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Protocol Narrative for Marine Ecosystem Monitoring in the Southwest Alaska Network of National Parks

Version 1.0

Natural Resource Report NPS/SWAN/NRR—2011/449

ON THE COVER
Katmai National Park and Preserve
Photograph by: Kelly Bodkin, USGS volunteer

Protocol Narrative for Marine Ecosystem Monitoring in the Southwest Alaska Network of National Parks

Version 1.0

Natural Resource Report NPS/SWAN/NRR—2011/449

Thomas A. Dean

Coastal Resources Associates, Inc.
5190 El Arbol Drive
Carlsbad, CA 92008

James L. Bodkin

US Geological Survey
616 Marrowstone Point Road
Nordland, WA, 98358

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Revision History Log

All edits and amendments made to this document since its inception should be recorded in the table below. Users of this protocol should promptly notify the project leader of the marine nearshore monitoring program of recommended edits or changes. The project leader will review and incorporate suggested changes as necessary, record these changes in the revision history log, and modify the date and version number on the title page of this document to reflect these changes.

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
Add rows as needed for each change or set of changes associated with each version.					

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Executive Summary

This document provides a comprehensive plan for long-term monitoring of nearshore marine resources in the National Park Service's (NPS) Southwest Alaska Network (SWAN) parks. The objective of plan is to assist managers in preserving park resources by documenting changes to these resources over time and suggesting possible causes for these changes. The monitoring encompasses all major elements of the nearshore trophic web, from primary producers to apex predators, and focuses on six vital signs: kelp and seagrasses, marine intertidal invertebrates, marine birds, black oystercatchers, sea otters, and marine water chemistry and quality. Sampling will be conducted in Katmai National Park and Preserve (KATM), Kenai Fjords National Park (KEFJ), and to a lesser extent in Lake Clark National Park and Preserve (LACL). Trends in different vital sign metrics (e.g. the number of sea otters) will be examined and the variation in the relative extent of change among different locations will be assessed.

Sampling will focus on estimating: cover by eelgrass and kelp; abundance (percent cover or density) of intertidal algae and invertebrates on sheltered rocky shores; density of infaunal invertebrates in gravel / mixed-sand gravel shores; size and density of Pacific blue mussels in mussel beds; abundance of marine birds; abundance, nest site density, and composition of prey provisioned to chicks for black oystercatchers; abundance, survival and diet of sea otters; and concentration of various organic and inorganic contaminants in mussels. In addition, temperature (both water and air) and salinity will be measured. All of these metrics will be examined at KATM and KEFJ, generally on a frequency ranging from once a year to once every three years. Sampling at LACL will consist only of less frequent sampling of intertidal invertebrates. Surveys of abundance of sea otters and marine birds will consist of estimating numbers of individuals along randomly selected transects. Survival of sea otters will be examined by determining age at death based on collection of sea otter carcasses from selected locations where carcasses tend to concentrate. Sampling of other metrics will be focused on five randomly selected locations within each park.

Generalized guidelines on analytical methods to be used to detect trends in various vital sign metrics are provided. Also given are preliminary estimates of the extent of change that is deemed ecologically important and might trigger management action. In addition, guidelines for data management, management structure, operational requirements, and costs are provided.

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1 Background and Objectives

1.1 Introduction

The purpose of this protocol is to provide a comprehensive plan to be used in implementing the SWAN Nearshore Vital Signs program. A well-developed, field-tested and reviewed Monitoring Protocol is a critical component of Quality Assurance for any monitoring program. This protocol summarizes the scoping and planning processes described by Bodkin and Dean (2003) and Bennett et al. (2006) and provides an overview of design elements and procedures to be used in implementation of the protocol. Specifically, it provides:

- Background and rationale for marine nearshore monitoring
- Marine nearshore vital signs, monitoring questions and objectives
- A sampling design with rationale for its selection
- Metrics selected for sampling
- Specific sites to be used in sampling
- Proposed frequency of sampling and a proposed master schedule for plan implementation
- A structure for a database management system to be used in the nearshore
- Proposed guidelines for analysis of the data
- Proposed guidelines and schedules for review and modification of the design over time
- Estimated costs associated with implementation of the design
- Standard Operating Procedures (SOPs) for each task outlined in sampling design

Details on how all aspects of the components described in the narrative will be carried out is provided in a series of Standard Operating Procedures (SOPs). The SOPs are written in the form of instructions, with step-by-step details of how to carry out the procedure. Both the Protocol Narrative and SOPs were developed using guidelines established in Oakley et al. (2003).

1.2 Rationale for monitoring the marine nearshore

The nearshore can be defined as that section of the marine ecosystem that extends from the high tide line, offshore to depths of about 20 m. It can be divided into the backshore (zone that extends landward from the higher high water line, or "spray zone" influenced by storm tides), intertidal zone (between high-high water and lower-low water), and the nearshore subtidal (from lower-low water to depths of 20 m). The intertidal shorelines are geologically diverse and vary from sheltered marshlands and beaches to steep rocky outcroppings subjected to high waves. The subtidal zone is a mix of cobble/ gravel, rocky outcroppings, and sand/silt. The subtidal substrate composition is only loosely correlated with that observed in adjacent intertidal zones.

The nearshore is considered an important component of the SWAN parks and the Gulf of Alaska (GOA) system because it provides:

- A variety of unique habitats for resident organisms (e.g. sea otters, harbor seals, shorebirds, seabirds, nearshore fishes, kelps, seagrasses, clams, mussels, and sea stars).
- Nursery grounds for marine animals from other habitats (e.g. crabs, salmon, herring, and seabirds).
- Feeding grounds for important consumers, including, killer whales, harbor seals, sea otters, sea lions, sea ducks, shorebirds, brown bears, and many fish and shellfish.
- A source of animals important to commercial and subsistence harvests (e.g. marine mammals, fishes, crabs, mussels, clams, chitons, and octopus).
- An important site of recreational activities including fishing, boating, camping, and nature viewing.
- A source of primary production for export to adjacent habitats (primarily by kelps, other seaweeds, and eelgrass).
- An important triple interface between air, land and sea that provides linkages for transfer of water, nutrients, and species between watersheds and offshore habitats.

The nearshore is broadly recognized as highly susceptible and sensitive to a variety of both natural and human disturbances on a variety of temporal and spatial scales (Reviewed in Valiela 2006, Bennett et al. 2006, Dean and Bodkin 2006). For example, observed changes in nearshore systems have been attributed to such diverse causes as global climate change (e.g. Barry et al. 1995, Sagarin et al. 1999), earthquakes (e.g. Baxter 1971), oil spills (e.g. Peterson 2001, Peterson et al. 2003), human disturbance and removals (e.g. Schiel and Taylor 1999), and influences of invasive species (e.g. Jamieson et al. 1998). Nearshore systems are especially good indicators of change because organisms in the nearshore are relatively sedentary, accessible, and manipulable (e.g. Dayton 1971, Sousa 1979, Peterson 1993, Lewis 1996). Also, in contrast to other marine habitats, there is a comparatively thorough understanding of mechanistic links between species and their physical environment (e.g. Connell 1972, Paine 1974, 1977, Estes et al. 1998) that facilitates understanding causes for change. Also, the nearshore is the one habitat within which it is most likely that we will be able to detect relatively localized sources of change, tease apart human induced from naturally induced changes and, provide suggestions for management actions to reduce human induced impacts. Because many of the organisms in the nearshore are sessile or have relatively limited home ranges, they can be geographically linked to sources of change with a reasonable degree of accuracy.

