salt-water coastal habitats that are some of the most productive habitats in the GOA and are highly susceptible to anthropogenic perturbations. These areas have abundant invertebrates such as barnacles, crabs and shellfish and juveniles of many species. The nearshore habitats provide important feeding grounds for larger animals. Terrestrial and aquatic birds, mammals, invertebrates, large fish and even humans depend on food from these rich meeting places of sea and river nutrients. In addition to their importance as feeding grounds, these areas provide nurseries for young marine organisms, unique habitats for specialized animals and are major sources of seaweed production. At the same time, contaminants such as persistent organic pollutants may be found in high concentrations in several invertebrate species of the inter- and subtidal zones, providing pathways and potential threats to wildlife and human health. For research purposes, some invertebrate species make excellent indicators of pollutants.

The GEM program calls for development of a nearshore-monitoring program that encompasses the entire GOA. The shoreline of the GOA stretches from the Aleutian Islands in the West to the Dixon Entrance in the East, a distance of over 4,000 km. Because of the geographic extent and complexity of the region, we recognize that it will not be possible to conduct a sampling program capable of detecting a reasonable level of change over such a large area within the anticipated budgetary constraints. Thus, we have restricted our efforts to the central GOA, which we define as the region from Kodiak to Cordova, a stretch of approximately 800 to 1000 km. We arbitrarily restricted our efforts to this region based on the following:

1) The habitats and processes observed within the central GOA nearshore region are representative of the larger GOA region. Changes that occur over the entire GOA (as the result of global climate change for example) are likely to occur and be detected within the more restricted central GOA region.
2) The central GOA region is the population center for the larger GOA and is the most likely to be impacted by a variety of future human activities over the next several decades.
3) The funding for the GEM monitoring program was obtained as a result of damage settlement for injuries caused by the Exxon Valdez Oil Spill, and the spill had the greatest impact within the central GOA region.
4) The relative ease of access to much of the region (compared to the more westerly Alaska Peninsula and Aleutians Islands for example) makes monitoring more tractable and cost effective.

Additionally, we excluded from consideration of sampling the Upper Cook Inlet and the shorelines along the Alaska Peninsula (from Cook Inlet to Sand Point). These were excluded because they are generally high-energy habitats characterized by exposure to waves (Alaska Peninsula) or strong currents (Upper Cook Inlet). Biological communities in these regions are largely structured by these physical forces, and as such, are likely to exhibit a high degree of variability that make detection of changes due to other factors (e.g. climate change or coastal development) difficult to detect. Also, these areas are difficult to access and therefore expensive to sample.

The remainder of the area is largely in the Prince William Sound, Kenai Peninsula, Lower Cook Inlet, and Kodiak Island regions. There are a wide variety of habitats within these regions. These are classified into ten predominant geomorphologic types (Ford et al. 1996): fine-medium sand beaches, coarse sand beaches, mixed sand-gravel beaches, gravel beaches, exposed rocky shores, exposed wave-cut platforms, sheltered rocky shore, exposed tidal flat, sheltered tidal flat, marsh.

For the purpose of the GEM monitoring program, we intend to restrict sampling of intertidal invertebrates and algae to sheltered-rocky shores and to gravel and mixed sand-gravel beaches. We selected these habitats because they represent over half (about 58%) of the shorelines within the region (Ford et al 1996); are biologically diverse; they harbor both hard bottom (epibenthic) and soft bottom (infaunal) organisms; are tractable to sample, and have a wealth of historical data relative to other habitats. Thus, they provide excellent indicators of change over the entire region. Of the other habitats, exposed rocky shores or exposed wave cut platforms are the most represented. However, these are generally less accessible for sampling. We do not deny the importance of habitats that we do not intend to sample (e.g. tidal flats as critical habitats for birds) but suggest that focusing sampling efforts on a few representative habitats will produce a monitoring plan that is more sensitive and is more likely to detect change.

Purpose and Nearshore Monitoring Goals

Detecting change--
The goals of the nearshore monitoring program are the same as for the overall GEM plan: to detect change; identify causes of change; predict the status and trends of natural resources for use by resource managers and consumers; 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 develop tools, technologies, and information that can help resource managers and regulators improve management of marine resources and address problems that may arise from human activities. The first goal, to detect change, is a necessary precursor for achieving the other goals. Therefore, much of the focus of the nearshore GEM program is placed on detecting change.

It is not possible to predict what changes might occur within the nearshore zone over the next several decades, and unforeseen changes that result from unforeseen causes, will almost certainly occur. Clearly, it would have been impossible to predict many important agents of global ecological change that have occurred over the past century. Our understanding of many agents of change now widely accepted as important, (e.g. El Nino events and pesticide contamination) have only come to light over the past half century. However, while predicting change with one hundred percent success is unlikely, hypothesizing changes, and the temporal and spatial scales over which they may occur, is an important initial step in the planning process. While not all causes of change can be specified or predicted, we anticipate that changes will result from both natural and anthropogenic agents, and will occur over varying scales of time and space. One of the major challenges of the program will be to design a sampling program that can effectively detect changes regardless of their cause and the temporal and spatial scales over which they occur.

Hypothesized changes, their causes, and the spatial and temporal scales over which they are likely to occur (Table 2) were gleaned from two major sources: a review of the changes that have occurred within the GOA over the past several decades, and a review of changes that have occurred in regions outside of Alaska where anthropogenic impacts have been more prevalent. The latter include areas such as Puget Sound or the coast of Southern California where there has been major population expansion and concomitant anthropogenic impacts. Some changes (e.g. global climate change) occur over very wide areas, much larger than the GOA. Such changes can be detected by sampling at just a few locations within the GOA over time. On the other hand, many changes that are expected to occur over smaller spatial scales (e.g. unplanned point source discharges of contaminants) can only be detected by sampling at many sites spaced throughout the GOA. Therefore, to detect changes that occur over both large and small spatial scales, we propose monitoring that combines three primary elements: 1) sampling a selected suite of variables over the entire study area (synoptic sampling), 2) sampling a large number of metrics at relatively high temporal frequency at a few widely scattered sites (intensive sampling), and 3) sampling a smaller number of metrics at a large number of sites on a less frequent basis (extensive sampling).

One other important aspect of the changes in the nearshore is the asymmetrical nature of temporal and spatial scales over which they may occur. Some changes (e.g. the spread of invasive introduced species, increases in concentrations of contaminants due to coastal development, or cumulative impacts of fishing on nearshore fish communities) tend to start at a small spatial scale, but the spatial extent of these impacts increases with time (Figure 1). For example, the spread of *Culerpa taxifolia*, an invasive bottom dwelling alga, was first observed in the Mediterranean Sea near Monoco in 1984. By 1989, the original patch had spread to cover approximately 1 ha. By 2000, the largest patch near Monaco had spread to over 10,000 ha, and at least 10 other patches measuring between 1,000 and 20,000 m^2 were observed elsewhere in the Mediterranean and nearby Adriatic Seas (Madl and Yip 2003). Similarly, contamination from coastal runoff in southern California that was likely restricted to a small section of coast a century ago, but now occurs widely throughout the region. These impacts are here termed “impacts of increasing spatial extent”. Other changes (e.g. those caused by changes in ocean circulation during an El Nino event or more localized geomorphologic changes resulting from an earthquake) have impacts over spatial scales that are relatively constant over time. We term these “impacts of constant spatial extent”. Finally, other changes (e.g. those caused by contamination from a major oil spill similar to the Exxon Valdez spill) have impacts that may increase in spatial extent over very short time frames (e.g. days or weeks) but generally decrease in spatial extent over larger time scales (years or decades). These are termed “impacts of diminishing spatial extent”.

The monitoring programs described here are designed to detect changes that occur on spatial scales of 1,000s of m of coastline or larger, and on temporal scales of year or more. Smaller scale changes (e.g. seasonal changes in algal cover, movements of nearshore fishes associated with tidal stage, or impacts from very small localized oil spills) are considered outside the scope of this program, and it is likely that they go undetected. Also, we intend to focus (albeit not exclusively) on detecting changes for which the spatial extent is expected to increase over time. Many of these changes are likely to result from anthropogenic influences and may have significant long-term impacts on the GOA system if they go unchecked. Detecting these impacts at an early stage should allow resource mangers to take timely action and eliminate or minimize impacts before they become pervasive.

While our focus will be on detecting changes whose impacts increase in spatial extent with time, it is also important to detect changes for which impacts remain constant or decrease over time. Detecting changes such as those resulting from global increases in temperature are clearly important in a larger, global context. Also, detecting and assigning cause to various types of change will be critical in the interpretation of the trends observed and advising resource mangers with respect to these. It is likely that changes will occur as the result of multiple causes, and identifying varying causes will be critical in factoring out individual agents of change and assigning cause appropriately. For example, determining the impacts of the Exxon Valdez oil spill on seabirds required an understanding of longer-term, region-wide declines in seabirds that were related to climate-related changes in seabird-food supplies (e.g. Golet et al 2002).

As indicated above, the conceptual model of our monitoring program calls for detecting change based on a sampling program that combines the following elements.

1) Synoptic sampling of a selected set of physical or biological variables (e.g. sea surface temperature or eelgrass distribution) that can be remotely evaluated over the entire study region or subsets of this region.
2) Intensive sampling of a suite of biological and physical parameters at a few widely scattered sites within the study area.
3) Extensive sampling of a subset of subset of biological and physical parameters at a relatively large number of sites throughout the study area.

Details with respect to metrics sampled, number and location of sampling sites, and frequency of sampling are provided for several alternative plans in the sections that follow.

Assigning Cause--
The second goal of the monitoring program is to assign cause. As with most biological systems, changes will likely result from multiple causes and we anticipate that the responses to these will be complex. Most responses are likely to be non-linear and those resulting from multiple causes are likely to be non-additive. As a result, we expect that assigning cause will be a difficult and often less than exacting. It is likely that we will be able to suggest that changes are, in part, related to certain causative agents. However, quantitative assessments (the proportion of observed change attributable to a given cause) will be more difficult.

We propose assigning causes for change by first examining the spatial and temporal patterns of change that occur in relation to the expected patterns. For example, changes that occur over large spatial scales might be attributable to large-scale climate changes, but are unlikely to be caused by more localized coastal development. Second, we will conduct concurrent monitoring of biological responses and likely forcing agents. The forcing agents will include both top down (i.e. predators and physical disturbance) and bottom up (food or productivity related) factors. Possible correlations between responses and changes in forcing agents will suggest possible causation. Finally, the plan calls for funding to be set aside to test hypotheses regarding mechanisms of change that are suggested by above observational or correlative evidence. These process studies will focus more narrowly on patterns observed during the course of monitoring and will test specific hypotheses regarding the causes for change. It is anticipated that the Trustee Council will invite proposals for process studies as the need arises. It is also anticipated that such process studies will be initiated no sooner than five years after the beginning of monitoring. This should allow sufficient time for trends to become apparent and research needs to be better defined.

Predicting change--
As indicated above, responses by biological systems to various causes for change are often complex. As a result, models of ecological change have not been particularly successful in making accurate quantitative predictions. However, predictive models may be useful in predicting generalized trends and guiding management decisions. For example, predictive models of the impacts of CO^2 emissions on global climate change suggest that mangers should consider regulation of those emissions.

The development of useful predictive models of ecological change is largely dependent on the existence of long-term data sets. For example, recent predictive models of climate change depend on long-term indicators of change as gleaned from historical paleontological or chemical records. At present, there are few such long-term records available for predicting change in the nearshore environment in the GOA. Therefore, while the development of predictive models is seen as an important part of the GEM program, we do not propose any predictive modeling at present. Instead, we suggest setting aside future funds to develop specific predictive models as long-term data sets become available.

Informing stakeholders and resource managers--
The transfer of information is a critical part of the GEM program. One important means of insuring timely transfer of information is the involvement of community members and stakeholders in the monitoring process. As part of the proposed plan, we specify particular tasks that will be done with the assistance of community members. It is anticipated that a formal information transfer protocol will be developed as part of the overall GEM program and no specific program is provided as part of the nearshore-monitoring plan. It is also anticipated that results from the nearshore monitoring program will be made in annual reports presented to the EVOS Trustee Council, and that the Council will be responsible for disseminating information from the reports to appropriate stakeholders and managers.

Providing tools for solving problems--
As with other GEM programs, it is anticipated that the nearshore monitoring program will provide tools, technologies, and information that can help resource managers and regulators improve management. For example, the nearshore database provided as part of this project (Appendix A) should assist resource mangers in efficiently gathering information on specific resources in specific geographic regions. It is anticipated that such problem-solving tools will be developed as part of evolving monitoring effort, or on an ad hoc basis to address specific management issues as they arise. No specific plans for development of such tools are provided as part of the nearshore-monitoring plan.

OVERVIEW AND REPORT ORGANIZATION

The remainder of this report will focus on details of three alternative monitoring plans that are designed to meet the previously described program goals. Each alternative will contain the basic elements described above (synoptic sampling, intensive sampling, extensive sampling, and process studies) as developed during prior workshops. The plans vary only with respect to emphasis. Alternative 1 will seek to provide a program that gives approximately equal emphasis to detecting large and small-scale spatial changes. Alternative 2 will emphasize detecting changes that occur on a smaller geographic scale (e.g. more localized changes due to coastal development and associated contaminants). Alternative 3 will focus more on process studies and on detecting large-scale changes (e.g. GOA-wide responses to climate change). For each alternative we will provide details and rationale regarding the sampling scheme (metrics to be sampled, number of sampling sites, sampling locations, and frequency of sampling) as well as cost estimates. For the purpose of this planning effort, we have assumed that the annual budget for the nearshore-monitoring program will be on the order of $900,000.

The report will also give a general framework for analyses of elements in the monitoring program. This is primarily provided as a means of indicating how the proposed plans might specifically be used to detect change and serve as triggers for additional study. We also provide some general guidelines and discussion of project management structure particularly as it pertains to inviting appropriate and timely proposals for carrying out the plan.

General Design Considerations

Selection of metrics--
The metrics to be sampled as part of the monitoring program will include both biological and physical elements. The biological component will be comprised of nearshore plants (algae and seagrasses) and invertebrates that are generally sessile or of limited mobility as well as larger, more motile vertebrate predators. The plant and invertebrate sampling will focus on species that inhabit the intertidal zone. This is primarily because these species can be sampled more efficiently than subtidal species. The intertidal zone can be sampled relatively simply by counting or collecting plants and animals in place during low tides. Precise estimates of abundance, biomass, size distributions, growth rates, etc. can be made by investigators on the ground, while coarser estimates of larger scale distribution and relative abundance can be made from an aircraft (e.g. Harper et al. 1991). Sampling in the subtidal is more labor intensive and generally requires trained scientific divers, remotely operated vehicles, or other sampling gear deployed from a ship. A comprehensive subtidal sampling effort that is sufficient to detect change would be too costly to conduct under and the budgetary constraints of the program. Therefore, sampling in the subtidal zone is restricted to a few selected taxa that can be sampled remotely (e.g. eelgrass and kelp cover assessed using aerial surveys) or indirectly (e.g. subtidal clams that can be evaluated by observing feeding sea otters).

Furthermore, sampling of intertidal plants and invertebrates will focus on macrofauna that can be seen, counted, and generally identified by the naked eye. Smaller species (e.g. bacteria, meiofauna, or smaller invertebrates and algae) are recognized as important components of the system, but are difficult and costly to sample. Sampling smaller species often requires a large numbers of samples to overcome small-scale spatial variability. Furthermore, evaluating smaller species often requires labor intensive sorting and identification procedures that are costly and therefore impractical given budgetary constraints.

Finally, the bulk of the plant and invertebrate sampling effort will be devoted to species that are numerically dominant, structurally important, or critical prey of specified nearshore vertebrate predators (including local human residents that rely on these resources as subsistence foods). A list of the species considered for sampling is given in Table 3. This list was compiled from previous works conducted in the nearshore zone in the central GOA that identified dominant intertidal and nearshore subtidal taxa, identified important structural components, and described nearshore food webs (e.g. Houghton et al. 1993, Highsmith et al. 1994). We have stressed these species because they provide a sound statistical basis for detecting change in a cost efficient manner (Houghton et al. 1993, Highsmith et al. 1994). Sampling of rarer species is costly, and complete tabulation of all species over the large number of sites necessary to detect change is cost prohibitive.

Sampling of larger vertebrate predators will focus on species that are closely linked to the nearshore system (primarily via their food resources) and especially on those considered strong top-down structuring agents of the intertidal and nearshore subtidal community. These include sea otters, black oystercatchers, Barrow's goldeneye, and harlequin ducks. For the most part, sampling will be aimed at estimating abundance, but may also include assessments of prey utilization (for sea otters and black oystercatchers) or contaminant levels (for harbor seals). Sampling of prey utilization and contaminants in predators is seen as an efficient and cost effective way of indirectly obtaining estimates of parameters that are otherwise difficult to sample over large spatial scales. Also, estimates of prey utilization and contaminants may provide clues to important processes affecting resource abundance and function. They may also provide clues as to linkages between components within the nearshore system, and between the nearshore and adjoining (watershed and coastal current) systems within the GOA.

Physical parameters to be measured will include shoreline geomorphology, water temperature, air temperature, and salinity. Shoreline geomorphology is an important habitat characteristic that helps determine community composition and relative abundance of intertidal plant and animal assemblages. Since geomorphology will help define our sampling universe (which is restricted to sheltered-rocky and gravel/mixed sand-gravel habitats) it is important that we initially assess geomorphology throughout the defined sampling area. Temperature (both air and sea) and salinity are critical to intertidal fauna and flora and are likely to be important determinants of both long-term and short-term fluctuations in the intertidal community. Other physical parameters to be measured under one alternative (Alternative 3) include pH and dissolved oxygen.

It is also anticipated that physical and chemical data obtained from other GEM programs (watershed, Alaska Coastal Current, and shelf) will also be utilized by the nearshore program to evaluate large-scale changes in the system.

One important component of the nearshore program is the evaluation of contaminants and their impact on the nearshore system. We intend to rely primarily on the sampling of animal tissues for evaluating contaminants. Animal tissues serve as integrative mechanisms that help to smooth out small-scale spatial and temporal variability often observed when making direct estimates of contaminants in soils or water. As a result, sampling of animal tissues rather than soil or water allows relevant impacts to the system to be detected with fewer samples. Furthermore, measuring contaminants in animals incorporates elements of uptake and allows more direct linkages between contaminants and biological effects. Contaminant sampling will focus on measuring the concentration of metals and persistent organic pollutants (pesticides, PAHs derived from oil spills, and PCB's).