1.3 Marine nearshore vital signs

This protocol will address six SWAN vital signs: Kelp and Seagrasses, Marine Intertidal Invertebrates, Marine Birds, Black Oystercatcher *(Haematopus bachmani*), Sea Otter (*Enhydra lutris)*, and Marine Water Chemistry and Quality.

Kelp, other algae, and seagrass are "living habitats" that serve as a nutrient filter, provide understory and habitat for planktivorous fish, clams, urchins, and a physical substrate for other invertebrates and algae. Kelps are the major primary producers in the marine nearshore and because they are located in shallow water they could be

significantly impacted by human activities. These include spills of oil or other contaminants, dredging and disturbance from anchoring of vessels, and increased turbidity caused by runoff of sediments or nutrients.

Marine Intertidal Invertebrates provide critical food resources for shorebirds, ducks, fish, bears, sea otters, and other marine invertebrate predators, as well as spawning and nursery habitats for forage fish and juvenile crustaceans. Benthic invertebrates and algae are ecologically diverse in terms of habitat and trophic requirements; have a wide range of physiological tolerances; are relatively sedentary, and have varied life-histories. As a result, they are good biological indicators of both short-term (e.g. annual) and long-term (e.g. decadal scale) changes in environmental conditions.

Marine Birds are predators near the top of marine nearshore food webs. Marine birds are long-lived, conspicuous, abundant, widespread members of the marine ecosystem and are sensitive to change. Because of these characteristics marine birds are good indicators of change in the marine ecosystem. Many studies have documented that their behavior, diets, productivity, and survival changed when conditions change. Public concern exists for the welfare of seabirds because they are affected by human activities like oil pollution and commercial fishing.

Black Oystercatchers are well suited for inclusion into a long term monitoring program of nearshore habitats because they are long-lived; reside and rely on intertidal habitats; consume a diet dominated by mussels, limpets, and chitons; and provision chicks near nest sites for extended periods. Additionally, as a conspicuous species sensitive to disturbance, the Black Oystercatcher would likely serve as a sentinel species in detecting change in nearshore community resulting from human or other disturbances.

Sea Otters are keystone species that can dramatically affect the structure and complexity of their nearshore ecological community. They cause well described top-down cascading effects on community structure by altering abundance of prey (e.g. sea urchins) which can in turn alter abundance of lower trophic levels (e.g. kelps). Sea otters generally have smaller home ranges than other marine mammals; eat large amounts of food; are susceptible to contaminants such as those related to oil spills; and have broad appeal to the public. Recent declines in sea otters have been observed in the Aleutian Islands. Currently declines are documented in areas to the west of Swan parks. However, as a result of these declines, the Western Alaska stock of sea otters (which includes populations in Katmai National Park and Preserve as well as Aniakchak National Monument and Preserve), was federally listed as threatened on September 2005 as threatened.

Marine Water Chemistry and Water Quality, including temperature 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 biotic community. Basic water chemistry parameters provide a record of environmental conditions at the time of sampling and are used in assessing the condition of biological assemblages. Water quality (including water temperature, salinity, and levels of contaminants such as heavy metals

and organic pollutants) are also critical in structuring nearshore marine ecosystems and can cause both acute and chronic changes in nearshore populations and communities.

1.4 SWAN monitoring questions and objectives to be addressed by this protocol

The overarching question to be addressed by the SWAN nearshore vital signs program is: "How will nearshore resources within the parks change over time?" A secondary question is "What are the potential causes for observed changes?" The objective of the SWAN nearshore program is to assess changes by annually monitoring vital signs (as described above) within the SWAN parks and to describe changes and assess potential causes by comparing values for different vital sign metrics (e.g. number of sea otters) over time and by examining how the relative extent of change over time varies among locations. Specific questions and objectives for each of the vital signs are:

Kelp and Seagrass

Question:

- What are the large-scale (park-wide, over decades) trends in the relative abundance and distribution of canopy forming kelps, intertidal algae, and eelgrass?
- What are annual trends in the abundance of canopy forming kelps, intertidal algae, and eelgrass?
- How do inter-annual changes in relative abundance of eelgrass differ among locations?

Objective:

- Estimate long-term trends in abundance and distribution of kelp and eelgrass at various locations.

Marine Intertidal Invertebrates

Questions:

- How are the composition and relative abundance of intertidal algae and invertebrates changing annually?
- How do inter-annual changes in relative abundance of intertidal algae invertebrates differ among locations?

Objectives:

- Monitor long-term trends in species composition and abundance of algal and invertebrate species at various locations.
- Document how the size distributions of limpets (*Lottia persona*), mussels (*Mytilus trossulus*), and clams are changing annually at various locations.

Marine Birds

Question:

- How is the species composition and abundance of birds (and especially those closely linked to the nearshore, such as harlequin ducks and Barrow's goldeneye) changing annually during summer and winter?
- How do inter-annual changes in the number of bird species present and the relative abundance of birds differ among locations?

Objective:

- Estimate long-term trends in the seasonal abundance of seabirds and seaducks at various locations.

Black Oystercatcher

Question:

- How are the relative density (pairs per linear kilometer of shoreline) of black oystercatcher nests and the nest site productivity (number of chicks or eggs per nest) changing annually?
- How is the composition of prey provisioned to black oystercatcher chicks changing over time?
- How do inter-annual changes in density of black oystercatchers and composition of prey provisioned to chicks differ among locations?

Objective:

- Estimate long-term trends in relative density and nest site productivity of black oystercatchers at various locations.
- Estimate long-term trends in black oystercatcher diet through collection of prey remains at various locations.

Sea Otter

Questions:

- How is abundance and spatial distribution of sea otters changing over time?
- How is age-specific survival of sea otters changing annually?
- How is the diet of sea otters changing annually?
- How do inter-annual changes in abundance, survival, and diet differ among parks?

Objectives:

- Estimate long-term trends in sea otter abundance and spatial distribution.
- Estimate and compare age-specific survival rates of sea otters among regions within the Gulf of Alaska.
- Estimate diet composition of sea otters at various locations.

Marine Water Chemistry and Quality

Questions:

- How are seasonal and annual patterns of sea surface temperature, chlorophyll-a standing stock, sediment levels, and flow patterns changing in nearshore waters of Shelikof Strait, Lower Cook Inlet and the Outer Kenai Peninsula?
- What is the daily, seasonal, and annual variation in intertidal water temperature and salinity and how are these changing over time?
- How is the concentration of contaminants in mussel tissue (an integrated index of contaminant concentrations in water) changing over time?
- How do inter-annual changes in water chemistry and contaminant levels differ among locations?

Objectives:

- Acquire regional synoptic nearshore oceanographic data collected by the Alaska Ocean Observing System (AOOS) and incorporate into regional (SWAN) data sets.
- Document daily, seasonal, and annual variability in temperature and salinity at various intertidal sampling sites.
- Monitor status and trends in the concentration of metals, PAHs (polycyclic aromatic hydrocarbons often associated with oil spill contamination), PCBs, pesticides, and metals in the tissues of mussels collected from various locations over time.

2 Sampling Design Overview

2.1 Meeting SWAN monitoring objectives

As indicated above, the objective of the vital signs monitoring program is to assess changes in nearshore resources within the SWAN parks over time and secondarily to identify potential causes for change. The nearshore is defined as that portion of the coastline that stretches from the high-tide line to approximately 20 m depth. The program described herein will meet these overall objectives using a design that calls for monitoring of vital signs (as described above) at various locations within the SWAN parks over time. Changes will be assessed and potential causes identified by comparing values for different vital sign metrics (e.g. number of sea otters) over time and by examining how the relative extent of change over time varies among locations. The design focuses on the Katmai National Park and Preserve (KATM) and Kenai Fjords National Park (KEFJ), and to a lesser extent on the Lake Clark National Park and Preserve (LACL) (Figure 1).

Except for shorezone mapping, no monitoring is planned for Aniakchak National Monument and Preserve (ANIA). Various vital sign metrics are evaluated on an annual (or for some metrics less frequent) intervals within each location. Sampling frequency was determined based on the expected extent of inter-annual variation for a given metric as well as cost and logistical constraints. For example, the species distribution and abundance of intertidal invertebrates that are known to exhibit high inter-annual variation are to be sampled either annually or bi-annually whereas less variable contaminant levels in mussel tissue are to be monitored every 5 years.

The number and location of sampling units differ among metrics, but in general the design calls for sampling at multiple locations within each park. The number of sampling locations and the rationale for this are specified in method specific SOPs, but in general were guided by preliminary estimates of effort required to detect ecologically meaningful levels of change. Sampling locations were selected to provide a random, spatially balanced distribution. The design allows for detection of large temporal or spatial-scale changes (e.g. changes that may occur over the entire SWAN region over time or at KATM vs. KEFJ). For some metrics (e.g. contaminants in mussels) the design will also allow for detection of changes that may occur on a more localized scale (e.g. at a site of heavy human influence).

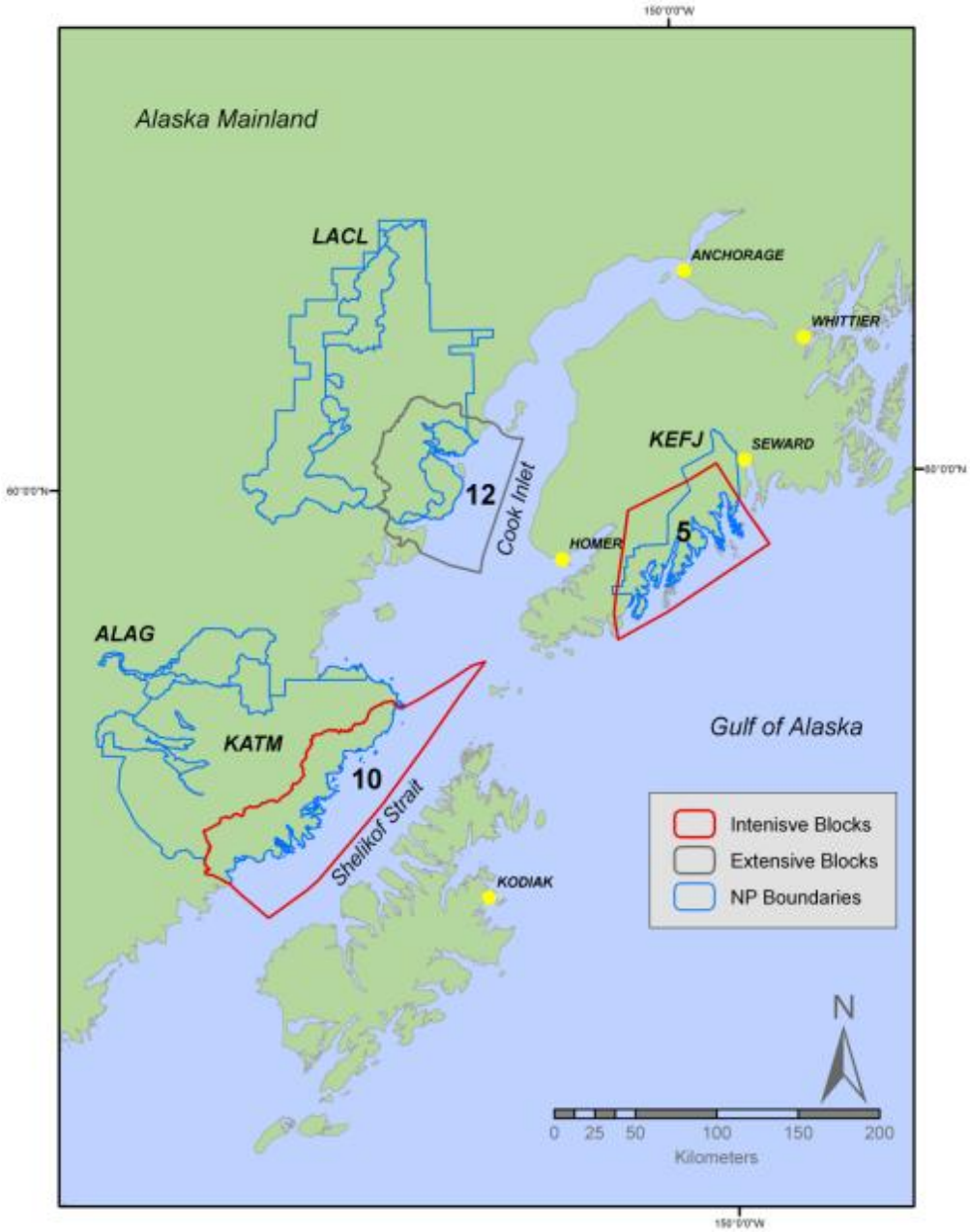


Figure 1. Sampling locations for the SWAN nearshore vital signs monitoring. Intensive sampling blocks (indicated in red) are locations for monitoring of all vital signs. Less frequent monitoring of a limited number of vital signs is to be conducted in the extensive block at LACL (indicated in grey). Sampling block numbers are those assigned as part of a larger Gulf of Alaska wide sampling design. Park boundaries are indicated in blue.

2.2 Design selection and alternatives considered

The SWAN nearshore vital signs monitoring program described here grew from a lengthy developmental process involving extensive input and evaluation from the public, resource

agencies, and the academic community. The initial program development for SWAN (Bennett et al. 2006) outlined the goals and objectives, identified vital signs, and outlined a process for future program development. In the same time frame, the *Exxon Valdez* Trustee Council sponsored a series of studies and workshops to develop a more geographically comprehensive program for monitoring changes in the nearshore over the region from Kodiak to Prince William Sound. The design presented here evolved from these earlier efforts that developed a conceptual design (Schoch et al. 2002), evaluated several design alternatives (Bodkin and Dean 2003), and provided a detailed nearshore monitoring and restoration plan (Dean and Bodkin 2006). The plan presented by Dean and Bodkin (2006) called for sampling within three blocks of approximately 10,000 km^2 within each of 4 regions: Kodiak archipelago, Alaska Peninsula, Kenai Peninsula, and Prince William Sound. A variety of metrics associated with the nearshore resources including sea otters, other marine mammals and birds, invertebrates, and algae were to be evaluated at various locations within each region. More frequent and comprehensive (in terms of metrics evaluated) sampling was to be conducted within one intensively sampled block per region. The sampling in intensive blocks was focused on detecting changes that may occur over larger spatial scales such as those associated with changes in climate. The plan also called for less frequent sampling at more widely dispersed sites within each of the 12 blocks that was aimed at detecting more localized changes such as those associated with point source discharges of contaminants.