Selection of sampling sites--

As indicated previously, our intent is to restrict sampling to the central Gulf of Alaska, from Kodiak to Cordova (Figure 2). Furthermore, areas along the Alaska Peninsula and Upper Cook Inlet will not be sampled because they are difficult to access, and appear to be largely regulated by periodic physical disturbance (strong currents and large waves) that make the detection of changes due to other factors difficult.

The generalized sampling design to be employed in the monitoring program combines elements of systematic sampling with the intent of distributing the sampling effort somewhat evenly throughout the sampling region. To this end, we have divided the coastline to be sampled into three regions (Kodiak, Lower Cook Inlet and Kenai Peninsula, and Prince William Sound, with three approximately equal size sampling blocks (in terms of the extent of shoreline) per region. This results in nine sampling blocks (Figure 2). The sampling procedures used within each block will depend on the metric to be sampled. For metrics that can be evaluated remotely (e.g. aerial survey estimates of eelgrass distribution and shoreline geomorphology) sampling will be conducted over the entire block, or over a relatively large sample of the entire shoreline within the block. For motile predators such as birds and sea otters, sampling will be conducted along transects that cover the entire block. For intertidal invertebrates and plants, and for physical parameters that require moored instruments (e.g. subsurface water temperature) sampling will be done at more discrete sites. A site is here defined as an approximately 100-m section of coastline and the water directly adjacent to it.

We envision that specific sampling sites will be selected based on the following criteria. First, in order to ensure approximately equal distribution of sampling sites throughout the block, the shoreline within the block will be divided into shoreline segments of approximately equal length. Different alternative sampling designs (see specific design alternatives below) require different numbers of sites to be sampled within each block. If, for example, a specific alternative calls for sampling at ten sites within a block, then the coastline within the block would be divided into ten segments of approximately equal length. The exact location of the sampling site within each segment would be selected based on the availability of sampling habitat (sheltered rocky shoreline or gravel / mixed sand –gravel). Of the potential sites within a segment, sites with historical data of interest (e.g. sites used previously for intertidal clam sampling) would be given preference. Otherwise specific sites would be chosen at random from a list of potential sites within the segment. The actual selection of sites within the segments will not specified in this report and will require further evaluation of habitat types.

At all sampling sites, we propose to sample intertidal plants and animals at only one tidal height, at approximately lower-low water (the zero tidal height). By restricting sampling to one tidal zone we will be able to complete sampling at a given site within one or two tidal cycles and will be able to sample a larger number of sites over the course of a sampling year. The zero tidal height is generally more productive and more diverse than higher tidal levels, and more accessible to sampling than lower tidal levels.

Some specific sites of special interest will be included in the sampling design. These are primarily to be used in the evaluation of impacts associated with shoreline development or for evaluation of impacts of special interest to local citizens. These sites will be selected based on their proximity to specific resources of interest (e.g. sites particularly important for subsistence use) or based on their proximity to sources of potential anthropogenic disturbance (e.g. near boat harbors or population centers).

It is important to recognize that there is a relatively high degree of subjectivity in choosing sampling sites within this design. As such, the design cannot be used to provide unbiased estimates of population size within a block or to make inference to block with respect to any given parameter. However, it is the purpose of this program to detect change. Selecting sampling sites that are anticipated to be of "high risk", have relatively low inherent variability, or have historical data should enhance our ability to detect change. A completely random or systematic design would have a high probability of concentrating sampling effort in locations where our ability to detect change was lower. The ability to detect change in a timely manner would be especially diminished in cases where changes were due to anthropogenic impacts that increase in spatial extent over time.

Sampling frequency--

The frequency of sampling will vary with metric and with alternative design. In general, biological metrics will not be sampled at a frequency of more than once per year. Some physical measurements such as temperature will need to be made more frequently in order to capture episodic events that may be determinants of changes in biological systems. Yet other metrics that are not as variable over time (e.g. shoreline geomorphology) might be measured less frequently than once per year, perhaps with additional sampling triggered by specific events such as an earthquake.

As part of the monitoring program, we also advocate hypothesis driven process studies and more focused studies of events of particular importance (e.g. a large die off of a particular organism). We anticipate that a certain proportion of the available funds will be set aside for these studies, and that they will be instituted on an as needed basis. We also anticipate that such studies will not be initiated until after the first 5 years or more of monitoring has been completed. This will allow identification of particularly compelling trends and development of hypotheses regarding causes for change, and will allow funding to be built to a sufficient level to support meaningful studies. Also, it is anticipated that there will be some need for increased capital expenditure (for instrumentation for example) in the first several years of the monitoring effort, and some funds that might initially be used for this purpose should be more available for process studies in subsequent years.

Adaptive management--
It is clear that we will be unable to anticipate all the changes that might occur within the GOA system over the next several decades, and that unanticipated agents of change will become apparent over time. Also, it is clear that technologies to be used in sampling and analyses of data will change with time. As a result, there is a strong need to develop an adaptive sampling approach. However, we caution that some core metrics should be maintained over the years, and that some restraint be used in drastically changing the sampling design or emphasis in order to explore a hot topic or respond to a crisis. For example, diverting a majority of the funds to evaluate the impacts of an oil spill comparable to the Exxon Valdez spill would hurt the ability of the program to detect long-term changes from multiple sources. Also, any change in sampling methodology or use of new technology should first be prefaced by a period in which both old and new methodologies or technologies are used simultaneously. This should allow the relatively seamless transition toward new program elements while assuring that data obtained using "old" technologies was not needlessly rendered useless in the analyses of long-term historical records.

ALTERNATIVE SAMPLING DESIGNS

There are a large number of permutations of design alternatives that could be presented. Some of these might include alternatives with an extreme weighting toward a certain component (e.g. an increase in intensive sampling sites and the elimination or drastic reduction contaminant sampling). In keeping with the recommendations of previous workshops to maintain a more balanced approach, we have elected not to include these extremes. Instead we present alternatives that we feel meet the goals of the GEM program, are within the boundaries set forth in previous workshops, and fit within the proposed budgetary constraints. Other possible alternatives might also include more subtle variations of the ones presented (e.g. an increase in the number of selected extensive sites with a concomitant decrease in the number of systematic extensive sites). We have narrowed the alternatives to three for the purpose of clarity, and therefore do not present these more subtle variations. However, we anticipate that there will be modifications to the alternatives presented as the plans and associated budgets are more fully developed. Having three clear alternatives should serve as a starting point for further fine-tuning and facilitate that process of developing a final plan. A summary of the metrics associated with each sampling task are given in Table 3 and a summary of each design alternative is given in Table 4. The distribution of sampling sites within blocks in one representative region (Prince William Sound) is given for each of the alternatives in Figures 3, 4, and 5).

Alternative 1. Balanced between intensive and extensive sampling efforts.

The first alternative sampling design calls for a relatively balanced approach between detecting large-scale changes, detecting smaller spatial scale changes (and especially those anticipated to increase in spatial scale with time), and understanding mechanisms of change. As with all alternatives, we propose a combination of synoptic sampling (over the entire sampling area), intensive sampling at a relatively few sites, and extensive sampling of a subset of metrics at a larger number of sites. All of the sampling will be conducted within 9 blocks measuring approximately 10,000 m^2 in size. Three blocks will be in the Kodiak region, 3 in the Lower Cook Inlet / Kenai Peninsula region, and 3 in Prince William Sound region (Figure 2).

Synoptic sampling--
Synoptic sampling will consist of aerial digital video surveys of the all shorelines within each block. The aerial video surveys are designed to determine the geomorphology or shorelines within the region and to estimate large-scale spatial patterns of distribution and abundance for eelgrass, canopy forming kelps, and dominant benthic invertebrates and algae in the intertidal (e.g. brown algae and mussels). A portion of the shorelines has been surveyed in this manner over the past several years and the remaining shorelines within the region are to be surveyed at the start of the monitoring program and once every twelve years subsequently. We also anticipate that satellite imagery describing sea–surface temperature and other physical chemical factors (e.g. surface chlorophyll) will be obtained and utilized as part of the nearshore program. However, we consider this more appropriate for inclusion in other habitat (i.e. Alaska Coastal Current or shelf) monitoring programs.

Intensive sampling--
Intensive sampling is designed to detect large-scale changes and to determine causes for change. Intensive sampling will be conducted within one block within each of three regions: Kodiak, Lower Cook Inlet, and Prince William Sound (Figure 2). These blocks were selected for intensive sampling because there is a large amount of historical data for metrics of interest within these blocks (See Appendix A) and, they are close to research centers that can facilitate sampling. Sampling within each block will consist of:

1) An aerial shoreline video survey of each block conducted annually. The methods used will be the same as described above for synoptic surveys of the entire region except that only a sample of the coastline in each block will be surveyed. We anticipate that the sample will consist of approximately 20% of the total coastline within each block. The metrics obtained will include shoreline geomorphology as well as the relative abundance and spatial distribution of eelgrass, canopy forming kelps, mussels, and brown intertidal algae. Surveys are to be conducted in summer when eelgrass and kelp canopies are expected to be near seasonal maxima.

2) Selected intertidal plants and invertebrates sampled annually on sheltered rocky shores at five sites within each block. The five sites will be selected from those used for extensive sampling (see extensive sampling below and Figure 3). These are to be selected so they are within areas that are not likely to be unduly influenced by anthropogenic influences over the foreseeable future (i.e. away from boat harbors, population centers, or beaches known to remain heavily oiled). Also they will be selected based on the availability of historical data and on obtaining as large a geographic representation as possible (i.e. use of adjacent extensive sites should be avoided when possible). Sampling will be conducted within a 1-m wide transect run parallel to the shoreline centered at the zero tide level at each site (for larger benthic invertebrates including sea stars) or in five randomly placed 0.25-m^2 quadrats within the transect (for smaller benthic algae and smaller invertebrates). A preliminary list of algae and invertebrates to be counted within each sampling unit is given in Table 3. This is not intended to be an exhaustive list of species that might be found at a given site, but will focus on those that are likely to be encountered frequently based on prior survey data. The list is not intended to be static, but may change if, for example, formerly rare species become more evident over time. A final list will be developed based on preliminary sampling. Sampling is to include a digital photo of each quadrat, counts of animals within blocks (for plants and animals for which individuals are easily distinguished), and estimates of percent cover (for plants or animals for which individuals are not easily distinguished). Percent cover is to be determined using standard point-contact techniques or visual estimates. Mussels (*Mytilus trossulus*) and limpets (*Tectura persona*) (a maximum of 20 per quadrat) will be collected for determination of size distribution. The mussels will also be used to determine levels of contaminants (see extensive sampling below). Metrics to be obtained from this sampling effort will include algal diversity, invertebrate diversity, abundances of selected dominant taxa, size distributions of mussels and limpets, and the concentration of contaminants in mussels.
3) Infaunal invertebrates sampled annually at five sites within gravel / mixed-sand gravel habitats in each block. Sampling of infaunal invertebrates will be conducted at five gravel / mixed sand-gravel sites within each sampling block. These are to be are to be located at the first appropriate habitat directly adjacent to sheltered rocky sites. Gravel/sand will be dug from five randomly placed 0.25-m^2 quadrats within a 100-m transect at each site. Sampling will focus on clams as representative infaunal species. (Sorting and identification of a complete infaunal sample, including polychaete worms, small snails, and amphipods for example was considered too costly). The substrate will be sieved and all clams collected for future counting and identification. Size distribution and growth rate determinations will be made for littleneck clams (*Protothaca staminea*) using methods described by Paul and Feder (1973). Metrics to be obtained from this sampling effort will include abundances of selected clam species, size distributions of littleneck clams, and growth rates of littleneck clams.
4) Sampling of sea otter abundance annually via aerial surveys of each block. Sea otter abundance will be estimated within each block in the summer of each year using aerial survey methods described by Bodkin and Udevitz (1999). These methods have been used to conduct annual surveys to estimate the abundance of sea otters in Prince

William Sound since 1993 (Bodkin et al. 2002), and on a less frequent basis elsewhere in the GOA. The metric obtained will be numbers of sea otters per block.

5) Sampling of sea otter carcasses annually in the spring of each year. Sea otter skulls will be collected from beaches by censusing, on foot, all accessible beaches within each of the three blocks each Spring and collecting all available sea otter skulls. A tooth will be extracted from each skull and sectioned to determine the age of the sea otter (Bodkin et al. 1997). The data on the age distribution of dead sea otters will be used to develop age-specific survival estimates based on models (Monson et al. 2000, Bodkin et al. 2002).
6) Sampling of sea otter diets. The species composition and relative abundance of sea otter prey will be sampled annually using direct observation of sea otter feeding (Calkins 1978, Estes et al. 1982, Dean et. al 2002). These observations are intended to provide a means of indirectly assessing the composition and relative abundance of representative subtidal invertebrates that are otherwise difficult to assess.
7) Sampling of seabird abundance. Seabird abundance will be estimated via boat surveys twice annually (summer and winter) along shoreline transects using the methods of Irons et al. (2000). The focus will be on estimating the abundance of birds closely linked to the nearshore (especially black oystercatchers, harlequin ducks, and Barrow's goldeneye) and will therefore be restricted to areas close to shore. Surveys will be conducted in summer and winter so that abundance estimates can be obtained for birds with different seasonal patterns (e.g. harlequin ducks that are more abundant in winter and black oystercatchers that are more abundant in summer).
8) Sampling of oystercatcher diets. The species composition and relative abundance of prey of oystercatchers will be evaluated by sampling prey remains at oystercatcher nesting sites (Andres 1996).
9) Sampling of selected physical variables. Water temperature and density will be measured at two depths (surface and 18 m depths), at each of three selected sites (one per block). These are to be measured at relatively high frequency (every 10 minutes) on a year round basis using moored monitoring stations. These will produce more or less continuous records of temperature and salinity (based on density and temperature). Also, temperature will be measured continuously (or at approximately hourly intervals) at the zero tide level at each of the five intertidal sites per block using temperature-recording devices. Sediment samples will be obtained from gravel / sand-gravel site for determination of grain size distribution. It is also anticipated that records of wind velocity and direction, rainfall, and air temperature will be obtained from weather stations close to each site.

Extensive sampling--

Extensive sampling is designed to detect changes that may occur on a smaller spatial scale. Sampling will be conducted at both systematically placed sites (here termed systematic extensive sites) and at sites selected based on their proximity to sources of likely anthropogenic impacts, proximity to fish hatcheries, or proximity to known locations of subsistence use (here termed selected extensive sites). In this alternative, we will sample at ten systematically placed sites within each of the 9 blocks (90 sites in all) plus 18 selected extensive sites (Figure 3). (In the three blocks used for intensive sampling, five of the ten systematically selected extensive sites will be sampled as part of the intensive sampling). Sampling at each site will focus on estimating abundance of a suite of selected intertidal plants and animals (epifauna from sheltered rocky habitats and infauna from nearby gravel / mixed sand gravel habitats) at each site, and on concentrations of contaminants in mussels at each site. The metrics to be sampled will be a subset of those used in the intensive sampling program, and will serve as sensitive indicators of local environmental change (Table 4). Invertebrates and algae will be sampled once every other year at each site. Concentrations of contaminants in mussels will be measured at all extensive sites every four years, and at the 18 selected extensive sites and a subset of 9 systematic selected sites every other year. Specific sampling methods are:

1) Selected intertidal plants and invertebrates on sheltered rocky shores. The location of the ten systematically placed sites per block will be determined by dividing the shoreline within each block into 10 segments of approximately equal length. Sampling sites within each segment will be selected based on the availability of appropriate sheltered-rocky habitat and on the availability of historical data for metrics that are to be sampled at each site. The location of the 18 additional selected sites will be chosen based on their proximity to shorelines where localized anthropogenic impacts are expected, at sites utilized for subsistence harvest of shoreline animals, or near fish hatcheries. The final determination of these locations will be made at the start of the program, but it anticipated that sites will be located adjacent to population centers (e.g. Cordova, Valdez, Whittier, Seward, Homer, Seldovia, Kodiak) near Native Villages (e.g. Tatitlek, Chenega) and near salmon hatcheries (e.g. Sawmill Bay and Long Bay in Prince William Sound). Sampling at each site will be conducted within a 100-m long by 1-m wide transect run parallel to the shoreline and centered at the zero tide level at each site (for larger invertebrate species) or at five randomly placed 0.25-m^2 quadrats within each transect (for smaller invertebrates and algae). Sampling will consist of taking a digital photo of each quadrat, and then estimating the abundance of selected algae and invertebrates that are numerically dominant within these habitats. The metrics will include (at a minimum) mussel (*Mytilus trossulus*) density or cover, *Fucus garderi* cover, limpet (*Tectura persona* and *Lottia pelta*) density, sea star (*Dermasterias imbricata*, *Pynopodia helainthoides*, *Evasterias trochelli*, and *Pisaster ochraseus*) density, and *Nucella* spp. density. These are a subset of suite of species to be sampled at intensive sites. These species were selected because they are the numerically dominant species within this portion of the intertidal zone. Also, past analyses (Houghton et al. 1993, Highsmith et al. 1994, Jewett et al. 1995) demonstrated that these metrics provide sufficient statistical power to detect reasonable levels of change. A final list of species to be sampled will be selected based on preliminary sampling to determine the species that can be counted within each site by two persons in a single low-tide period (about three to four hours). Plants and animals for which individuals are easily distinguished will be counted. Percent cover will be estimated for species for which individuals are not easily distinguished. Percent cover is to be determined using standard point-contact techniques or visual estimates.
2) Infaunal invertebrates in gravel / mixed-sand gravel habitats. Sampling of infaunal invertebrates will be conducted at gravel / mixed sand-gravel sites within each

sampling block. These are to be are to be located at the first appropriate habitat directly adjacent to sheltered rocky sites. Gravel/sand will be dug from five randomly placed 0.25-m^2 quadrats within a 100-m transect at each site. Sampling will focus on littleneck clams (*Protothaca staminea*) as representative infaunal species. Sampling will be as described above for intensive sites. Metrics to be obtained from this sampling effort will include abundances of selected clam species.

3) <u>Determination of contaminant concentrations in mussels</u>. Five mussels (*Mytilus trossulus*) will be collected from the five quadrats at each of the sheltered rocky sites (10 systematic sites within each block plus 18 selected sites). The meat of the mussels will be removed, the samples from each site combined, and the composite sample analyzed to determine the concentration of contaminants. The chemical analyses will consist of a metals screen, an organic carbon screen, a fluorescent aromatic hydrocarbon screen, and mercury analyses. These analyses should detect any major trends for most of the contaminants of concern.