The SWAN nearshore monitoring plan described here is based on the larger EVOS plan, but with several key differences. First, the SWAN nearshore vital signs program focuses only on the three blocks that include KATM, KEFJ, and LACL. Second, only metrics that were identified as SWAN vital signs are to be measured. Finally, most of the emphasis is on intensive sampling within the KATM and KEFJ blocks that is aimed at evaluating large geographic-scale impacts. These blocks are located in designated "regions" such as the Alaska Peninsula (AP) and Kenai Peninsula (KP) regions. KATM is in the AP region while KEFJ is in the KP region.

In the process of developing the SWAN and EVOS Nearshore monitoring programs we investigated most, if not all of the active nearshore monitoring programs along the west coast of North America (e.g. PISCO, MARINe, LIMPET, NAGISA, PSP, NOAA mussel watch). Where feasible we adopted and designed species and location specific procedures that would facilitate comparison of common metrics among existing and prior programs. For example, we employ point contact methods to estimate percent cover of intertidal invertebrates and algae that are similar to PISCO and MARINe methods that will facilitate comparison. We also estimate densities of large motile invertebrates (e.g. stars), that will be comparable to estimates from PISCO, MARINe, and other programs employing comparable techniques. In many instances species differences existed between existing nearshore monitoring programs in the contiguous US and Alaska requiring modification to available procedures. Where appropriate we adopted widely used and published methods to estimate marine bird densities (Irons et al. 2000) black oystercatcher abundance and diet (Andres 1998, Webster 1941) and sea otter abundance (Bodkin and Udevitz 1999), diet (Calkins 1978, Estes et al. 1981), and survival (Monson

et al. 2000). There are however fundamental differences between some of the SWAN objectives and other nearshore monitoring programs that are important. These include a SWAN objective to allow statistical inference to entire Parks and therefore required a random component to site selection, rather than focusing on specific selected sites. Compared to other existing programs, SWAN sites are remotely located and access is difficult and costly. As a result, our sampling frequency is generally equal to or greater than one year (with a few exceptions such as water quality), with limited ability to detect within year variation or trends. Furthermore, there are additional location-specific factors (e.g. a large tidal prism and high degree of disturbance due to ice and storms) that led us to different sampling designs than employed by other programs. Perhaps most importantly, the SWAN program attempts to encompass all major elements of the nearshore trophic web: kelps and seagrasses as primary produces, benthic invertebrates as primary consumers, and the birds and mammals as apex predators (i.e. Black oyster catchers, sea ducks and the sea otter). We know of no other nearshore monitoring program that incorporates this breadth of trophic interaction that will allow both "bottom-up" and "top-down" perspectives on causes of change in the nearshore marine ecosystem. This approach required adapting existing procedures where available and appropriate, and developing new ones as needed.

2.3 Design Overview

For most of the vital signs, sampling will be restricted to the KATM and KEFJ regions (here called intensive sampling blocks, Figure 1). Sampling in KATM and KEFJ will consist of:

1) Surveys of eelgrass and kelp canopy – The area covered by canopy forming kelps and eelgrass will be evaluated based on park-wide aerial surveys (Harper and Morris 2004) to be repeated on a ten to twelve year frequency. Changes in percent cover by eelgrass will also be evaluated in selected eelgrass beds on an annual basis. Selected sites will be areas of historical eelgrass cover (as documented by previous shorezone mapping conducted by Harper and Morris 2004) that are the nearest sites where intertidal and algal invertebrates are sampled. The boundaries of each bed will be located (either visually or using a fathometer and underwater camera) and positions recorded using a GPS.
2) Sampling of intertidal plants and invertebrates on sheltered rocky shores - Sites on sheltered rocky shores will be selected and sampled annually to estimate the abundance and distribution of intertidal invertebrates and algae. Five to six sites will be sampled within each block. Metrics will include number of algal and invertebrate species, abundances of selected dominant taxa and size distributions of limpets.
3) Sampling of infaunal invertebrates in gravel / mixed-sand gravel shores - Sampling of infaunal invertebrates will be conducted every other year at 5 gravel/mixed sand-gravel sites in each block. Sampling will focus on bivalves that are relatively large, long-lived, and common (Lees and Driskell 2006). Metrics obtained will include abundances of selected clam species and size distributions of several dominant species. Sediment samples will be obtained from gravel / sand-gravel site for determination of grain size distribution (every 6 to 10 years).

4) Sampling of Pacific blue mussels in mussel beds – The density and size distribution of mussels will be measured annually in 5 mussel beds in each park. The focus will be on larger mussels that are important prey for sea otters, sea ducks, and black oystercatchers. The selected beds will be the nearest beds to sheltered rocky intertidal sampling sites.
5) Sampling marine bird and mammal abundance – Marine bird and mammal abundance will be estimated via boat annually in summer and every two to three years in winter. Counts will be made 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 including harlequin ducks, Barrow's goldeneyes, and black oystercatchers (Webster 1941, Goudie and Ankey1986, Andres 1998). 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).
6) Sampling of black oystercatcher nest site density and oystercatcher chick provisioning - The number of black oystercatcher nest sites will be surveyed annually along shoreline transects. The number of eggs and/or chicks present will be counted as an index of nest productivity. The species composition and relative abundance of oystercatcher prey provided to chicks will be evaluated by sampling prey remains at oystercatcher nesting sites (Webster 1941, Andres 1998).
7) Aerial surveys of sea otter abundance - Sea otter abundance will be estimated within each block in the summer of every second or third 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. Changes in the spatial distribution of sea otters will also be examined using boat based surveys in summer.
8) Sampling of sea otter diets - The species composition and relative abundance of sea otter prey will be estimated annually using direct observation of sea otter feeding (Calkins 1978, Estes et al. 1981, Dean et. al 2002). These observations will provide an assessment of foraging efficiency (energy obtained per hour of feeding) as well as the composition of prey being consumed by sea otters. The latter will provide an indirect measure of the composition and relative abundance of representative intertidal and subtidal invertebrates that are difficult to sample directly.
9) Coastline surveys for collection of sea otter carcasses - Specified beach segments will be walked annually for collection of sea otter skulls. The segments will be in areas where sea otter carcasses accumulate and will be based on preliminary surveys within KATM and KEFJ. A tooth will be extracted from each skull and sectioned to estimate the age of the sea otter (Bodkin et al. 1997). The data on the age distribution of dead sea otters will be used to evaluate changes in age specific survival and to develop age-specific survival estimates based on an age-structured demographic model (Monson et al. 2000, Bodkin et al. 2002).
10) Sampling of water/air temperature, salinity, and contaminants in mussels- Intertidal water/air temperature will be measured at each of the sheltered rocky intertidal sites. Temperature recording devices will be fixed at the 0.5 m tidal elevation in the intertidal zone and will record temperature every 30 minutes on a year round basis.

Initially, salinity will be measured at a single site in each park. It is anticipated that more sites will be added if instruments prove reliable. The concentration of contaminants will be measured in mussels collected form rocky intertidal sites once every five years.

Sampling within the LACL region will be limited to estimating abundance of infaunal invertebrates on gravel / mixed sand gravel beaches. There is little rocky habitat within this region, and there are few sea otters or black oystercatchers. Sampling on gravel / mixed sand gravel beaches will be conducted at 5-8 sites as described above for the KATM and KEFJ blocks.

A summary of the sampling design, with sampling sites and sampling frequency associated with each task is given in Table 1.

Table 1. Summary of sampling design indicating sampling locations, number of sites sampled per location (if applicable) and frequency of sampling for each task. (continued).

Tasks	**Sampling sites**	**Frequency**
Kelp and eelgrass surveys	Shorezone mapping over entire KATM, KEFJ, LACL, and ANIA KATM and KEFJ -5 eelgrass beds per block	1 per 10 to 12 years 1 per year
Sheltered rocky intertidal invertebrates and algae	KATM and KEFJ – 5 sites per block	1 per year
Limpet size distribution	KATM and KEFJ	1 per year
Gravel / mixed sand gravel intertidal invertebrates	KATM, KEFJ, LACL – 5 sites per block	1 per 2 years
Mussel size and density in mussel beds	KATM and KEFJ	1 per year
Marine bird and mammal surveys - summer	KATM and KEFJ	1 per year
Marine bird and mammal surveys - winter	KATM and KEFJ	1 per 2 to 3 year
Black oystercatcher nest density and diet	KATM and KEFJ	1 per year
Sea otter abundance (aerial surveys)	KATM and KEFJ	1 per 2 to 3 year.
Sea otter diet	KATM and KEFJ	1 per year
Sea otter survival	KATM and KEFJ	1 per year
Temperature	KATM and KEFJ – 5 to 6 sites per block	Year round

Table 1. Summary of sampling design indicating sampling locations, number of sites sampled per location (if applicable) and frequency of sampling for each task. (continued).

Tasks	Sampling sites	Frequency
Salinity	KATM and KEFJ - 1 or more sites per block	Year round
Contaminants in mussels	KATM and KEFJ – 5 to 6 sites per block	1 per 5 years

Aerial digital video surveys of all shorelines within each park will be obtained approximately every 12 years using methods described by Harper and Morris (2004). The aerial video surveys are designed to characterize the geom[illegible] 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). All of the NPS shoreline has been surveyed in this manner over the past several years (Harper and Morris 2004). We also anticipate that satellite imagery describing sea–surface temperature and other physical chemical factors (e.g. surface chlorophyll) will be obtained and used as part of the nearshore program.

2.4 Selection of the sampling universe

As indicated above, sampling will be largely restricted to the KATM, KEFJ, and LACL coastlines, and will be concentrated in two blocks that correspond to the KATM and KEFJ boundaries (Figure 1). 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 vital signs 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. Of the other habitats, exposed rocky shores or exposed wave-cut platforms are the most represented. However, these are generally less accessible for sampling. The habitats that we do not intend to sample are clearly of ecological importance (e.g. tidal flats as critical habitats for birds), but focusing sampling efforts on a few representative habitats should produce a monitoring plan that is more sensitive and is more likely to detect change.

2.5 Selection of the size and number of sampling units

The size and number of sampling units to be included for evaluation of each metric within a given sampling period are given in Table 2 and described in detail in specific

Standard Operating Procedures. A sampling unit is defined as the smallest unit for which a particular metric is measured and expressed. For example, the number of sea stars will be counted within a 200 m^2 area and expressed as number per 100 m^2. For each metric, the size of the sampling unit and number of sampling units varies dependent largely on the behavior of the species associated with the vital sign being examined. In estimating abundance of larger, more motile species that have large and variable home ranges that can cover large portions of a block (e.g. sea otters), sampling will be conducted along relatively large random or systematically placed transects of several hundred meters or more that cover the entire block. For species that do not move about or have limited home ranges (e.g. invertebrates) sampling will be conducted at discrete, permanently established sites within each block. A site is here defined as an approximately 50 to 100-m section of coastline and the water directly adjacent to it. For these smaller, less motile species, sampling will be conducted within quadrats or transects ranging in size from approximately 0.10 to 200 m^2 at each site. The number of transects or quadrats sampled per site will range from one (for larger invertebrates like sea stars) to 24 (divided equally between two vertical strata) for smaller invertebrates and algae. The intent is to sample the number of units to provide sufficient statistical power to detect changes ranging from 20% to 80% (dependent on the metric, see section 2.9 below). These criteria were selected as ones that were both biologically meaningful and achievable given budgetary and logistical constraints.

Table 2. Overview of the sampling designs used in the evaluation of each vital sign.

Vital Sign	Primary metric	Sampling unit	Size of sampling unit	Number of sampling units per stratum & sampling period	Selection process for sample locations	Strata	Smallest spatial scale at which trends will be examined
Kelp and seagrass	Proportion of shoreline with canopy forming kelps and eelgrass	Park	Entire park shoreline	None	Not applicable	Blocks	Block
	Eelgrass bed area	Transect	Variable, ~ 200 m long	5 sites per block	Closest to rocky intertidal site	Blocks	Site
Intertidal invertebrates and algae – rocky shores	Sea stars abundance	Transect	200 m^2	5	GRTS	Blocks	Site
	Intermediate invertebrate (*Nucella* spp. and *Katharina tunicata*) abundance	Quadrat	2.0 m^2	12 quadrats per transect,10 transects per block (5 at each of 2 tidal elevations)	GRTS for transect, Systematic with random start for quadrats within transect	Mid and lower intertidal transects, blocks	Tidal level of transect at a site (50 m long)

Vital Sign	Primary metric	Sampling unit	Size of sampling unit	Number of sampling units per stratum & sampling period	Selection process for sample locations	Strata	Smallest spatial scale at which trends will be examined
Intertidal invertebrates and algae – rocky shores	Sessile invertebrate and algae abundance	Quadrat	0.25 m^2	12 quadrats per transect, 10 transects per block (5 at each of 2 tidal elevations)	GRTS for transect, Systematic with random start for quadrats	Mid and lower intertidal transects, blocks	Tidal level of transect at a site (50 m long)
	Limpet density and size distribution	Quadrat	Variable based on density of mussels or limpets	120 per site, pooled from 6 quadrats	GRTS for site, Systematic with random start for collection sites	Blocks	Site
Intertidal invertebrates – gravel/sand	Intertidal invertebrate abundance	Quadrat	0.25 m^2	12 quadrats per transect, 5 transects per block	GRTS for transect, systematic with random start for quadrats within transect	Blocks	Site
	Clam size, by species	Quadrat	Not applicable	Variable, dependent on the number of clams per site	GRTS for site, Systematic with random start for quadrats used for collection within transect	Blocks	Site

Vital Sign	Metric	Sampling unit	Size of sampling unit	Number of sampling units per stratum & sampling period	Selection process for sample locations	Strata	Smallest spatial scale at which trends will be examined
Mussels in mussel beds	Density	Quadrat	Variable based on density ($\leq 1 m^2$)	10 quadrats per site	Bed closest to rocky intertidal site	Blocks	Site
	Size distribution	Quadrat	Variable based on density ($\leq 1 m^2$)	10 quadrats per site	Bed closest to rocky intertidal site	Blocks	Site
Marine birds and mammals	Density	Transect	Variable, 2.5 - 5 km long x 100 m wide	30-40	Systematic with random start	Winter/summer, Blocks	Block
Black oystercatchers	Nest density	Transect	Variable, ~ 20 km long	5-6	Centered on GRTS site	Blocks	Block
	Productivity – eggs and chicks per nest site	Nest site	Variable, ~ 0.25 m^2	Variable, ~ 12	Selected - Dependent on nests sites	Blocks	Block
	Diet – Relative abundance of prey	Nest site	Variable, ~ 100 m^2	Variable, ~ 12	Selected - Dependent on nests sites	Blocks	Block
Sea otter	Abundance (aerial survey)	Transect	Variable, ~ 0.4 to > 10 km	Variable, ~200	Systematic with random start	Blocks	Block