Sampling of contaminants in subsistence food--
Contaminants in mussels will be determined as part of the extensive sampling described above. In addition, we will measure contaminants within harbor seals as an indicator of potential contamination of subsistence foods. This will provide a more integrated examination of contaminants, and especially those that may enter the nearshore system via trophic pathways more linked to the Alaska Coastal Current and shelf habitats. Harbor seals feed on a diverse diet of nearshore fishes and serve as important indicators of contamination via this pathway. Harbor seals are utilized as an important subsistence food resource, and as such, serve as a potential source of contamination of local residents. Harbor seals are currently being sampled as part of an existing program conducted by the Harbor Seal Commission. We intend to utilize these samples and to provide funds to conduct contaminant analyses of tissues of ten animals from each of three regions each year. The chemical analyses will consist of a metals screen, an organic carbon screen, a fluorescent aromatic hydrocarbon screen, and mercury analyses.

Process studies--
We anticipate that process studies will be conducted to further investigate patterns of interest and concern that become apparent as part of the sampling described above. No specific studies are identified at this time, but a portion of the budget will be set aside to fund future process studies. We also anticipate that funds set aside for process studies may be available to pursue adaptation of emerging technologies to improve sampling efficiency and pursue inclusion of new metrics that would advance our understanding of ecosystem processes.

Alternative 2. Sampling weighted toward extensive sampling.

The second alternative sampling design is weighted toward extensive sampling aimed at detecting smaller spatial scale changes (and especially those anticipated to increase in spatial scale with time). As with Alternative 1, sampling will be conducted within 9 blocks between Kodiak and Cordova). The primary differences between this alternative and Alternative 1 are:

1) An increase in the number of extensive sites
2) An increase in the frequency of sampling for contaminants at extensive sites, and
3) A decrease in the frequency of sampling at intensive sites

Specifics of the sampling design are:

Synoptic sampling--
Synoptic sampling will be the same as described for Alternative 1.

Intensive sampling--
Intensive sampling will be similar to that described in Alternative 1 except that sampling will be done at a frequency of once every other year.

Extensive sampling--
Extensive sampling will be similar to that described in Alternative 1 except

1) The number of systematically placed extensive sites will be increased from 10 to 15 per block (an increase in the total number of systematic extensive sites from 90 to 135, Figure 4).
2) An increase in the frequency of sampling at 18 selected extensive sites from once every other year to every year.
3) An increase in the frequency of contaminant sampling at systematic extensive sites from once every fourth year to once every other year.
4) An increase in the frequency of contaminant sampling at 18 selected extensive sites plus 9 systematic intensive sites from once every other year to once per year.

Sampling of contaminants in subsistence food--
This will be the same as described for Alternative 1.

Process studies--
This will be the same as described for Alternative 1.

Alternative 3. Sampling weighted toward intensive sampling.

The third alternative sampling design is weighted toward intensive sampling aimed at detecting larger spatial scale changes and determining mechanisms of change. The primary differences between this alternative and Alternative 1 are:

1) An increase in effort afforded to sampling of physical / chemical parameters at intensive sampling sites
2) A decrease in the number of systematic extensive sites sampled
3) A decrease in the frequency of sampling for contaminants at selected extensive sites

Specifics of the sampling design are:

Synoptic sampling--
This will be the same as described for Alternative 1.

Intensive sampling--
This will be the same as for Alternative 1 except that the number of physical / chemical parameters measured within each of the three intensive sampling blocks will be increased. Added metrics are pH and dissolved oxygen.

Extensive sampling--
This will be similar to that described in Alternative 1 except

1) The number of systematically placed extensive sites will be decreased from 10 to 5 per block (a decrease in the total number of systematic extensive sites from 90 to 45, Figure 5).
2) The frequency of contaminant sampling at 18 selected extensive sites plus 9 systematic intensive sites intensive will be decreased from once every other year to once every fourth year.

Sampling of contaminants in subsistence food--
This will be the same as described for Alternative 1.

Process studies--
This will be the same as described for Alternative 1.

COST ESTIMATES

Cost estimates for alternative sampling designs are summarized in Table 5, with details given in Appendix B. All costs are given in 2004 dollars, with no escalators for inflation. Also, costs are average annual estimates. It is anticipated that the spending will not be equally distributed between years. In some years, (e.g. in the initial year of sampling when the purchase of physical instruments is required and in years when an aerial census of the shoreline in all 9 blocks is conducted) costs will be higher than average. In other years (e.g. when aerial surveys are limited to three blocks or when only intensive sites are sampled) costs will be lower than average. The alternatives were designed so that each could be accomplished within a budgetary limit of approximately $900,000 averaged annually. The cost estimates do not take into account possible matching funds obtained from other funding agencies. However, because of the uncertainty of a long-term commitment from other funding sources, it is our contention that sufficient EVOS funds should be set aside to carry out this “core” plan and that matching funds should be used to supplement this plan. The designs were developed through an iterative process in which basic elements of each alternative were laid out, labor and associated costs were estimated for various elements, and then the elements were modified (e.g. by changing frequency of sampling or number of sampling sites) to fit within the budgetary constraints.

Personnel costs were estimated to be the same for each alternative, and make up slightly more than half of the total costs for each. We estimated that the tasks outlined in each alternative could be completed with four full time staff, three half-time staff, and seasonal staff equivalent to 1 full time position. In developing cost estimates for personnel, we used approximate salary equivalents for federal agency staff of comparable experience and qualifications. We also assumed a benefit rate of 50% of salary for full time and half time employees and 20% of salary for seasonal employees.

In estimating personnel requirements and contract vessel requirements for various design elements, we assumed that a team of six persons could complete most of the required sampling at an intensive site in two days. Evaluation of sea otter diets would require an additional 2 days per block. Additional sampling effort, using an aircraft or separate vessel, would be required for sea otter abundance estimates, sea otter carcass surveys, and winter seabird surveys. We also estimated that a team of three persons could complete sampling at one extensive site per day. We assumed that intensive and extensive intertidal sampling would be conducted during low tide series each summer. Tides are generally low enough to complete sampling during a two-week period once each month. Thus, multiple cruises of a maximum of two-weeks in duration would be required to complete sampling each year. We also assumed that one mobilization day and one demobilization day would be required for each cruise. In estimating vessel charter costs, we assumed a charter rate of $1,200 per day for a vessel capable of carrying six scientific personnel**.**

We fully anticipate that the proposed monitoring plans will be modified to some extent. We caution that there are some elements of the proposed alternatives that, if modified, could have a disproportionate impact on the budgets given. Of special concern are alterations in elements of intertidal invertebrate and algal sampling at a given site that would require a change in staffing assumptions, or a change in the number of days required to complete the sampling at a site. Any increase in the number of field crew to more than six would require a larger vessel and would substantially increase charter costs. Similarly, a reduction in field crews to less than six would have no impact on charter costs and relatively little impact on the overall budget. Also, small incremental increases in tasks conducted by intertidal sampling crews could cause a sizable increase in the budgets. Sampling windows are tide-restricted and extensive travel time is required to get from one site to another. Therefore, even small increases in tasks may result in a doubling of the number of days required to complete sampling at each site.

ANALYSIS OF MONITORING DATA

Analyses to Detect Change

It is important in developing a monitoring plan to determine how the data generated might be analyzed to detect change and how results of these analyses might be interpreted. The analysis for all of the sampling elements described (synoptic, intensive, and extensive) can be thought of in terms of a nested, two-way analysis of variance, with time and location as the primary factors. The location factor consists of multiple regions

(Kodiak, Cook Inlet / Kenai Peninsula, and Prince William Sound), and in some cases with replicate blocks within region, and replicate sites within blocks. A nested analysis of variance would examine the extent of variation due to location (region and block within region), time, and the interaction between these factors. GOA-wide changes (e.g. changes that might be caused by an El Nino, PDO cycle, or global climate change) would likely result in significant variation with time, but no significant interaction between location and time. That is, while the absolute values of a measured metric would increase or decrease with time, the relative differences between locations would likely remain constant. Spatial differences that are constant over time (e.g. variation among locations due to geomorphologic differences or variation due to persistent point source release of contaminants) would result in a significant effect of location, but no time by location effect. That is, the value of a metric would vary with location, but the relative difference between locations would be constant over time. Finally, those changes resulting from impacts of either increasing or diminishing spatial extent over time (e.g. impacts of invasive species or large oil spills) would result in significant time by location interaction. That is, the relative differences between sites would change with time. In the real world, it is likely that changes will result from multiple causes. Time effects (due to things like El Nino events) will likely overlay significant differences among sites (due to natural variation in geomorphology for example). The key to detecting changes of increasing or decreasing spatial extent (contamination as the result of continued shoreline development or a large oil spill) will be to examine the interaction between time and space. For impacts of increasing spatial extent, the interaction term would be significant, and the extent of difference between sites would increase with time. For impacts of decreasing spatial extent, the interaction term would be significant, and the extent of difference between sites would diminish with time.

For some metrics that will be examined (e.g. the concentration of contaminants) there will be no replication at the site level and it will be impossible to test for smaller spatial-scale effects (i.e. differences between sites) using the above analysis. In these cases, potential outliers (e.g. sites with abnormally high concentrations of a given contaminant) could be detected by comparing the value for the metric at each site to the mean of all sites within the block. By plotting the means (with confidence intervals) and individual site values over multiple sampling periods, one should be able to determine if sites are persistent outliers.

The above examples rely on some form of statistical test to indicate change. However, it should be stressed that the monitoring program as designed is unlikely to provide the strong statistical power. That is, it is unlikely that we will be able to detect changes with a high degree of statistical confidence unless they are very large. Also, some changes clearly not of statistical significance (e.g. the occurrence of a small patch of a highly invasive exotic alga) may be of grave concern and require action. Furthermore, not all changes that are statistically significant will be biologically or ecologically significant. Therefore, it is important that the monitoring program not rely wholly on statistical criteria to detect changes or determine their magnitude or importance. We suggest that relatively lax statistical criteria for detecting change be used as triggers for further hypotheses driven process studies, and that statistical criteria should not be the sole means of assessing change.

It is anticipated that the power associated with a selected sampling design will be evaluated after a first year of preliminary sampling, and at regular intervals thereafter. This will allow designs to be modified accordingly and should enhance our ability to detect change.

Analyses to assign cause

Possible causes for observed environmental changes will be examined using two primary analytical methods. First, the spatial and temporal patterns of change, and the scales over which they occur, will be examined using the analytical tools described above. The temporal and spatial scales of change should help to suggest possible causes. For example, a change that occurs over decades and is roughly of equal magnitude at all sites (a significant time effect, but no location or time by location effect) would suggest that the change was due to some large scale event (e.g. global climate change or PDO), rather than a more localized one (release of a toxicant from boat harbors). Second, we will rely on correlative evidence to suggest cause. For example, a correlation between a block-wide reduction in oystercatchers and an increase in the concentration of contaminants in mussels within the block might suggest a causal relationship.

It should be stressed that it is unlikely that we will be able to assign cause with a high degree of confidence based on the data generated in the proposed monitoring plans. Assigning cause will rely heavily on further process studies that are designed to test hypotheses regarding specific cause and effect relationships. These process studies can not be designed or carried out until there is sufficient observational or correlative evidence produced to detect a change and suggest a possible cause.

MANAGEMENT STRUCTURE

There are several management structures that could be used to carry out the alternative sampling designs presented. These can range from very diffuse (with separate contracts issued for each task in each region) to very centralized (with all tasks being conducted by a single contractor or Trustee employee and his or her staff). In developing the plan and associated cost estimates, we assumed that the work would be carried out by a combination of management forms. We assumed that there would be a full time staff of four persons (a principal investigator, an analyst, and two technicians) that would be housed in a single location. This staff would manage the project, organize and oversee sampling, serve as a central repository of all data, coordinate all data analysis, and be responsible for reporting the results. We also assumed that the centralized staff would be complemented by three half-time investigators, one in each of three regional centers (e.g. Kodiak, Homer or Seward, and Cordova). These regional coordinators would be responsible for all local coordination and management of tasks that require frequent local attention (e.g. servicing of physical instrumentation) and would be responsible for the all or part of the initial data preparation and analyses for data gathered within that region.

The regional staff would also be responsible for coordination of seasonal or other part-time assistance as related to sampling within that region. We assume that many (if not all) of the seasonal employees would be residents of the regions. It was anticipated that some services (e.g. chemical analyses for contaminants and vessel charter) would need to be contracted to outside sources (i.e. local universities, government agencies, or private contractors). Finally we assumed that process studies could be carried out under separate contract to persons with specific areas of expertise. These persons could be from the regional facilities or elsewhere. We feel that the centralized staff is important in achieving consistency and continuity in the program while the presence of regional collaborators provides for local expertise and a higher degree of community involvement.

COMMUNITY INVOLVEMENT

It is anticipated that each of the alternative plans presented will have a strong community involvement component. Regional coordinators in Kodiak, Homer or Seward, and Cordova will be the primary liaisons between the scientific staff and community members. Residents of the GOA communities will be enlisted and trained as seasonal employees to assist in sampling efforts, and especially the sampling of sea otter carcasses; the deployment and servicing of physical instrumentation; and sampling of intertidal invertebrates and algae. Community members will also be directly involved in the program as suppliers of charter vessels and aircraft.

ACKNOWLEDGEMENTS

This project benefited from the contributions of Dede Bohn, Heather Coletti, George Esslinger, Carol Gorbics, Carrie Gray-Wolf and Kim Kloecker. The Library staff at ARLIS was always helpful. We also acknowledge the many individuals that provided important and constructive suggestions and thoughts that resulted in the document in hand.

LITERATURE CITED

Andres, B.A. 1996. Consequences of the Exxon Valdez oil spill on black oystercatchers inhabiting Prince William Sound. Ph. D. Thesis. Ohio State University. Columbus. 98 pp.

Bodkin, J.L., and M.S. Udevitz. 1994. An intersection model for estimating sea otter mortality along the Kenai Peninsula. In: Loughlin T (ed) Marine mammals and the *Exxon Valdez*. Academic Press, San Diego, p 81-95

Bodkin J.L., J.A. Ames, R.J. Jameson, A.M .Johnson , and G.M. Matson. 1997. Estimating age of sea otters with cementum layers in the first premolar. J Wildl Manag 61:967-

Bodkin, J.L., B.E. Ballachey, T.A. Dean, A.K. Fukuyama, S.C. Jewett, L.L. McDonald, D.H. Monson, C.E. O'Clair, and G.R. VanBlaricom. 2002. Sea otter population status and the process of recovery following the 1989 *Exxon Valdez* oil spill. Mar Ecol Prog Ser. 241:237-253.

Calkins, D.G. 1978. Feeding behavior and major prey species of the sea otter, *Enhydra lutris*, in Montague Strait, Prince William Sound, Alaska. US Fish Bull 76:125-131

Dean, T.A., J.L. Bodkin, A. Fukuyama, S.C. Jewett, D.H. Monson, C.E. O'Clair, G.R. VanBlaricom. 2002. Food limitation and the recovery of sea otters following the *Exxon Valdez* oil spill. Marine Ecology Progress Series 241;255-270

Estes, J.A., R.J. Jameson, and A.M. Johnson. 1981. Food selection and some foraging tactics of sea otters. In: Chapman JA, Pursley D (eds) The worldwide furbearer conference proceedings. Worldwide Furbearer Conference. Frostburg, Maryland, p 606

Ford, R.G., M.L. Bonnell, D.H. Varoujean, G.W. Page, H.R. Carter, B.E. Sharp, D. Heinemann, and J.L. Casey. 1996. Total direct mortality of seabirds from the Exxon Valdez oil spill. Pp. 684-711 In: S.D. Rice, R.B. Spies, D.A. Wolfe, and B.A.Wright, editors. American Fisheries Society Symposium.18.

Golet, H.G., P.E. Seizer, A.D. McGuire, D.D. Roby, J.B. Fischer, K.J. Kuletz. D.B. Irons, T. A. Dean, S.C. Jewett, and S.H. Newman. 2002. Long-term direct and indirect effects of the *Exxon Valdez* oil spill on pigeon guillemots in Prince William Sound, Alaska. Marine Ecology Progress Series 241:287-304.

Harper, J.R., D.E. Howes, and P.D. Reimer. 1991. Shore-zone mapping system for use in sensitivity mapping and shoreline countermeasures. Pgs 509-523. In Proc. 14th arctic marine oil spill program technical seminar. Environment Canada, Ottawa

Highsmith R.C., M.S. Stekoll, W.E. Barber, L.L. McDonald, D. Strickland, W.P. Erickson. 1994. Comprehensive assessment of coastal habitat. *Exxon Valdez* oil spill state/federal natural resource damage assessment. Final report of coastal habitat study 1A. Exxon Valdez Oil Spill Trustee Council, Anchorage, AK

Houghton, J. P., D. C. Lees, T. A. Ebert, and W.B. Driskell. 1993. Evaluation of the condition of Prince William Sound shorelines following the Exxon Valdez oil spill and subsequent shoreline treatment. NOAA Technical Memorandum NOS ORCA 67. Bethesda. 210 pp.

Irons, D.B., S.J. Kendall, W.P. Erickson, and L.L. McDonald. 2000. Nine years after the Exxon Valdez oil spill: effects on marine bird populations in Prince William sound, Alaska. Condor 102:723-737.

Jewett, S.C., T.A. Dean, R.O. Smith, L.J. Haldorson, D. Laur, M. Stekoll, L. McDonald. 1995. The effects of the *Exxon Valdez* oil spill on shallow subtidal communities in Prince William Sound, Alaska: 1989-1993. Report to the *Exxon Valdez* Trustee Council. Anchorage.

Madl, P. and M. Yip. 2003. Literature Review of *Caulerpa taxifolia*. Contribution of the 31st BUFUS newsletter.

Monson D.H., D.F. Doak, B.E.Ballachey, A. Johnson, and J.L.Bodkin. 2000. Long-term impacts of the *Exxon Valdez* oil spill on sea otters, assessed through age dependent mortality patterns. Proc Nat Acad Sci 97:6562-6567

Paul, A.J. & H.M. Feder. 1973. Growth, recruitment, and distribution of the littleneck clam, *Protothaca staminea*, in Galena Bay, Prince William Sound, Alaska. Fishery Bulletin 71:665-677.

Schoch, K., G. Eckert, and T. Dean. 2002. Long Term Monitoring in the Nearshore: Designing Studies to Detect Change and Assess Cause. Draft Report to the Exxon Valdez Oil Spill Trustee Council, Anchorage.

Table 1. 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 **Natural** Climate	Physical Effect	Biological Effect	Temporal/spatial scale[1]
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 habitat destruction	Years/Area or Location
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 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 – Sub areas on the order of Western Prince William Sound 50-100 km
Site - E.g. Herring Bay, Orca Inlet, Jakalof Bay,,Etc.(5-10 km)
Spot – 10s to 100s of m

Table 2. 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. Priorities, as derived from prior workshops, are also given (1 = highest).