Vital Sign	Metric	Sampling unit	Size of sampling unit	Number of sampling units per stratum & sampling period	Selection process for sample locations	Strata	Smallest spatial scale at which trends will be examined
Sea otter	Diet – Relative abundance of prey, Energy obtained per hour	Feeding bout	Not applicable	Variable, ~20	Selected – Dependent on where feeding otters are observed	Blocks	Block
	Age at death	Individual carcass	Not applicable	Variable, ~ 30	Selected – Dependent on where dead otters are found	Blocks	Block
Water Quality - Contaminants, temperature, and salinity	Concentration of contaminants in mussels	Site	Not applicable	60 per site, pooled from 12 quadrats per site	GRTS for site, systematic with random start for quadrats used for collection within site	Blocks	Site
	Temperature	Recorded every 30 minutes year round	Not applicable	1 recorder per site, 48 observations per day	GRTS for site	Block	Site
	Salinity	Recorded every 30 minutes year round	Not applicable	1 recorder per site, 48 observations per day	One or more GRTS sites	Block	Site

2.6 Locations for sampling

For shorezone surveys of kelp canopy cover and eelgrass cover, the entire shorelines of each park are censused. Discrete kelp bed locations selected for monitoring of the presence or absence of kelp were randomly selected from all kelp canopies designated as "continuous" in the shorezone surveys. Eelgrass beds used to estimate change in abundance annually were selected as the eelgrass bed closest to sites used for sampling of intertidal invertebrates (see below).

Transects used for sampling of marine birds and mammals were selected using a systematic selection with a random start point within the coastlines of each park.

Transects used for estimating black oystercatcher density were centered on sites used to sample intertidal invertebrates on rocky shores. Nest productivity is to be estimated at each nest site located within these transects and prey composition is measured at any nest site where prey are observed.

Sea otter abundance (aerial surveys) is to be estimated using counts of sea otters along transects within each block that were selected systematically with a random start point. Sea otter foraging observations are to be made at sites wherever sea otters are seen foraging within a 5 km radius of invertebrate sampling sites. This radius roughly corresponds to the home range for sea otters. Sampling will be focused as close to the invertebrate sites as possible but will be dependent on the presence of sea otters required to obtain the minimum sample of 50 forage bouts. Carcasses of sea otter skulls are collected from wherever skulls are found within each park, but will focus on specific locations where large numbers of sea otter carcasses have been found in the past.

Discrete sampling sites used to sample intertidal invertebrates and algae on sheltered rocky shorelines were selected using a generalized random tessellation stratified (GRTS) sampling scheme (Stevens and Olsen, 2004). This design provides a random yet spatially balanced distribution of sites within each Park. A GRTS design also allows for expansion or contraction of the number of sites to be sampled over time by pre-selecting a large number of sites that are ordered with respect to priority. Thus, sampling sites can be added or deleted without compromising the statistical or spatial integrity of the design.

Sites were selected using S-Draw, a windows-based GRTS sampling software program developed by McDonald (2005) (the users guide (GRTS for the Average Joe: A GRTS Sampler for Windows) for downloading the program go to: http://www.west-inc.com/computer.php). First, shorelines representing sheltered rocky or gravel/mixed sand gravel geomorphologic types were identified using Geographic Information System (GIS) software. The shoreline classifications used were from Environmentally Sensitive Index (ESI) maps produced for each region (RPI, 1983a, 1983b, 1985, 1986). The shorelines for a given habitat type were then divided into 1-m long segments and a data

file was produced which contained all segments within each block and their geographic coordinates. The S-Draw software was then used to produce an ordered list of 100 potential sampling sites within each block. A "pixelsize" of 1 m was used in the selection process to maintain a relatively widely dispersed array of sampling sites. In cases where two sites were in close proximity to one another (two or more within an embayment of a size roughly equivalent to 1 km^2) we eliminated the second site within that bay and chose the next site in the ordered list for sampling. This was done to maintain a relatively even spatial distribution. The actual sites sampled were not specified until an "on site" evaluation of habitat type was made. It was well known that there were misclassifications in the ESI index maps (Sundberg et al 1996) and in some cases selected sites were not of the appropriate habitat. In these cases sites were either moved to appropriate habitat up to two hundred meters from the selected location, or if there was no appropriate habitat within two hundred meters, alternative sites within the same bay were selected from the GRTS list of sites. For Katmai and Kenai sites, we conducted site evaluations in 2006 and 2007 respectively. Evaluation of sites in Lake Clark is planned for 2009. The location of actual (for Katmai and Kenai) or proposed (for Lake Clark) sampling sites is given in Figures 2a through 2c.

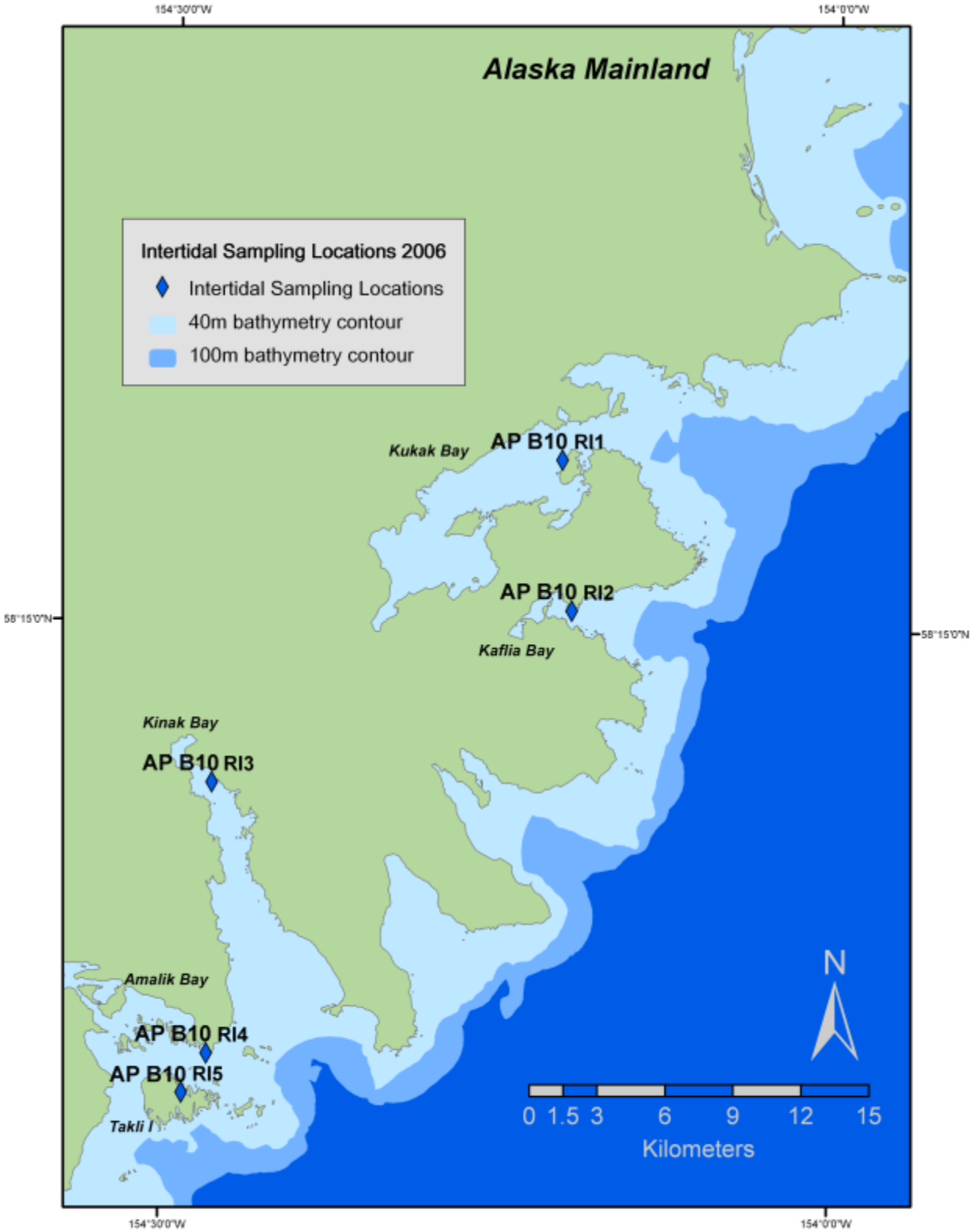


Figure 2a. Locations of intertidal invertebrate and algae sampling sites in Katmai National Park and Preserve.