Entire Region

Metric	**Sites per region**	**Frequency**	**Priority**	**Comments**
Synoptic ocean color, temperature, altimetry	Not applicable	Continuous	1	Develop algorithms for nearshore corrections
Habitat maps	Not applicable	Once / decade?	1	
Human Use maps	Not applicable	Once per decade?	2	
Special Use maps (e.g. fish take)	Not applicable	Annual	2	
Event documentation (E.G. earthquake activity)	Not applicable	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	Profiles or near surface and near bottom
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	Profiles or near surface and near bottom
Nutrients				
Nitrate, Nitrite, Ammonium, Phosphate	1-3	C	2	“
POC	1-3	Monthly	2	“
PON	1-3	Monthly	2	“
DOM	1-3	Monthly	2	“
Energy				
Wave energy	1-3	C	2	“
Current speed/direction	1-3	C	2	“
Habitat Characteristics				
Kelp and eelgrass mapping	All	Once / yr.	1	

Biological				
Abundance - sea otters	Entire area	Yearly	1	Aerial surveys
Mortality rate – sea otters	Entire area	Yearly	2	Based on recovered skulls/carcasses
Diet – sea otters	3-4	Yearly	2	
Disease – sea otters	All	Yearly	2	Based on recovered carcasses
Contaminant levels – sea otters (POPs, PAHs)	All	Yearly	2	Possible archival of samples
Abundance – selected birds (Oyster catchers, goldeneye, scooters, harlequin ducks)	All	Yearly	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 substrates		Once / yr		
Abundance - all macro inverts and algae	All	“	1	
Distribution - selected inverts and algae (Fucus, mussels, kelp)	All	“	1	
Temperature	All	C	2	High and low intertidal;
Size distribution – selected inverts (mussels, stars..)	All	“	2	
Recruitment – selected inverts and algae	All	“	2	
Growth – selected inverts and algae	All	“	2	
Condition – selected inverts/algae	All	“	3	
Body burdens of metals, PAHs, and other contaminants in mussels	All	Rotating subset once per year	2	Possible archival of samples
Intertidal – soft substrate				
Abundance – Protothaca and selected clams., crabs	All	“	2	
Body burdens of metals, PAHs, and other contaminants in clams (Protothaca)	All	Rotating subset once per year	2	Possible archival of samples

Extensively 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	2	
Slope	All	Once/5-10 yr	2	
Exposure	All	Once/5 10 yr	2	

Biological				
Body burden of contaminants in selected fish (e.g. greenling)	All	Once / yr	2	Possible archival of samples
Kelp and eelgrass mapping	All	Once / yr.	2	
Intertidal – hard substrates		Once / yr		
Abundance - Selected macro inverts and algae (Fucus, mussels, limpets, stars)	All	“	2	
Distribution - selected inverts and algae (Fucus, mussels...)	All	“	2	
Size distribution – selected inverts (mussels, stars…)	All	“	2	
Body burdens of metals, PAHs, and other contaminants in mussels	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

Table 3. List of metrics to be sampled for each task. Lists of intertidal plant and invertebrate species to be counted are tentative and will be finalized after an initial sampling.

Task	Metrics associated with each task
Aerial shoreline surveys	Shoreline geomorphologic type
	Relative slope and exposure
	Eelgrass canopy cover
	Kelp canopy cover
	Fucus (or brown algae) cover
	Mussel bed cover
Algae – sheltered rocky	Algal diversity
	Invertebrate diversity
	*Fucus garderi cover**
	Halosaccion glandiforme cover
	Neorhodomela larix cover
	Neorhodomela oregona cover
	Palmaria spp. cover
	Rhodoglossum – Matocarpus cover
	Ulva – Ulvaria sp. cover *
	Filamentous brown algae cover*
	Filamentous green algae cover*
Invertebrates – sheltered rocky	Invertebrate diversity
	Balanus / Semibalalnus spp. cover
	Cthamalus spp. cover
	Littorina scutulata density
	Littorina sitkana density
	Mytilus trossulus density*
	Tectura person density*
	Lottia pelta density*
	Searlesia dira density
	Nucella lamellosa density
	*Pcynopodia helianthoides density**
	Dermasterias imbricata density*
	Evasterias trochelli density*
	Pisaster ochraceus density*
	Tectura persona size distribution
	Mytilus trossulus size distribution

Table 3. Continued

Tasks	**Metrics associated with each task**
Invertebrates – gravel / mixed sand gravel	*Protothaca staminea* density*
	Protothaca staminea size distribution
	Protothaca staminea growth rate
	Macoma spp. density
	Saxidomus gigantea density
	Grain size distribution
Sea otter abundance	Number of sea otters per block
Sea otter carcass survey	Sea otter age at death
	Sea otter survival
Seabird abundance	Loon abundance
	Cormorant abundance
	Harlequin duck abundance
	Scoter abundance
	Barrow's goldeneye abundance
	Common goldeneye abundance
	Merganser abundance
	Black oystercatcher abundance
	Mew gull abundance
	Glaucous-winged gull abundance
	Black-legged kittiwake abundance
	Tern abundance
	Pigeon guillemot abundance
	Murrelet abundance
Sea otter diet	Dive success rate
	Percent clams in diet
	Percent crabs in diet
	Percent sea urchins in diet
	Percent mussels in diet
	Energy of prey consumed
Oystercatcher diet	Percent mussels in diet
	Percent limpets in diet
	Percent snails in diet
	Percent chitons in diet
CTD	Temperature (2 depths)
	Density (2 depths)
Temperature	Temperature (air/water at 0 m depth)
PH, DO	PH and dissolved oxygen (2 depths)

Table 3. Continued

Contaminants in mussels	Metal screen (concentration of approximately 12 metals)
	Fluorescent hydrocarbon concentration
	Organics screen (concentration of approximately 10 organochlorides and PCBs)
	Mercury concentration
Contaminants in harbor seal tissue	Metal screen (concentration of approximately 12 metals)
	Fluorescent hydrocarbon concentration
	Organics screen (concentration of approximately 10 organochlorides and PCBs)
	Mercury concentration

* indicates the species included in sampling at extensive sites.

Table 4. Summary of sampling design alternatives indicating the number of sampling locations and frequency of sampling for each task. Metrics associated with each task are given in Table 3.

Tasks		**Alternative 1**		**Alternative 2**		**Alternative 3**	
		Number of sampling locations	Frequency	Number of sampling locations	Frequency	Number of sampling locations	Frequency
Synoptic	Aerial shoreline surveys	9 blocks	1 per 12 yr.	9 blocks	1 per 12 yr.	9 blocks	1 per 12 yr.
Intensive	Aerial shoreline survey	3 blocks	1 per yr.	3 blocks	1 per 2 yr.	3 blocks	1 per yr.
	Invertebrate and algae	3 blocks 5 sites per block	1 per yr.	3 blocks 5 sites per block	1 per 2 yr.	3 blocks 5 sites per block	1 per yr.
	Sea otter Abundance	3 blocks	1 per yr.	3 blocks	1 per 2 yr.	3 blocks	1 per yr.
	Sea otter diet	3 blocks	1 per yr.	3 blocks	1 per 2 yr.	3 blocks	1 per yr.
	Se otter survival	3 blocks	1 per yr.	3 blocks	1 per 2 yr.	3 blocks	1 per yr.
	Seabird abundance	3 blocks	1 per yr.	3 blocks	1 per 2 yr.	3 blocks	1 per yr.
	Oystercatcher diet	3 blocks	1 per yr.	3 blocks	1 per 2 yr.	3 blocks	1 per yr.
	Temperature	3 blocks 5 sites per block	Year round	3 blocks 5 sites per block	Year round	3 blocks 5 sites per block	Year round
	CTD	3 blocks 1 site per block	Year round	3 blocks 1 site per block	Year round	3 blocks 1 site per block	Year round
	PH, DO	None		None		3 blocks	Year round

						1 site per block	
Extensive	Invertebrates and algae	9 blocks 10 systematic sites per block[1]	1 per 2 yr.	9 blocks 15 systematic sites per block[1]	1 per 2 yr.	9 blocks 5 systematic sites per block[1]	1 per 2 yr.
		9 blocks 18 selected sites per 9 blocks	1 per yr.	9 blocks 18 selected sites per 9 blocks	1 per yr.	9 blocks 18 selected sites per 9 blocks	1 per 2 yr.
	Contaminants in mussels	9 blocks 10 systematic sites per block[1]	1 per 4 yr.	9 blocks 15 systematic sites per block[1]	1 per 2 yr.	9 blocks 5 systematic sites per block[1]	1 per 4 yr.
		9 blocks 18 selected sites per 9 blocks	1 per 2 yr.	9 blocks 18 selected sites per 9 blocks	1 per yr.	9 blocks 18 selected sites per 9 blocks	1 per 4 yr.
		3 blocks 3 sites per block[2]	1 per 2 yr.	3 blocks 3 sites per block[2]	1 per yr.		
Other	Contaminants in harbor seals	3 blocks 10 animals per block	1 per yr.	3 blocks 10 animals per block	1 per yr.	3 blocks 10 animals per block	1 per yr.

[1] Of the 90 total sites, 15 (five in each of three blocks) are the same sites where intensive sampling is conducted.
[2] These sites are a subset of the five intensive sites per each of three blocks.

Table 5. Cost summaries for each Alternative sampling design proposed. Budget details are given in Appendix B.

Cost Category	Alternative 1	Alternative 2	Alternative 3
Personnel	468,000	468,000	468,000
Contract			
Vessel charter	138,600	112,800	145,200
Aircraft charter	33,000	16,500	33,000
Shoreline aerial survey	60,000	45,000	60,000
Chemical analyses	68,678	114,960	45,536
Travel	17,500	20,500	17,500
Equipment	18,200	18,200	32,000
Overhead	67,195	66,347	66.647
Set aside for process studies	30,000	30,000	30,000
Total	$901,173	$892,307	$897,883

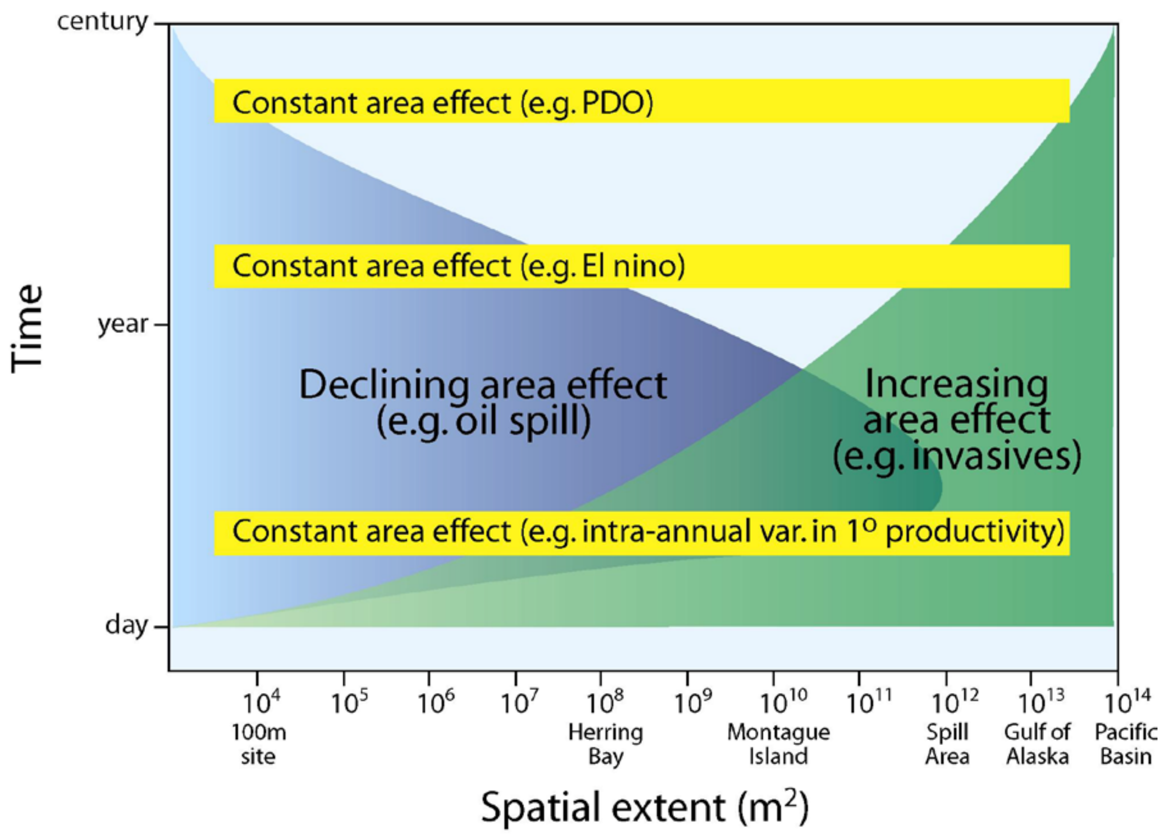


Figure 1. Representation of the change of spatial extent of impact over time for different types of impacts that may occur within the nearshore zone.
Location names on the x axis are representative of the given spatial scales and are given for perspective. Yellow shaded horizontal bars indicate impacts that may vary with respect to the spatial or temporal extent, but whose spatial extent of impact remains relatively constant over time. For example, PDO cycles have impacts that occur over scales of decades and extend over the entire GOA throughout that period. The blue shaded area indicates impacts of declining spatial extent over time. For example, the spatial extent of impacts from a major oil spill may increase rapidly over the first few days or weeks, but then declines with time. The green shaded area indicates impacts that increase in spatial extent over time. An example might be impacts from an invasive exotic species that starts as a small patch in a bay and then expands rapidly over time, eventually expanding throughout the Pacific Basin. The proposed nearshore monitoring program focuses on detecting changes that occur on temporal scales greater than one year and on spatial scales greater than about 10^8 m^2. Of special concern is the early detection of impacts that increase in spatial extent over time.

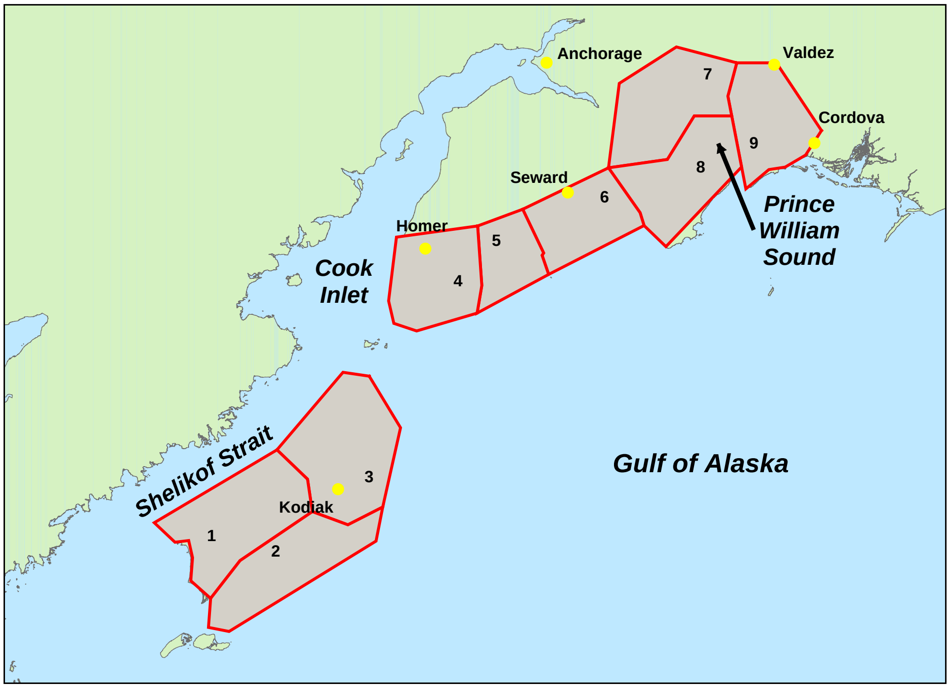


Figure 2. The proposed sampling areas to be used in the nearshore monitoring program are indicated by the blocks outlined in red. Blocks 3, 4, and 8 are designated for intensive sampling.

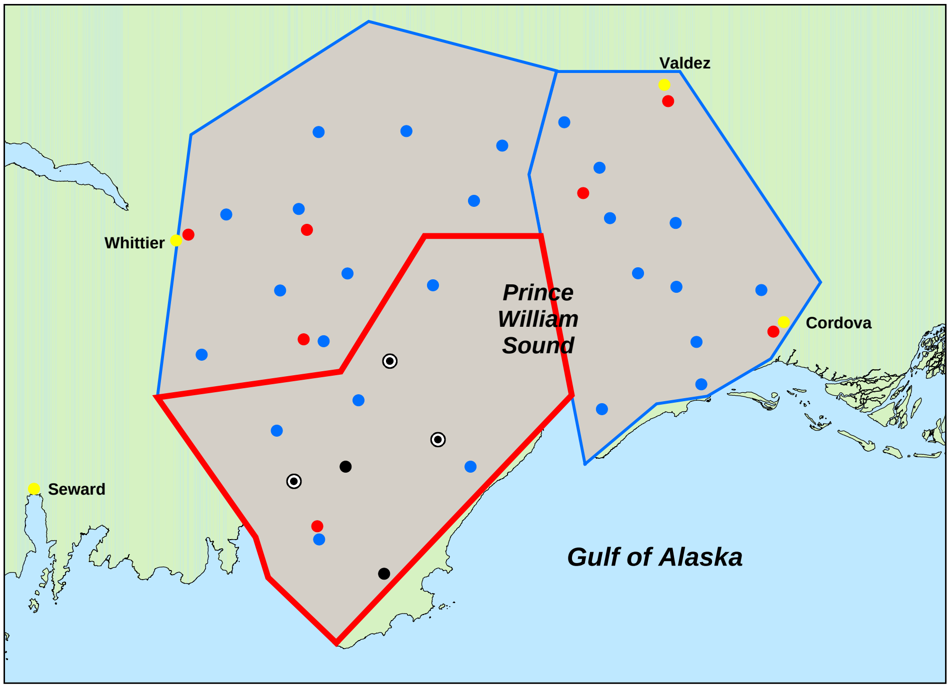


Figure 3. Map showing the number and approximate distribution of sampling locations for different types of sampling as prescribed in Alternative 1.
The Prince William Sound region is given as representative of the design used in all regions. The block outlined in red is designated for intensive sampling. Black dots are intensive sampling sites where invertebrates, algae, and contaminants are to be sampled. Those with white borders are intensive sampling sites where contaminants are to be sampled more frequently (every other year). Blue dots are systematic extensive sites and red dots are selected extensive sites placed near towns, villages, and fish hatcheries.

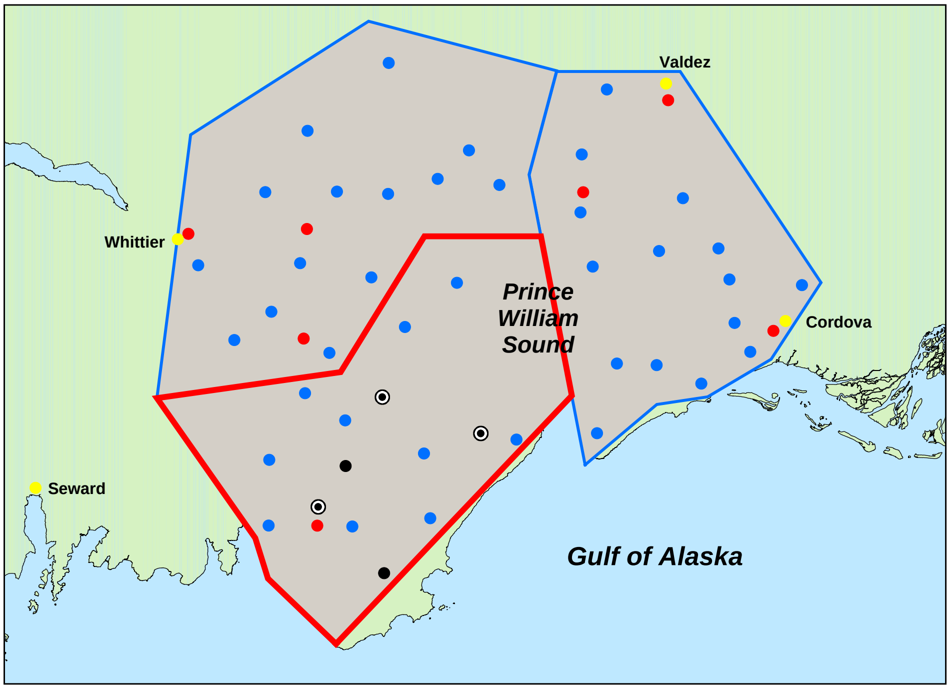


Figure 4. Map showing the number and approximate distribution of sampling locations for different types of sampling as prescribed in Alternative 2.
The Prince William Sound region is given as representative of the design used in all regions. The block outlined in red is designated for intensive sampling. Black dots are intensive sampling sites where invertebrates, algae, and contaminants are to be sampled. Those with white borders are intensive sampling sites where contaminants are to be sampled more frequently (every year). Blue dots are systematic extensive sites and red dots are selected extensive sites placed near towns, villages, and fish hatcheries.

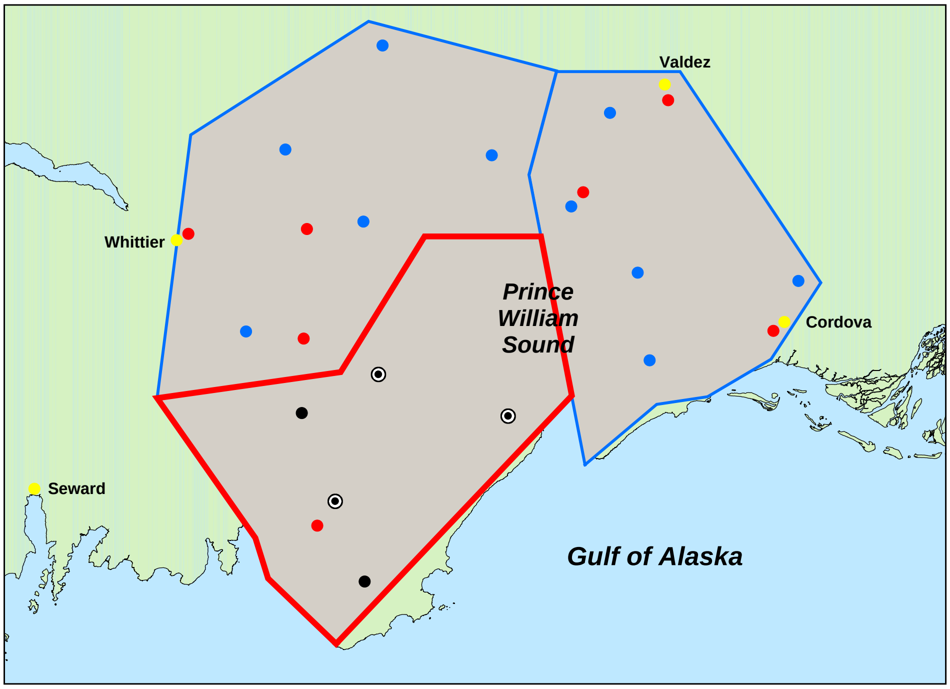


Figure 5. Map showing the number and approximate distribution of sampling locations for different types of sampling as prescribed in Alternative 3.
The Prince William Sound region is given as representative of the design used in all regions.   The block outlined in red is designated for intensive sampling. Black dots are intensive sampling sites where invertebrates, algae, and contaminants are to be sampled. Blue dots are systematic extensive sites and red dots are selected extensive sites placed near towns, villages, and fish hatcheries.

APPENDIX A. Geographical Information System database of the availability of historical data in the nearshore zone of the Gulf of Alaska

<u>Study History</u>: This project was initiated in December of 2002 with approval of funding by the *Exxon Valdez* Oil Spill (EVOS) Trustee Council. Early in 2003 we hired staff and began research and compilation of references to be included into a historic metadata base. The reference collection would include prior and current studies of a select assemblage of marine taxa, including alga, invertebrates, fishes, birds, and mammals that occupy nearshore habitats of the Gulf of Alaska. Concurrently we implemented a process to provide input into the selection of resources (biological taxa and physical attributes) and metrics to be included in our metadata. By 15 September of 2003 we concluded compilation of references and began finalizing inclusion of references in hand into the data set and began developing a GIS (ArcView themes) dataset that would eventually allow geographic representation of the metadata. Concurrently with the development of the metadata, we began conceptualizing and developing sampling alternatives for the nearshore habitats in the Gulf of Alaska for consideration of inclusion within the GEM program.

<u>Abstract</u> We have compiled a metadata base that includes >13,000 entries representing one or more nearshore resources (from physical attributes such as water and air, to birds and mammals). Each entry is viewable in three formats, 1) a geospatial explicit format (ArcView 3.3), 2) a spreadsheet format (Excel 2002 and within ArcView, and 3) A Procite database of references included in 1 and 2 above. The metadata base includes more than 1,100 independent references dating from 1896 to 2003 that are sorted into one or more of 15 ArcView themes, with associated areas of inference that can be sorted and displayed through any one of up to 24 fields that include location, author, metric, year, taxa, and method. The hierarchical GIS data base contains the following layers: 1) A base map of the GOA, 2) 15 files (ArcView themes) with resource specific references (e.g. algae, invertebrates, fishes, seabirds, and sea otters), and 3) buffer files for each resource that provides spatial reference to the area of inference for each reference. Attribute data (location, taxa, metrics, methods…) for each reference are accessible through the ArcView tables and the Excel spreadsheet. All references included in the metadata base, plus references such as review articles without geo-spatial reference can also be accessed through a Procite database. The metadata set and the ArcView themes will aid the EVOS Trustee Council members with their decision-making regarding the long-term monitoring and restoration plans for nearshore environments in the Gulf of Alaska. The metadata base and the ArcView themes will allow informed decisions regarding selection of species, methods, and locations for inclusion into the nearshore component of the EVOS GEM program. This component of Project 03687 provides documentation of the process and method used to create the metadata base, and provides instruction for accessing and using the databases.

Introduction

During 2002, a series of workshops were convened to help develop a conceptual model for monitoring in the nearshore (Project 02395) aimed principally at detecting and understanding change. As part of the development process, it was recognized that changes in nearshore communities are likely to occur and to be attributable to a number of different agents (e.g. global climate changes, shoreline development and associated inputs of pollutants). It was also recognized that changes are likely to occur over varying temporal and spatial scales. For example, global climate change may result in a gradual change in the nearshore community that occurs over decades and has impacts over the entire Gulf of Alaska (GOA), and beyond. On the other hand, impacts from shoreline development will likely be more episodic and more local. Thus, one challenge of designing a monitoring program is to detect changes occurring over widely varying scales of space and time. In response to this challenge, the conceptual design for monitoring in the nearshore (Schoch et al. 2002) called for a multi-pronged approach consisting of the following:

1) Synoptic sampling of specified physical and biological parameters (e.g. weather, sea surface temperature) over the entire GOA
2) Intensive sampling of a variety of specified biological and physical parameters (e.g. abundance and growth of intertidal organisms, abundance of selected birds and marine mammals) within a few specified areas spread throughout the GOA using a nested sampling approach. The nested design calls for sampling at some number of locations within the GOA, and at a number of sites within each of those locations.
3) Sampling of a smaller suite of selected biological and physical parameters (e.g. the abundance, growth, and contaminant levels in mussels and clams) at a larger number of less intensively studied sites stretching across the GOA. These are referred to as extensive sites.
4) Conduct of shorter-term studies aimed at identifying important processes regulating or causing changes within a given system or subsystem.

Sampling at intensive sites was designed primarily to detect large-scale changes (e.g. those due to global climate change) while sampling at extensive sites was designed primarily to detect changes that might occur as a result of more localized events such as shoreline development or logging activities.

A long list of potential parameters to be measured was developed and priorities were given for each of these within the synoptic, intensive, and extensive components. This provided a reasonable framework for development of a nearshore GEM monitoring program, but specifics as to the parameters to be measured, the number of sites to be sampled, and the location of sampling sites were not determined. Furthermore, no specific cost estimates were provided and no determination was made as to the appropriate allocation of effort (and costs) among the various components (synoptic, intensive, extensive and process studies).

As a means to aid in the selection of nearshore resources to include in the GEM monitoring program we have developed a metadata set to allow a view of recent and historic work with nearshore resources within the Gulf of Alaska. The metadata are viewable in a hierarchical ArcView format that allows prior work to serve as a guide in selecting resources and locations for monitoring within GEM.

Methods

Development of the metadata bases was achieved through a series of activities. We began by developing a preliminary list of nearshore biological resources and physical attributes for consideration in a long-term monitoring program. This preliminary list was revised following extensive public and peer review and comment. We then began our literature search and development of Excel and Procite metadata bases. We generally limited our literature search to materials that pertain specifically to metrics that could be useful to monitoring, (e.g. measures of abundance, distribution, diversity, life history attributes (reproduction and survival), movements, and contaminants, and standard physical measurements of marine ecosystems such as temperature, salinity and substrates. Following review and revision of the metadata bases we created ArcView themes to graphically display the results of the literature compilation.

To facilitate the project we hosted a GEM Nearshore Monitoring workshop at the 2003 North Pacific Symposium in Anchorage, Alaska. Our goals were to 1) disseminate project information, and 2) make contacts with individuals, non-government organizations (NGOs'), and government agencies, and 3) receive suggestions into the preliminary selection of biological resources and physical attributes for nearshore monitoring (hereafter referred to as "resources"). At this workshop we requested historical documents and on-going project reports and began the process of creating and compiling references for inclusion into the metadata bases.

Most reference materials were obtained from the Alaska Resources Library & Information Services (ARLIS) in Anchorage, Alaska. The on-line library catalog, library staff, and bibliographies were heavily utilized for the literature searches. Additional information was obtained through in-person interviews, personal libraries, electronic mailings, web searches, and the GEM Nearshore Metadata entry forms.

A letter of inquiry and GEM Nearshore Metadata entry form were sent to 189 individuals or organizations representing various government agencies, NGO's, special interest groups, research organizations, native corporations, and the University of Alaska potential interest in our project. The letter of inquiry (Attachment A1) described project goals, defined the nearshore habitat, and listed potential biological resources of interest. The metadata questionnaire (Attachment A2) provided 9 fields of inquiry as follows: 1) information about the person filling out the form, 2) citation, 3) citation description, 4) nearshore resources of interest, 5) status of the data set, 6) keywords, 7) spatial domain, 8) information about how to obtain the data, and 9) constraints. Response to the letter and form was generally limited although contributions to the metadata base were obtained through mailings. Respondents requesting additional information were promptly called or emailed a reply.

Ms. Gray Wolfe arranged to meet with selected individuals in Homer, Seward, Kodiak, and Cordova. The Valdez trip was cancelled due to lack of interest from prospective individuals. The meetings were arranged with employees from various government agencies, special interest groups, research organizations, native corporations, and the University of Alaska. Meeting in-person with interested individuals was usually more effective than the questionnaire mailings. However, travel to these Alaskan cities was time consuming and costly.

The historical literature review was limited to the following: 1) study area boundaries, 2) published technical documents, 3) unpublished reports (usually government or academic) available to the public, and 4) projects completed and documented by 2003. No study results or raw, unreported data were included. The metadata of interest included the complete citation, taxa (at least three levels where appropriate), study locations (requiring coordinates or maps from which coordinates could be derived), duration and frequency of study, and metrics and methods specific to data collection.

Excel was the software selected for the development of the metadata base for the following reasons: 1) ease of use, 2) availability on most computers, and 3) graphing capabilities (Coutsoubos 2002). Procite was elected as the bibliographic software and ArcView 3.3 as the software to graphically present the Excel metadata set.

Results

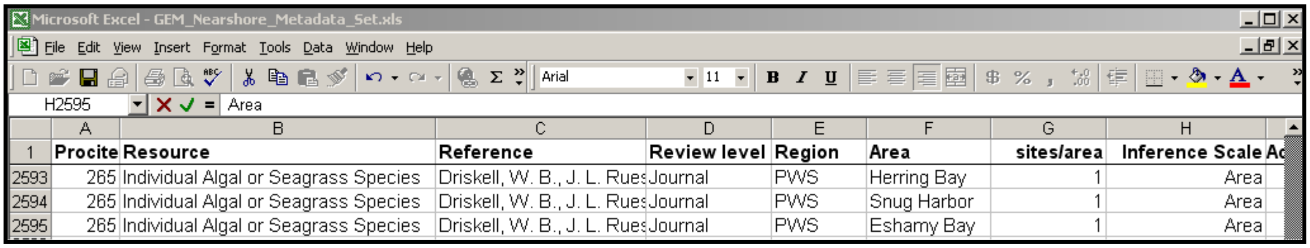
Results of the literature searches, compilation of references, and development of the metadata base are presented below. The Excel data bases that provides the foundation of the metadata used in development of the ArcView Near GEM database (themes) and the Procite data base is described first, followed by a description of the Procite data base. The ArcView product is available on CD. We assume the user has access to ArcView 3.3, and while experience with this software would be valuable, we provide basic instructions that will allow the novice to navigate through the various ArcView themes, query the database, and generate and display new themes. A description, and instructions to use the ArcView data is described lastly. The user is advised to become familiar with the resources included in the Metadata set (Table A1), the metrics that can be used to view specific types of data and create specific themes (Table A2), and the methods employed to measure those metrics (Table A3). The user will also benefit from becoming familiar with the fields in the Metadata set, as these can be used to further refine the spatial and temporal scales with which references can be sorted and visualized in the Near GEM ArcView project.

Excel Database

The information obtained from the literature review was entered into an Excel database labeled GEM Nearshore Metadata Set (APPENDIX C, CD-ROM). The Nearshore

Metadata Set contains a worksheet with the field information listed below. The Excel database is also viewable in ArcView within tables specific to resources. The Excel database features the following fields : (Illustrated in Figures A1-A3)

PROCITE #: The citations are linked to a ProCite database. The ProCite database record number corresponds to the Excel Procite Number.



	A	B	C	D	E	F	G	H
1	Procite	Resource	Reference	Review level	Region	Area	sites/area	Inference Scale
2593	265	Individual Algal or Seagrass Species	Driskell, W. B., J. L. Rues	Journal	PWS	Herring Bay	1	Area
2594	265	Individual Algal or Seagrass Species	Driskell, W. B., J. L. Rues	Journal	PWS	Snug Harbor	1	Area
2595	265	Individual Algal or Seagrass Species	Driskell, W. B., J. L. Rues	Journal	PWS	Eshamy Bay	1	Area

Figure A1. Examples of ProCite #, Resource, Reference, Review Level, Region, Area, Site/Area, and Inference Scale in the GEM Nearshore Metadata Excel database and viewable in ArcView tables.

RESOURCE: A generic, biological resource describing the species studied (Table A1).

REFERENCE: Referenced citations included unpublished and published materials, magazine articles, dissertations, journal articles, books, maps, environmental impact statements, websites, and CD-ROMs.

REVIEW LEVEL: The citations level of critical review was denoted as reviewed or unknown.

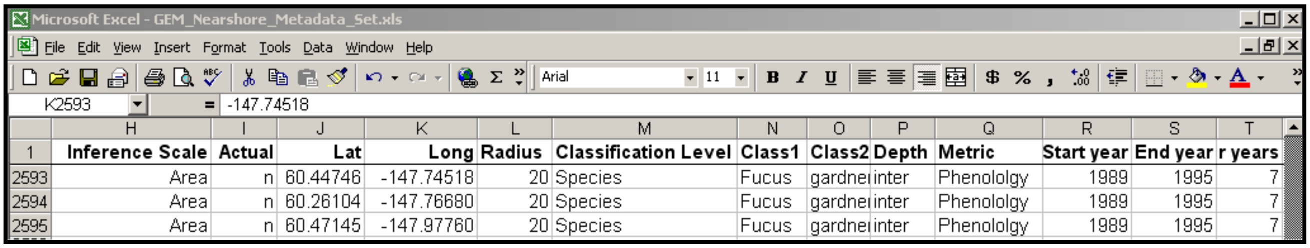
REGION: A general location was assigned to each study which included the following: Gulf of Alaska (GOA), western Gulf of Alaska (WGOA), eastern Gulf of Alaska (EGOA), Cook Inlet (CIK), Kodiak Island (KOD), Alaska Peninsula (AKP), Prince William Sound (PWS), eastern Prince William Sound (EPWS), western Prince William Sound (WPWS), and Cooper River Delta (CRD). The Gulf of Alaska study area encompasses the region between Chignik, Alaska, and Yakutat, Alaska.

AREA: If reported, specific location was listed (e.g. Green Is., Nelson Bay, Pt. Valdez).

SITES/AREA: The number of study sites per project.