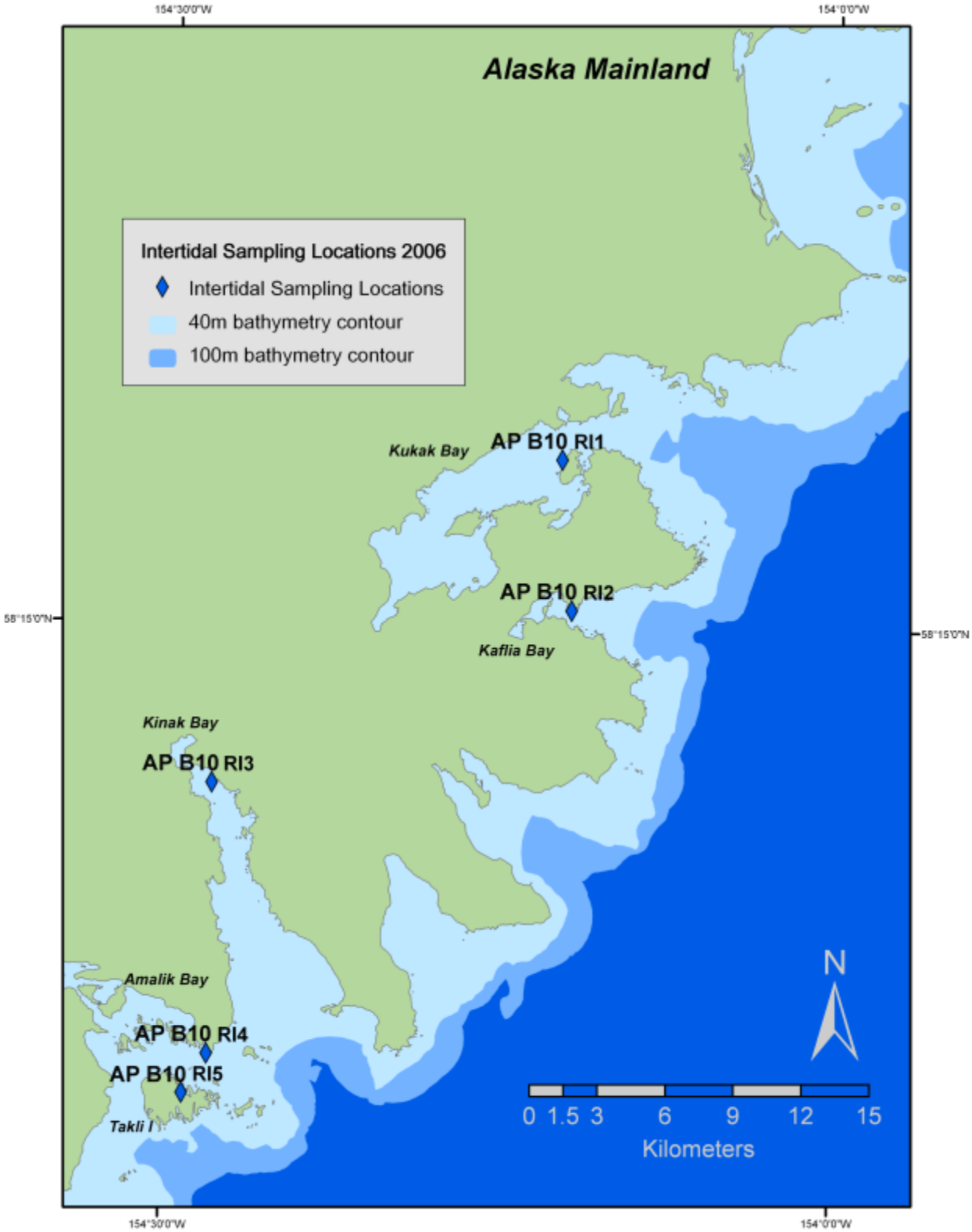


Figure 2b. Locations of intertidal invertebrate and algae sampling sites in Kenai Fjords National Park.