INFERENCE SCALE: Projects concentrated on the regional (e.g. GOA), area (e.g. Montague Island), or site level (e.g. Island Flats).

ACTUAL: An “n” for no (generic) or “y” for yes (actual) states if the lat/long was an exact or estimated location.



	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Inference Scale	Actual	Lat	Long	Radius	Classification Level	Class1	Class2	Depth	Metric	Start year	End year	r years
2593	Area	n	60.44746	-147.74518	20	Species	Fucus	gardnei	inter	Phenololgy	1989	1995	7
2594	Area	n	60.26104	-147.76680	20	Species	Fucus	gardnei	inter	Phenololgy	1989	1995	7
2595	Area	n	60.47145	-147.97760	20	Species	Fucus	gardnei	inter	Phenololgy	1989	1995	7

Figure A2. Examples of Inference Scale, Actual, Lat, Long, Classification Level, Class 1, Class 2, Depth, Metric, Start Year, and End Year in the GEM Nearshore Metadata Excel database and viewable in ArcView tables.

LAT/LONG: The latitudes and longitudes were recorded to the 5th decimal. A GPS unit or GIS mapping tool were used to determine the lat/longs for each study. If a study covered a large area, one generic, centralized location was recorded.

RADIUS: Values in the radius field represent areas of inference, or the geographic scale at which the sampling described in each reference represents. For example a survey of sea otters in all of Prince William Sound would be represented by a single latitude /longitude in the center of the Sound, but with a radius of 100 km to indicate the geographic extent of the survey. These radii are referred to as buffer.shp themes for each resource theme in the ArcView product. It is probably not useful to display buffers.shp themes until themes that represent subsets of the full resource are created, as they may obscure points. Radii values range from 5 to 1000 km.

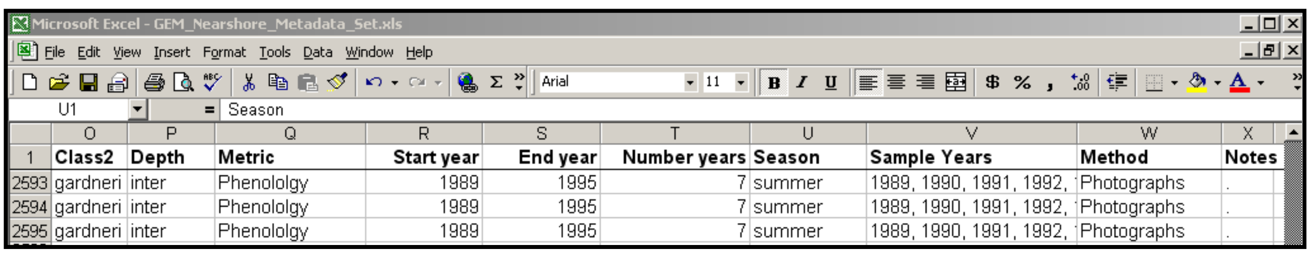
CLASSIFICATION LEVEL: The lowest taxonomic level was identified to phylum, class, or species.

CLASS 1: Identification to the genus taxonomic level.

CLASS 2: Identification to the species taxonomic level.

DEPTH: Only intertidal (inter) or subtidal (ssub) depths were recorded. Ssub was used only when specifically mentioned or illustrated within an article.

METRIC: The metrics describe "what" data a project collected (Table A2).



	O	P	Q	R	S	T	U	V	W	X
1	Class2	Depth	Metric	Start year	End year	Number years	Season	Sample Years	Method	Notes
2593	gardneri	inter	Phenololgy	1989	1995	7	summer	1989, 1990, 1991, 1992,	Photographs	.
2594	gardneri	inter	Phenololgy	1989	1995	7	summer	1989, 1990, 1991, 1992,	Photographs	.
2595	gardneri	inter	Phenololgy	1989	1995	7	summer	1989, 1990, 1991, 1992,	Photographs	.

Figure A3. Examples of Season, Sample Years, Method, and Notes in the GEM Nearshore Metadata Excel database and viewable in ArcView tables.

START YEAR: The first year a project was conducted.

END YEAR: The last year a project was conducted.

NUMBER OF YEARS: The number of years a project was conducted.

SEASON: A year was separated into the following seasons: Winter (Novermber – March), Spring (April – mid-May), Summer (mid-May – August), and Fall (September – October).

SAMPLE YEARS: The specific years the project was conducted. An "all" was entered for any long-term, continuous study. An unknown (U) was entered when a project neglected to cite the specific study years.

METHODS: The methods describe "how" the data was collected (Table A3).

NOTES: Additional comments section.

".": A **"."** was entered for any cell with an unknown or not applicable status.

GIS ArcView 3.3 Near GEM project

The ArcView database provides a geospatially explicit, hierarchical view of each historical citation that references one or more of 15 physical or biological "resources". The base map of the Near GEM project is a projection of the state of Alaska that can be sized to include one or all records. Each resource is at the apex of the hierarchy, and is represented by "themes" in the ArcView Near GEM project. One or more themes can be displayed, and each theme contains all references to that particular resource. Each resource theme can be easily queried to display all or any subset of references based on time, location, taxa, metric, or method used to describe that resource. For each resource there is also a "buffer" theme that displays the area of inference around the coordinates that identify the central location of each study referenced.

Following are basic instructions to use the ArcView Near GEM project.

Basic Instructions for ArcView Use
(For users with ArcView 3.x or higher)

I. <u>To open the Near GEM.apr file</u>: Navigate to the .apr file on the CD and open it in ArcView 3.3. All .shp files (themes) that have been created are in the legend to the left of the displayed map and represent the 15 resources selected for potential monitoring in the nearshore GOA (Figure A4). Table A1 provides a list of each of the themes, and the physical and biological resources represented by those themes. There is one base map of the GOA and 15 themes (resources); 3 physical, 4 community, 5 species specific, and 3 groups of taxa (fishes, invertebrates and algae). Each of the 15 themes is accompanied by a buffer theme (buffer.shp) that displays circles around each point that defines the area of inference surrounding each point. Buffer sizes range from 5 to 1000 km.

II. To view a theme: Check the box next to the desired theme (Figure A4). The shape, size or color of the theme can be changed by double-clicking on the symbol. A 'Legend Editor' will appear. Double-click on the symbol again, and one can choose color, size, shape, etc. Checking the box will display on the map all of the points representing studies of one or more particular resources. Highlighting a bar will make available in a table format all of the records for that resource. More than one bar can be highlighted at a time (Figure A5).

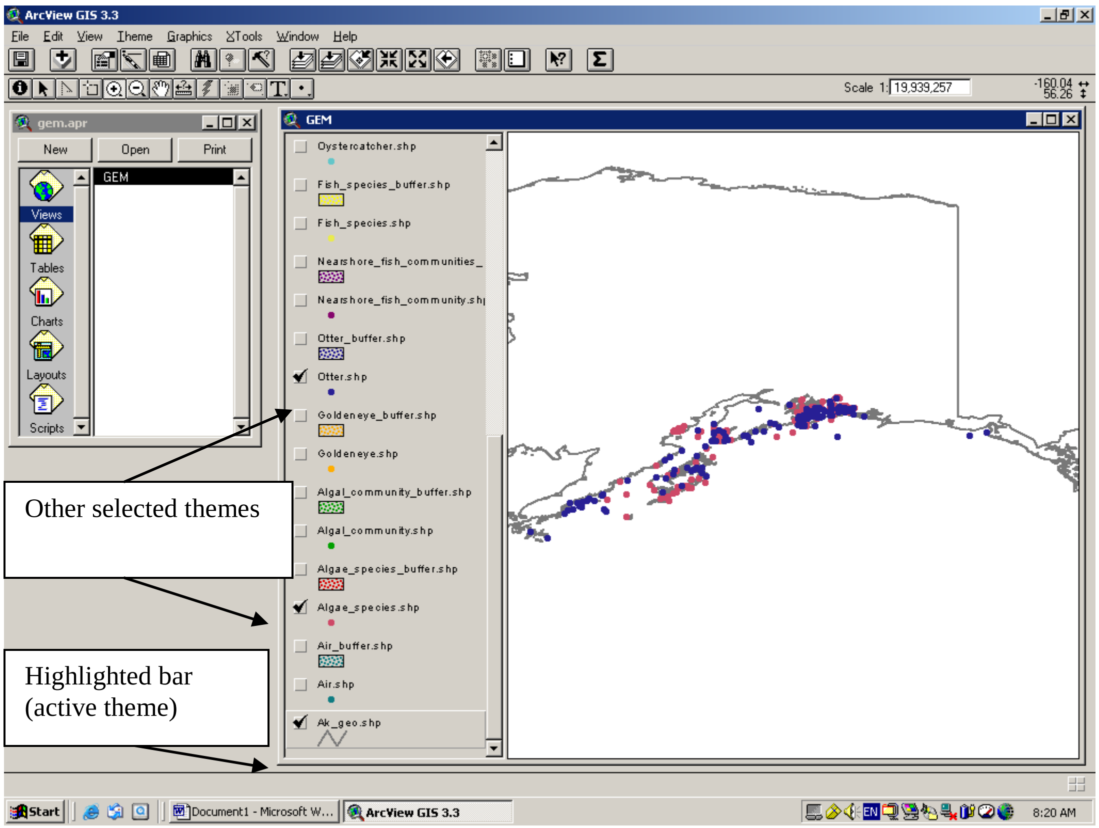


Figure A4. Viewing a Near GEM ArcView theme by checking a box and highlighting a bar. In this example sea otter and algal species studies are displayed on the Alaska shoreline theme.

III. To query a theme: The purpose of the query is to select a subset of the records in the theme for viewing. As an example, one may wish to view only records specific to a region, metric, or time period of a particular resource. In order to query an existing theme, the following procedure should be followed (Figure A5): Highlight the desired theme by clicking on it (Figure A4). Then, click on the 'Table' button (or navigate to Theme/Table via the toolbar). The theme's attribute table will appear (Figure A5, note for the invertebrate species theme you will need to click on the "update values" box before proceeding). Under the table tab, click on 'query'; a query table will appear. Next double click on the field to be queried (e.g. region, area, metric…). After selecting the desired field, double click on one of the operators (e.g. =, >, and, or…). Next, double click on the "value" desired to be included (e.g. Bay of Isles). Once the query is completed as indicated in the lower left attribute box, click on 'New Set'; this will highlight the selected features from that query in the attribute table as well as in the view, indicated by points of different color.

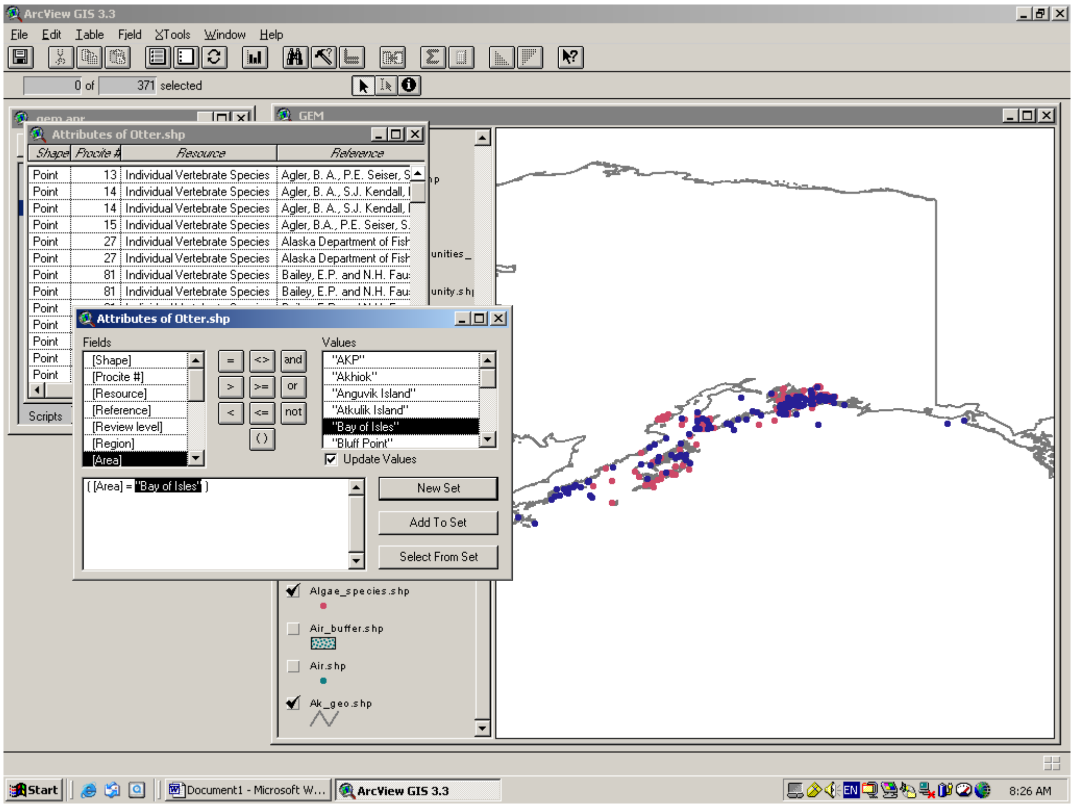


Figure A5. The query box, displaying a query of invertebrate species where only records where "area" equals "Bay of Isles" will be displayed.

Selected Features:

IV. <u>To create a new theme from the selected features:</u> Make sure the view window is selected (not the table window) and that the queried theme is also highlighted. Under the theme tab, click on 'Convert to Shapefile' (Figure A7). This will take the highlighted features from the query and create a new shape file, so the selected features can be viewed independently. You will need to provide a file name and directory to save the new theme to (Note: be conscious of where the new .shp file is saved). You will then be asked if you would like to view the new theme you created. Click yes and the new theme will be added to the top of the theme bar. To view this new theme only, you will need to deselect the original theme and select the "new" theme you added. Once the theme is selected and highlighted you can select the Table button and if desired you can export as a .dbf or text file or simply print the table.

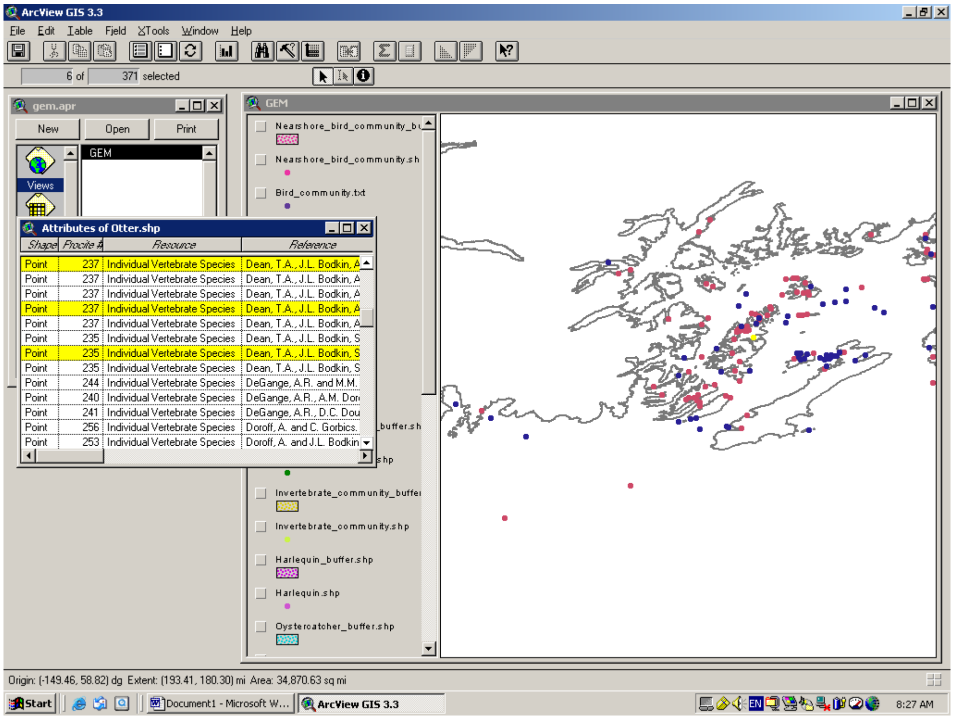


Figure A6. Creating a new theme from features selected though the “query”. The highlighted records will be included into the new theme.

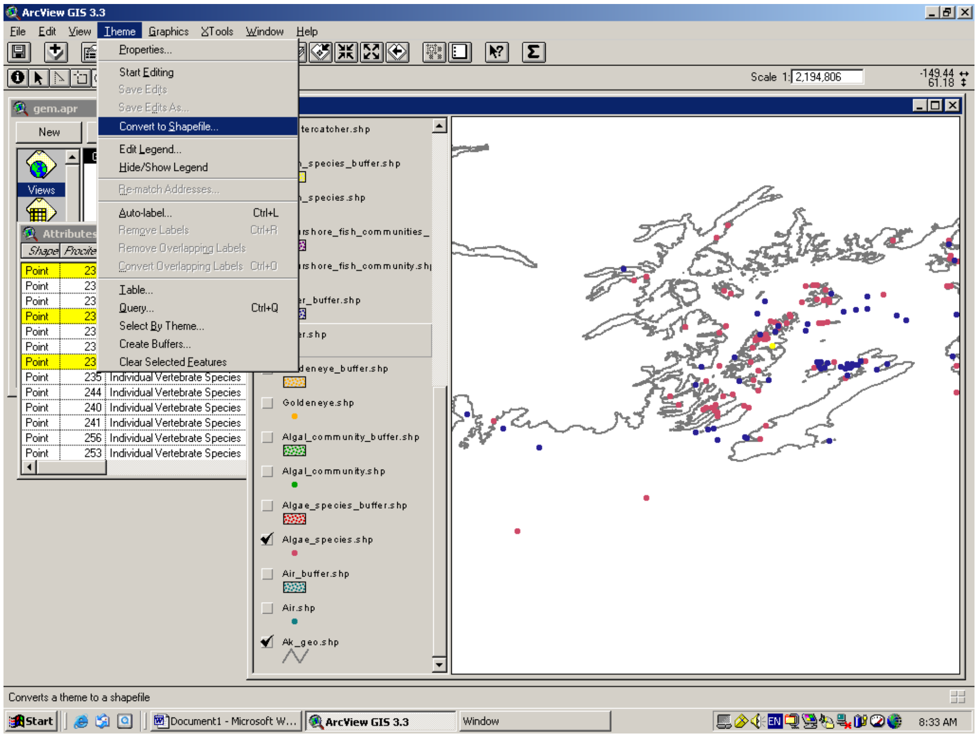


Figure A7. Dropdown menu for converting the results of a query into a new theme (shape file).

V. Using the 'Identify' button: The 'identify' button is the lowercase 'i' at the top of the screen. Highlight the desired theme in the view legend, click on the 'i' button, and then navigate to a point on the map that illustrates a point of the highlighted theme. Click on the point and a table will appear, listing the attributes of that point (Figure A8). Note: there may be several attributes per point. Also, more than one theme can be highlighted in the view legend by holding down the 'shift' key as themes are selected.

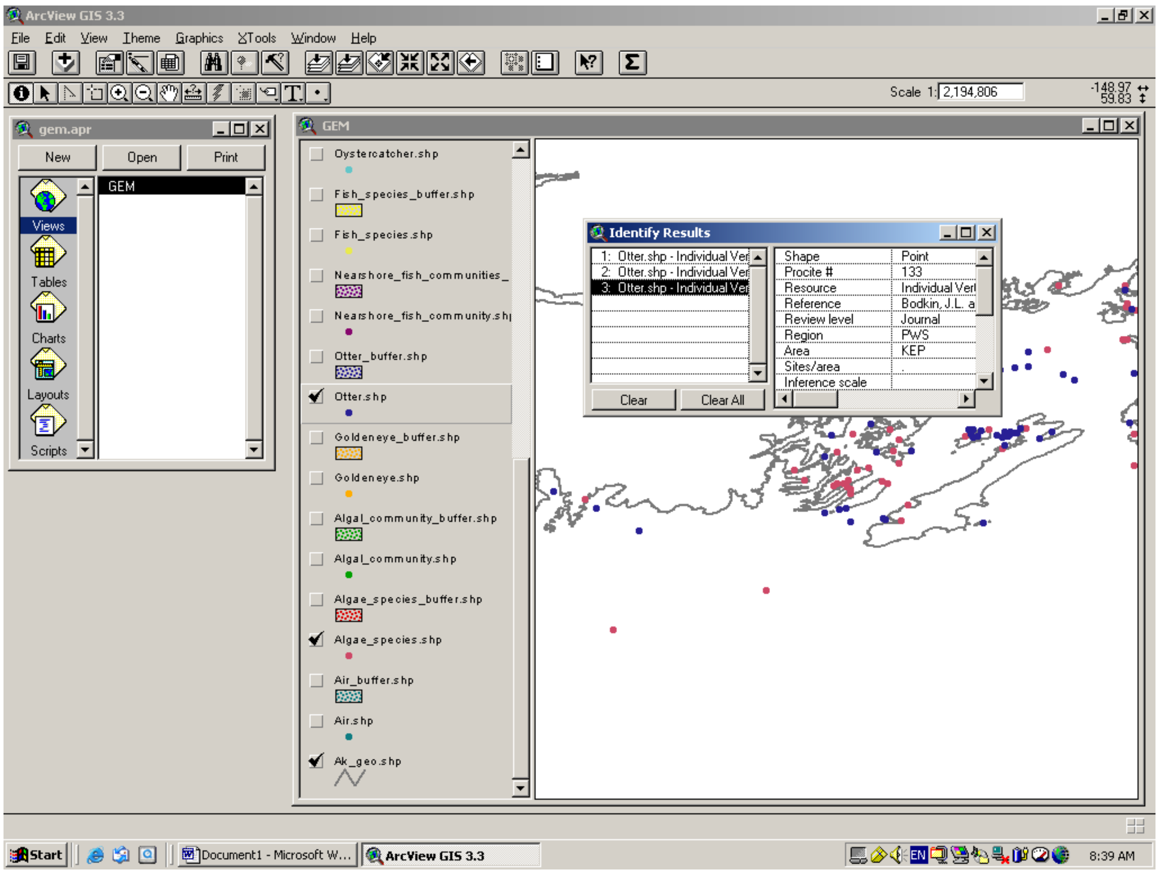


Figure A8. Results of the procedure to view records through the "identify" process described above. Selected points will result in the inset view.

VI. For further assistance, use the 'Help' tab at the top of the screen or questions can be answered by the creators of ArcView at www.esri.com.

ProCite Database

The citations discovered during the literature review process were entered into a ProCite database named GEM Nearshore Metadata References. The citation record number links the ProCite database to the Excel database. All references in the Excel database are cited in the ProCite database; whereas, the ProCite database contains additional citations. The ARLIS library was unable to locate copies of numerous documents; therefore, the metadata for those particular articles was not entered into the Excel database.

ProCite is an easy and straightforward database to manipulate. Database users will be able to search for a citation by record number, author, title, or date. In ProCite, a bibliography can be printed as a Microsoft Word or WordPerfect document. The citations entered into the Excel database can be found in either a hard copy or digital format at the USGS, Alaska Science Center, in Anchorage, Alaska. Selected articles may only include a title page, abstract, summary, and/or map in hard copy. A citation with a "0000" record number is in digital format on CD-ROM.

Discussion

Our research included a compromise between the number of resources we could include and the time we could allocate in our search of the literature for each resource. Following development of an initial list of resources and metrics for inclusion and incorporation of review and suggestions we limited our list to 15 primary resources that explicitly included 33 species, 41 metrics and 132 methods. By necessity we made decisions to include and exclude physical and biological resources. The principal criteria driving our decisions were based on our perception of the potential utility of that resource to serve not only as an indicator of change in the nearshore community, but also for the potential to elucidate why the community changed. When faced with uncertainty we attempted to be more inclusive than exclusive. While our compilation of literature was extensive, we recognize that it was not exhaustive, and that references of prior and ongoing work were likely omitted. We apologize to those authors whose work was not included and assure them that omission was not intentional. In an endeavor such as this there will be errors in data transcription. We accept responsibility for the errors that resulted from our work.

Using the simple procedures we outlined in the results you will be able to use this product to view locations and attributes for any or all of the nearshore resources have been included in the GEM Nearshore Metadata Set (Tables A1-A3) in ArcView software.

Literature Cited

Coutsoubos, N.P. 2002. Building and linking the Coast Walk Database. Report Submitted to the Center for Alaskan Coastal Studies, Homer, Alaska.

Schoch, K., G. Eckert, and T. Dean. 2002. Long Term Monitoring in the Nearshore: Designing Studies to Detect Change and Assess Cause. Draft Report to the Exxon Valdez Oil Spill Trustee Council, Anchorage.

Map A1. GEM Nearshore Metadata Project study area of the Gulf of Alaska between Chignik and Yakutat, Alaska, 2003.

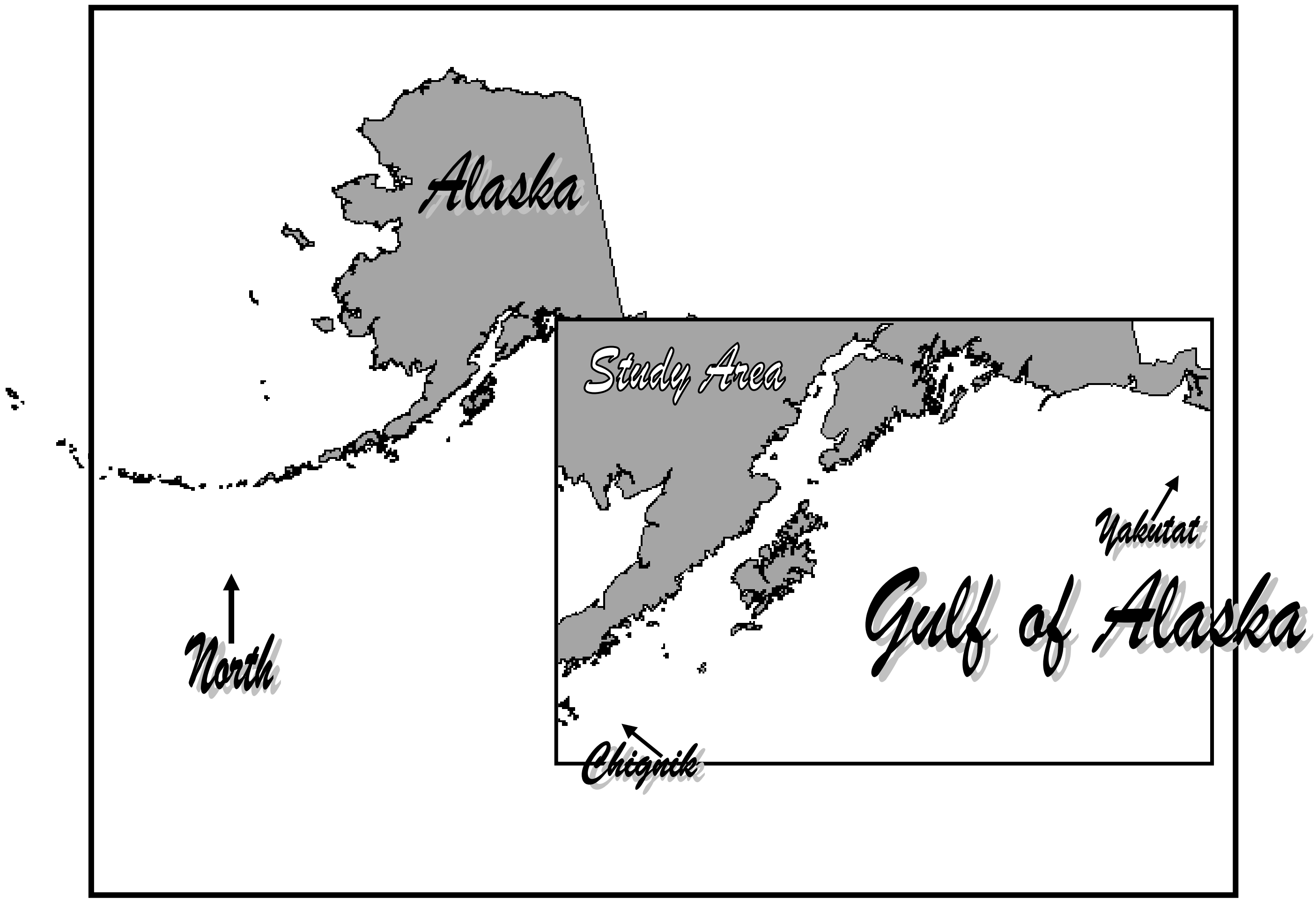


Table A1. The 15 **r**esources (biological and physical) used in the GEM Nearshore Metadata Set (Excel) and viewable as themes in the ArcView 3.3 database. Resources are **bolded,** further taxonomic discrimination is provided in the fields *class1* and *class2*, that usually refer to genus and species.

RESOURCES		*Class1*	*Class2*
Air			
Water			
Sediments			
Algal Community			
Invertebrate Community			
Nearshore Fish Community			
Nearshore Bird Community			
Sea Otter		*Enhydra*	*lutris*
Harlequin Duck		Histrionicus	*histrionicus*
Goldeneye		*Bucephala*	*islandica, spp.*
Black Oystercatcher		*Haematopus*	*bachmani*
Scoter		*Melanitta*	*spp.*
Fish Species		Clupea	*pallasi*
		Ammodytes	*hexapterus*
		Anoplarchus	*purpurescans*
		Pholis	*laeta*
		Hexagrammos	*decagrammos, lagocephalus, octogrammus, stelleri*
Invertebrate Species			
	Bivalves	*Protothaca*	staminea
		Saxidomus	*gigantea*
		Mytilus	*trossulus*
		Macoma	*balthica, brota, alaskana, calcarea, nasuta, irus, inconspicua, inquinata, carlottensis, yolidiformis*
		Modiolus	*modiolus*
		Mya	*truncate, areneria,*
		Clinocardium	*nuttali, ciliatum, fucanum, californiensis*
		Spisula	*polynyma*
		Siliqua	*patula, alta, media*
	Snails	*Littorina*	*sitkana, scutulata, grolandica, rudis*
		Lottia	*pelta*
		Tectura	*persona*
	Sea Stars & Sea Urchins	Strongylocenttotus	*droebachiensis*
		Pisaster	*ochraceus*
		Dermasterias	*imbricata*
		Pycnopodia	*helianthoides*
		Evasterias	*troscellii, echinosoma*
	Crabs	Telmessus	*cherigonus*
Algal Species		Algae, Kelp, or Seagrass	
		Fucus	*gardneri, distichus*
		Nereocystis	*luetkeana*
		Alaria	*fistulosa, taeniata, pylaii*
		Zostera	*marina*
		Laminaria	*dentigera, saccharina, groenlandica, yezoensis, setchelli*

Table A2. Metrics used by researchers in the Gulf of Alaska between the years 1896 to 2003 as entered in the GEM Nearshore Metadata Set Excel database to describe how resources (Table 1) were evaluated. The metric field can be used in ArcView queries to display and view specific types of studies (e.g. age or size for biological resources, and salinity for a physical resource) or metrics used to evaluate resources. All metrics are not applicable to all resources.

Metric		
Abundance	Geographic Distribution	Salinity
Age Distribution	Grain Size Distribution	Shoreline Geomorphological Type
Barometric Pressure	Growth	Size Distribution
Bathymetry	Habitat Utilization	Species Composition
Behavior	Harvest Data	Species Richness
Biomass	Harvest Location	Survival
Chemical Composition	Health Measures	Suspended Load
Cloud Cover	Light Transmissivity	Temperature
Current Direction	Morphometrics	Topography
Current Velocity	OC Contaminants	Visibility
Diet	Oil Contaminants	Wave Height
Diversity	Precipitation	Wind Direction
Earthquake	Production	Wind Speed
Freshwater Discharge/Input	Richness	

Table A3. Data collection methods in the Gulf of Alaska between the years 1896 to 2003 as entered in the GEM Nearshore Metadata Set Excel database to describe how measurements of a specific metric were obtained. The method field can be used in ArcView queries to display and view specific types of methods (e.g. body weight for size) used to acquire data related to specific metrics or resources. All methods are not applicable to all metrics.

	Method	
Aerial Photography	Fat Index	Prey Collection
Aerial Surveys	Fecal Samples	Projections
Agassiz Trawl	Field Collection	Radar
Annuli Measurements	Fish Measuring Board	Radar Drogue Trajectories
Area	Gill Net	References
Bag Checks	Gonadal Index	Regulations
Beach Mapping	Gonadal Tissue	Regurgitation
Beach Net	Grab Samples	Remote Sensing
Beach Restoration	Gun	Satellite Imagery
Beach Seine	Harvest Records	Scales
Beach Seine/Trawl	Hematology	Schnute Model
Beach Surveys	Histology	Sediments
Beckman Salinometer	Historical Records	Seine Surveys
Bill Width	Hydrographic Stations	Semipermeable Membrane Device
Bird Banding	Hydroproduct Transmissometer	Serum Chemistry
Blumer Technique	Interviews	Shoreline Treatment
Boat Observations	Laboratory	Size Weight
Boat Surveys	Length	Slope
Body Weight	Length Weight	Small-mesh Trawl
Bottom Skimmer	List	Sonar
By hand-destructive	Maps	Spatial Distribution
By Size Class	Mark Recapture	Statistical Analysis
Capture	Maximum Leaf Length	Stomach Contents
Carcass Counts	Measurements	Surface Oil Distribution
Carcass Recovery	Mid-Water Trawl	Systematic Surveys
Checklist	Model	Taxonomic Key
Collection	Molt stage	Telemetry
Commercial Harvest	Morphology	Thallus
Compilation	Morphometrics	Tide Level
Core Samples	Multiplate sampler	Tissue Burden
Counting Threads	Necropsy	Tissue Samples
CTD	Oil Pollution survey	Tow Net
Current Meter Deployments	Oil Removal	TPAH
Cytochrome P450 1A	Orion Specific Ion Meter	Trammel Net
Depth	Otter Trawl	Transplant
Depth of Penetration	Ova Counts	Trawl Survey
Digital Maps	Ovarian Weight	Try Net
Direct Observations	Participation-Observation	Ultraviolet Fluorescence Indices
Distance to Water	Pathology	Van Veen Grab
Distribution Mappping	Photographs	Vertical Tow Sampling
Diver Observations	Photovolt Digicord Meter	Volume

Drift Cards Egg Count Elevation	Pipe Dredge Potential effects of oil and gas exploration	Weight

Attachment A1. GEM Nearshore Metadata Project letter of inquiry including definition of nearshore marine communities and potential resources for inclusion into metadata set.

United States Department of the Interior

U.S. GEOLOGICAL SURVEY
BIOLOGICAL RESOURCES DIVISION
Alaska Science Center
1011 E. Tudor Road
Anchorage, Alaska 99503
James_Bodkin@USGS.gov

IN REPLY REFER TO:
25 March, 2003

Dear Colleagues,

We have been asked by the Exxon Valdez Oil Spill Trustee Council to compile and provide a Gulf of Alaska nearshore habitat metadata set, in a geographically and temporally explicit format (ArcView) that will aid the Trustee Council in making decisions regarding the design of the nearshore component of their Gulf of Alaska Ecosystem Monitoring (GEM) Program. Our efforts began with developing a tentative list of nearshore resources or metrics that we intend to include (see below), and a working definition of the nearshore habitat. We derived our definition of the nearshore habitat as a means to focus the scope of our work. Certainly we recognize that marine habitats are fluid in nature and that interchange of matter and energy among GOA habitats are critical to the GOA ecosystem and are an important component of the GEM Plan.

At the January 2003 Marine Science in North Pacific Symposium held in Anchorage we convened a workshop to refine a list of resources and make contacts with individuals and organizations that may have contributions in the form of historical or ongoing reports or papers that are relevant to our efforts. Our purposes in this letter are to 1) seek additional input into refinement of our list of resources (are we missing something?), and 2) solicit additional contact information, either your own, or others you may be aware of, that may provide access to unpublished reports relevant to our resource list, within the GOA (tentatively defined as cape Suckling to Kodiak Is.). We do not intend to include results of studies in our project, but plan on identifying locations and time frames of historic and ongoing work in the GOA pertaining to those resources identified below. We are also limiting inclusion of materials into this project to either published technical documents, or unpublished reports of results that are available to the public. Raw, unreported data will not be included. We intend to prioritize the list below to in the event not all resources can be included within the duration of the project. Because we are conducting literature searches it is not necessary for you to identify work previously published or generally available through common literature search processes. Further, we are generally limiting materials that pertain specifically to metrics that could be useful to monitoring, (e.g. measures of abundance, distribution, diversity, life history attributes (reproduction and survival), movements, and contaminants.

If after reviewing the definition and resource list below, you believe you may have reports that should be included in this effort, or suggested revisions to the resource list, please contact us. Contact and resource information can be provided to Carrie GrayWolfe, at Carrie_Graywolf@usgs.gov. We anticipate circulating this request to organizations and individuals that may know of, or have access to, materials that should be included in this project. We intend to produce a draft of our results by mid summer that can be provided to communities, individuals, and organizations for their review.

Thank you for your support and contribution to this effort.

Jim Bodkin
Alaska Science Center

Dr. Tom Dean
Coastal Resources Associates

(Attachment)

Resources of Interest

Preliminary Nearshore Definition

Coastal marine habitats can be defined by the zone between the high water mark and the 10 fathom bathymetric contour, where food webs are supported by carbon fixed by attached macroalgae (as opposed to micro-algae or phytoplankton), and populations are generally limited by substrate availability, as opposed to nutrients. Nearshore biota are defined as those species that either form the base of the food web (e.g. attached plants), those that occupy benthic habitats within the 0-10 fathom bathymetric zone, or are consumers of animals that rely on the nearshore macro-algae food base. (The definition is intended to be useful in identifying taxa to be included our analyses)

Biological Resources

Community Measures
- Intertidal invertebrate diversity
- Intertidal algal diversity
- Intertidal algal production
- Subtidal algal production
- Phytoplankton production
- Number of bird species
- Number of fish species

Individual Taxa
- Mammals
    - Sea otter
- Birds
    - Harlequin duck
    - Barrows goldeneye
    - Oyster catcher
    - Surf scooter
- Intertidal and nearshore subtidal invertebrates

- Bivalves
  - *Protothaca staminea*
  - *Saxidomus gigantea*
  - *Mytilus trossulus*
  - *Macoma spp.*
- Snails
  - *Littorina spp.*
  - *Lottia pelta*
  - *Tectura persona*
- Sea stars and sea urchins
  - *Strongylocentrotus droebachiensis*
  - *Pisaster ochraceus*
  - *Dermasterias imbricata*
  - *Pycnopodia helianthoides*
  - *Evasterias troscellii*
- Crabs
  - *Telmessus cherigonus*

Intertidal and nearshore subtidal algae and grasses
- *Fucus gardneri*
- *Nereocystis luetkeana*
- *Alaria fistulosa*
- *Zostera marina*
- *Laminaria*

Intertidal and nearshore fishes
- Herring
- Sandlance
- High cockscomb
- Crescent gunnels
- Greenling

Related physical features
- Geomorphology
- Bathymetry
- Slope
- Temperature
- Salinity
- Precipitation

<u>Cultural Resources and human use</u>

Major cultural resources
Areas of importance for subsistence use
Major human settlements
Waste water discharges
Areas of major recreational use

Attachment A2. GEM Nearshore Metadata Project form mailed to prospective individuals, agencies, or organizations, 2003.

1.0 Information About the Person Filling Out the Form

Date: _________________
Name:____
Organization/Institution:____

Address Type (Check One) **Mailing Address** **Physical Address** **Mailing & Physical Address**

Address:____ **City:**_____________________________________ **State or Province:**__________________________
ZIP:______________________________________**Country:**___________________________
Phone:____________________________________**FAX:**_____________________________**Email:**____

Metadata Standard Name: <u>FGDC Content Standards for Digital Geospatial Data</u>
Metadata Standard Version: <u>19940608</u>

☐ **I can't respond now, but I know of data that may be of interest to you. Please contact me.**

2.0 Citation

Originator:____ **Unknown**

Publication Date:___________________________ **Unknown** **Unpublished Material**

Title:____

3.0 Description

Abstract:____
____
____
____
____

Purpose:____
____
____
____

Time Period of Content
Pick One

Single Date/Time: **Date:**______________________________ **Time:**__________________

OR

Multiple Dates/Times: ____

OR

Range of Dates/Times: **Beginning Date:**_____________________ **Beginning Time:**_________
Ending Date:________________________ **Ending Time:**____________

OR

Unknown **Unpublished Material**

4.0 Nearshore Resources of Interest

Community Measures:
☐Intertidal invertebrate diversity
☐Intertidal algal diversity
☐Intertidal algal production
☐Subtidal algal production
☐Number of bird species
☐Number of fish species
☐Primary productivity*

Mammals:
☐Sea Otter*

Birds:
☐Harlequin duck*
☐Barrows goldeneye*
☐Oyster catcher*
☐Surf scooter

Intertidal & Nearshore Fishes:
☐Herring (Spawn)*
☐Sandlance*
☐High cockscomb
☐Greenling*
☐Crescent gunnels

Intertidal & Nearshore Subtidal Invertebrates:
Bivalves:
☐*Protothaca staminea**
☐*Saxidomus gigantea**
☐*Mytilus trossulus**
☐*Macoma spp.**

Snails:
☐*Littorina spp.*
☐*Lottia pelta*
☐*Tectura persona**

Sea Stars & Sea Urchins:
☐*Strongylocentrotus droebachiensis**
☐*Pisaster ochraceus**
☐*Dermasterias imbricata**
☐*Pycnopodia helianthoides**
☐*Evasterias troscellii**

Algae & Grasses:
☐*Fucus gardneri**
☐*Nereocystis luetkeana**
☐*Zostera marina**
☐*Alaria fistulosa**

Crabs:
☐*Telmessus cherigonus*

Related Physical Features:
☐Geomorphology*
☐Bathymetry*
☐Slope*
☐Temperature
☐Salinity
☐Precipitation
☐Exposure
☐Remote images

Cultural Resources & Human Use[1]:
☐Major cultural resources
☐Areas of importance for subsistence use
☐Waste water discharges
☐Areas of major recreational use
☐ Major human settlements
☐ Contaminants (by taxa)

[1]Resource of importance in site selection, but not necessarily sampled by GEM.
****Indicates resources of priority for inclusion into database.***

5.0 Status of the Data Set

Progress: ☐**Published** ☐**Complete/Peer Reviewed** ☐**Unpublished Report**

6.0 Keywords

Theme Keyword Thesaurus:
____
____
☐**None** ____
Theme Keyword(s): ________________________-
_________________-
____
____
____

7.0 Spatial Domain

Bounding Coordinates

North

West **East**

South

8.0 Information About How to Obtain the Data

Date: _______________
Name:____
Organization/Institution:____

Address Type **Mailing Address** **Physical Address**
(Check One) **Mailing & Physical Address**

Address:____
____
City:__________________________________ **State or Province:**_______________________
ZIP:__________________________________**Country:**________________________
Phone:_________________________________**FAX:**__________________________**Email:**_________________
____

9.0 Constraints

Access Constraints:
____
____
☐ **None**
Use Constraints:
____
____
☐ **None**

Thank you for your time and cooperation.

PLEASE RETURN TO:
Carrie A. Gray Wolfe
US Geological Survey
1011 East Tudor Road
Anchorage, AK 99503
Phone: (907) 746-8008 (Home Office)
Phone: (907) 786-3449 (Work Office)
cgraywolfe@usgs.gov

APPENDIX B. Cost estimates for alternative designs for the nearshore sampling program.

Option 1 **Approximately equal weight to extensive and intensive sampling**

Salary

Title	$ /year	FTE	Total	Notes and assumptions
Principal investigator	$100,000	1	$100,000	All salaries for full time personnel (50% time or greater) include a 50% benefit rate
On site supervisor	$100,000	1.5	$150,000	3 half-time positions at each of three centers (Kodiak, Homer, Cordova)
Analyst	$80,000	1	$80,000	
Tech 1	$60,000	1	$60,000	
Tech 2	$45,000	1	$45,000	
Tech 3	$33,000	1	$33,000	Six part-time technicians at 2 months each for field work
Sub-total			$468,000	

Contracts

Description	$/day or sample	Days or Samples	Total	
Vessel – Extensive & Intensive sampling	$1,200	73.5	$88,200	Assumes a 6 person vessel – 2 days per site to sample intensive sites. 2 days x 5 sites per block x 3 blocks = 30 days. 2 extensive sites sampled per day, 6 extensive sites per region x 0.5 = 3 days per region. Assumes 2 additional days per block to sample sea otter diets. Assumes 1 mobilization and 1 demobilization day per area

				Total = for every other year when only intensive sites are sampled is 14 days per block x 3 blocks = 42 days. plus 3 days for selected intensive sites per region x 3 regions = 9 days for a total of 51 days. Assumes 6 person vessel - 2 sites per day for 25 extensive sites per area = 13 days Assumes 2 trips (2 low tide series) to complete extensive site sampling. Assumes 2 mobilization and 2 demobilization days for extensive sampling. Total = for every other year when both intensive and extensive sites are sampled is 17 days per region x 3 regions = 51 days for intensive sites, plus 15 days per area x 3 areas = 45 days for intensive sites = 96 days Average = 73.5 vessel days per year.
Vessel – winter Predator surveys	$1,200	21	$25,200	Assumes 7 days/area x 3 areas - 1 day mob/demob per trip
Vessel - sea otter Carcass surveys	$1,200	21	$25,200	Assumes 7 days/area x 3 areas - 1 day mob/demob per trip
Aircraft - sea otter Aerial surveys	$1,100	30	$33,000	Assumes 5 flight hour days at $220/hour
Shoreline aerial Survey	$60,000		$60,000	Assumes sample of 3 intensive blocks yearly, with survey of entire coastline once every 12 years
Chemical analyses – extensive sites	$935	40.5	$37,868	Assumes 81 additional samples from extensive sites every four years. Average is 54 samples per year. Assumes costs for analyses are OC screen $585, metals screen $225, Mercury $50, FAC screen for HCs $75.00

Chemical analyses – Subsistence foods	$1,027	30	$30,810	Assumes costs for analyses are OC screen $585, metals screen $225, Mercury $50, FAC screen for TPAH = $215.00 Assumes 30 samples from selected subsistence sites every year,
Sub-total			$300,278	

Travel

Description	$/day or trip	Days or Trips	Total	
Airfare, RT Kodiak/ANC	$250	9	$2,250	For sampling. Assumes 12 RT in "extensive" years, 6 in "intensive only" years for average of 9/year.
Airfare, RT Homer/ANC	$150	9	$1,350	For sampling. Assumes 12 RT in "extensive" years, 6 in "intensive only" years for average of 9/year .
Airfare, RT to ANC from Homer, Kodiak, or Cordova	$200	9	$1,800	For coordination/meetings.
Per diem	$150.00	54	$8,100	2 days per diem per person per trip
Vehicle rental	$50	80	$4,000	20 days of vehicle use in each of 4 areas: ANC, Kodiak, Cordova, Homer
Sub-total			$17,500	

Equipment				
Physical Instruments	$17,300		$17,300	Assumes 6 CTD instruments x 8,400 per instrument, plus 15 temperature recorders x $100 per instrument and replacement cycle of once every 3 years.
Scopes for sea otter diets	300	3	900	Scopes to be purchased in first year at cost of 3,000 per scope x 3 = 9,000. Replacement cycle every 10 years.
Sub-total			$18,200	
Overhead				
Overhead and G&A			$67,195.50	Assumes overhead to cover all supplies, insurance, office equipment, computers, software, office rent etc. Uses a rate of 20% non-salary costs
Other				
Set aside for future process studies			30,000	
Total			$901,173	

Option 2 Weighted toward extensive sampling

Salary

Title	$/year	FTE	Total	Notes
Principal investigator	$100,000	1	$100,000	All salaries for full time personel (50% time or greater) include a 50% benefit rate
On site supervisor	$100,000	1.5	$150,000	3 half-time positions at each of three centers (Kodiak, Homer, Cordova)
Analyst	$80,000	1	$80,000	
Tech 1	$60,000	1	$60,000	
Tech 2	$45,000	1	$45,000	
Tech 3	$33,000	1	$33,000	Assumes 6 part-time technicians at 2 months each for field work
Sub-total			$468,000	

Contracts

Description	$/day or sample	Days or Samples	Total	
Vessel – Extensive & intensive sampling	$1,200	73	$87,600	Assumes a 6 person vessel - 66 days/area x 3 areas for for extensive and intensive sites. Total for every other year when only intensive sites are sampled is 14 days per block x 3 areas = 42 days. plus 3 days for selected intensive sites per region x 3 regions = 9 days for a total of 51 days. Total for every other year when only extensive sampling is done Is 17 sites per block x 9 blocks = 153 sites with 2 sites sampled per day = 77 days,

				Plus 18 days for mobilazation and demobilization = 95 days Assumes 1 day mob de-mob for each trip. Average per year = (51 days+95 days)/2=73 days
Vessel – winter predator surveys	$1,200	10.5	$12,600	Assumes 7 days/area x 3 areas for int. - 1 day mob/demob per trip, sampling every other year.
Vessel - sea otter Carcass surveys	$1,200	10.5	$12,600	Assumes 7 days/area x 3 areas - 1 day mob/demob per trip, sampling every other year
Aircraft - sea otter Aerial surveys	$1,100	15	$16,500	Assumes 5 hour days at $220/hour, sampling every other year
Shoreline aerial Survey	$45,000		$45,000	Assumes sample of 3 intensive blocks every other year. With survey of entire coastline once every 12 years
Chemical analyses – extensive sites	$935	90	$84,150	18 samples from extensive "selected impact" sites plus 9 from intensive sites every other year = 27. Average is (153+27 samples)/2=90 per year. Assumes costs for analyses are OC screen $585, metals screen $225, Mercury $50, FAC screen for HCs $75.00
Chemical analyses – subsistence foods	$1,027	30	$30,810	Assumes costs for analyses are OC screen $585, metals screen $225, Mercury $50, FAC screen for TPAH = $215.00 Assumes 30 samples from selected subsistence sites every year,
Sub-total			$289,260	

Travel

Description	$/day or trip	Days or Trips	Total	
Airfare, RT Kodiak/ANC	$250	12	$3,000	For sampling. Assumes 24 RT every other year.
Airfare, RT Homer/ANC	$150	12	$1,800	For sampling. Assumes 24 RT every other year.
Airfare, RT to Anc from Homer, Kodiak, or Cordova	$200	9	$1,800	For coordination/meetings.
Per diem	$150.00	66	$9,900	2 days per diem per person per trip
Vehicle rental	$50	80	$4,000	20 days of vehicle use in each of 4 areas: ANC, Kodiak, Cordova, Homer
Sub-total			$20,500	

Equipment

Physical Instruments	$17,300		$17,300	Assumes 6 CTD instruments x 8,400 per instrument, plus 15 temperature recorders x $100 per instrument and replacement cycle of once every 3 years.
Scopes for sea otter diets	300	3	900	Scopes to be purchased in first year at cost of 3,000 per scope x 3 = 9,000. Replacement cycle every 10 years.
Sub-total			$18,200	

Overhead

Overhead and G&A	$66,347	Assumes overhead to cover all supplies, insurance, office equipment, computers, software, office rent etc. Uses a rate of 20% non-salary

costs

Other	
Set aside for future process studies	30,000
Total	$892,307

Option 3 **Weighted toward intensive sampling**

Salary

Title	$/year	FTE	Total	Notes
Principal investigator	$100,000	1	$100,000	All salaries for full time personnel (50% time or greater) include a 50% benefit rate
On site supervisor	$100,000	1.5	$150,000	3 half-time positions at each of three centers (Kodiak, Homer, Cordova)
Analyst	$80,000	1	$80,000	
Tech 1	$60,000	1	$60,000	
Tech 2	$45,000	1	$45,000	
Tech 3	$33,000	1	$33,000	Assumes 6 part-time technicians at 2 months each for field work
Sub-total			$468,000	

Contracts

Description	$/day or sample	Days or Samples	Total	
Vessel - Extensive & intensive sampling	$1,200	61	$73,200	Assumes a 6 person vessel - 2 days per site to sample intensive sites. 2 days x 5 sites per block = 10 days. Assumes 2 additional days per block to sample sea otter diets. Assumes 1 mobilization and 1 demobilization day per block Total = for every other year when only intensive sites are sampled is 14 days per area X 3 areas = 42 days. Assumes 6 person vessel - 2 sites per day for 16 extensive sites per region = 8 days

				Assumes 1 mobilzation and 1 demobilization day for each region. Total = for every other year when both intensive and extensive sites are sampled is 17 days Per region x 3 regions = 51 days for intensive sites, plus 10 days per area x 3 areas = 30 days for Intensive sites = 81 days. Average = (42+80)/2=61 sample days per year.
Vessel- physical chemcial	$600	36	$21,600	Assumes 6 visits to each of 3 areas per year times 2 days per visit
Vessel - winter predator surveys	$1,200	21	$25,200	Assumes 7 days/area x 3 areas - 1 day mob/demob per trip
Vessel - sea otter Carcass surveys	$1,200	21	$25,200	Assumes 7 days/area x 3 areas - 1 day mob/demob per trip
Aircraft - sea otter Aerial surveys	$1,100	30	$33,000	Assumes 5 hour days at $220/hour
Shoreline aerial survey	$60,000		$60,000	Assumes complete survey of 3 intensive blocks yearly, with survey of entire coastline once every 8 years
Chemical analyses - extensive sites	$935	15.75	$14,726	Assumes 18 samples from selected extensive sites and 45 from systematic extensive sites every 4 years Average is 15.75 samples per year. Assumes costs for analyses are OC screen $585, metals screen $225, Mercury $50, FAC screen for HCs $75.00
Chemical analyses – subsistence foods	$1,027	30	$30,810	Assumes costs for analyses are OC screen $585, metals screen $225, Mercury $50, FAC screen for TPAH = $215.00 Assumes 30 samples from selected subsistence sites every year,

Sub-total			$283,736	

Travel

Description	$/day or trip	Days or Trips	Total	
Airfare, RT Kodiak/ANC	$250	9	$2,250	For sampling. Assumes 12 RT in "extensive" years, 6 in intensive only years for an average of 9/year.
Airfare, RT Homer/ANC	$150	9	$1,350	For sampling. Assumes 12 RT in "extensive" years, 6 in intensive only years for an average of 9/year
Airfare, RT to ANC From Homer, Kodiak, or Cordova	$200	9	$1,800	For coordination/meetings.
Per diem	$150.00	54	$8,100	2 days per diem per person per trip
Vehicle rental	$50	80	$4,000	20 days of vehicle use in each of 4 areas: ANC, Kodiak, Cordova, Homer
Sub-total			$17,500	

Equipment

Physical Instruments	$31,100		$31,100	Assumes 6 instruments x 15,000 per instrument and replacement cycle of once every 3 years.
Scopes for sea otter diets	300	3	900	(Scopes to be purchased in first year at cost of 3,000 per scope X 3 = 9,000)
Sub-total			$32,000	

Overhead

Overhead and G&A	$66,647	Assumes overhead to cover all supplies, insurance, office equipment computers, software, office rental, etc. Uses a rate of 20% non-salary costs
Other		
Set aside for future process studies	30,000	
Total	$897,883	

APPENDIX C. CD-ROM