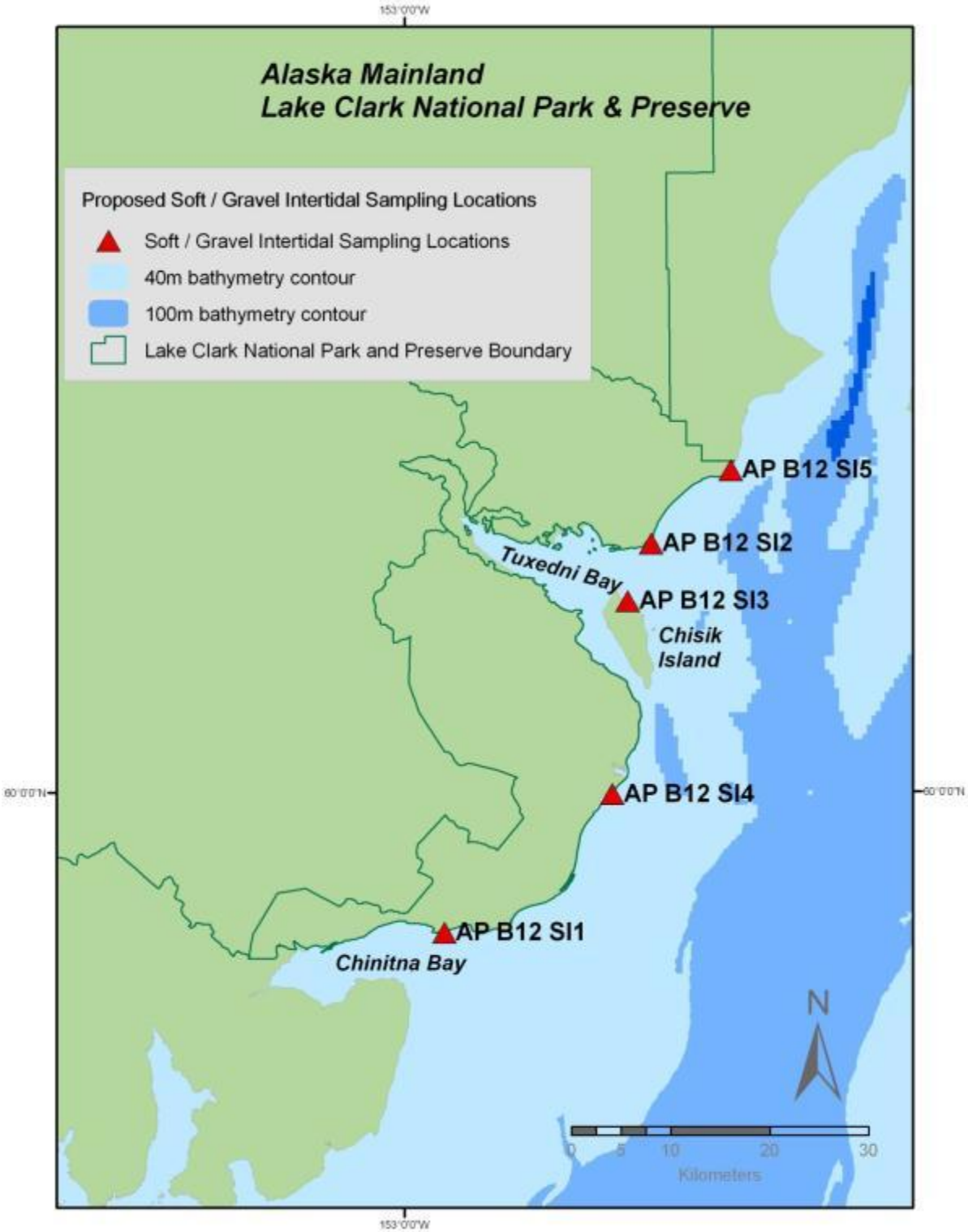


Figure 2c. Locations of intertidal invertebrate sampling sites in Lake Clark National Park and Preserve.

In addition to sites selected using the GRTS design, sampling may also be conducted at several sites that are selected based on their proximity to locations of probable future impact from shoreline development, sites with historical data of interest, or sites 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 as bird nesting and feeding habitats), based on their proximity to sources of potential anthropogenic disturbance (e.g. near boat harbors or population centers), or sites that have been sampled in the past and can be utilized to capture historical data and extend historical data sets. A list of potential selected sites is given in Table 3.

Table 3. Potential selected sampling sites.

Selected sites	Block	Reason for Inclusion
Ninagiak Island	KATM	Bird nesting site and sea otter foraging site.
Illiamna Bay	AP	Port site (mining logging)
Sukoi Bay	AP	Close to shipping lane

Data obtained from randomly selected sites that were chosen using the spatially- balanced GRTS procedure can be used to make inference to the specific habitat and block with respect to the parameters measured at these sites. Data from selected sites cannot be used in this manner, but will likely be beneficial in detecting change. Sampling sites that are anticipated to be of high risk to anthropogenic disturbance or have historical data should enhance our ability to detect change and likely will provide early indicators of change that might trigger further studies.

Water quality metrics (contaminants in mussels, temperature, and salinity) are to be measured at sites identified for sampling of intertidal invertebrates on rocky shores.

2.7 Sampling frequency

The frequency of sampling will vary with metric (Table 2). In general, biological metrics will not be sampled at a frequency of more than once per year. Some physical measurements such as temperature will be measured 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) will 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 funds for such studies may need to be obtained from agencies other than NPS. 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.

2.8 Power and the levels of detectable change

As indicated in Section 2.1 above, the objective of the sampling program is to assess how various metrics change over time and how those changes vary with respect to location. The levels of

change that we can expect to detect and the time and spatial scales over which they are to be detected vary with metric. The spatial scales over which trends will be examined range from a block (for large motile species like sea otters) to a site (for smaller, less motile species like mussels) (Table 2). In general, the goal for most biological metrics (e.g. abundance of sea otters, harlequin ducks, or dominant intertidal invertebrates like mussels) is to detect levels of change that are deemed to be of ecological importance (see section 4.2.6 for a discussion of determination of levels of change that are deemed ecologically important for each metric). In general, we hope to detect changes ranging from 20 to 80% (depending on the metric) at a given location (e.g. park). The ability to detect change can be expressed as power, the probability that a given level of change could be detected given the sampling design employed. Power analyses can also be used as a planning tool, to determine the sampling effort required to detect a given level of change with a prescribed power. As indicated in Section 4.0 below, it is anticipated that one of the primary methods used to detect change will conceptually take the form of mixed-model analyses (McCullouch et al. 2008) that examine, at a minimum, time (year) and location as the primary factors. The location factor consists of parks (and in some cases sites nested within each park) with replicate samples within the park. Various mixed models would examine the extent of variation for a particular metric could be attributed to location (e.g. park or sites within a park), time, and the interaction between these factors.

The power of a given design to detect a given level of change depends on the sample mean, sample size (n), variances for a given factor. Variances of importance in determining power are among locations (to detect a time effect), among times (to detect a location effect), and in the relation between locations over time (to detect an interaction). Unfortunately, for the metrics of interest in the Vital Signs program, data have not been collected over multiple years within each region. Therefore, variances needed to conduct the appropriate power analyses (those required to determine sample sizes required to detect reasonable levels of change for time, location, or time by location effects) are currently unavailable.

It may be possible to make a reasonable approximation of power for each metric by estimating ranges of means and variances, based in part on data from elsewhere, and then performing simulations to estimate a range in levels of detectable change that might be expected. However, these have not been performed to date because such an effort is outside of the current scope of work. This is especially the case given the number of metrics that would need to be examined. Instead, it is suggested that the appropriate power analyses be performed as data are gathered (after five years, and at five year intervals thereafter) to determine the power to detect changes and to modify sampling designs as required. These changes might suggest reducing sampling effort to achieve greater efficiency or increasing sampling effort in order to achieve reasonable power to detect change.

It is reasonable to assume that the power required to detect a given level of change will increase over time as the number of surveys increases. This again stresses the need for conducting periodic power analyses to suggest modifications to sampling designs over time and to ensure efficiency in the sampling.

The power to detect a given level of change also depends on biases associated with a particular sampling regime (Tyre et al, 2003, Earnst et al. 2005). For example, these might include biases introduced by using different observers in aerial surveys of sea otters or birds or those associated with the inability to detect all individuals present. When possible, we will account for these biases in our analyses. For example, we will use COMDYN software (Hines et al. 1999) or similar procedures to account for potential biases resulting from differences in detection probabilities where appropriate (Nichols et al. 1998, see section 4.2 below). However, for some of the metrics we will examine, we have no easy means of accounting for biases (including those related to detection probabilities) and no corrections will be made. Specific methods used to account of undetected species or individuals, or the rationale for why this was not done are given in individual standard operating procedures.

3 Field Methods

3.1 Field Methods

Field methods used in the vital signs program are outlined in specific standard operating procedures. In most instances, we rely on specific methods that have been field tested and used previously to successfully provide data for each metric. However, in several instances (e.g. surveys of kelp canopy and eelgrass cover) there are several possible methods, and newer untested technologies or techniques need to be explored before definitive decisions can be made regarding methods to be used. In these cases, we provide a general discussion of the methods and suggest what further work needs to be conducted before a particular technique is adopted.

It is a certainty that there will be technological advances over the coming years that will make for more efficient or more precise estimation of given metrics. Thus, it is anticipated that methods described in standard operating procedures will need to be modified over time. It is recommended that when new techniques are adopted, that there be a period when both new and existing protocols are conducted simultaneously. This will ensure that any protocol specific biases will be revealed and that the integrity of long-term data sets will be maintained.

4 Data Management, Analysis and Reporting

4.1 Data Management

4.1.1 Introduction

Effective archival and communication of information can only be achieved through the use of a data management plan that provides a means of documenting and storing data, transferring information among scientists and the public. A comprehensive data management plan is currently under development with the assistance of National Park Service staff, and is being developed under guidelines set forth for the larger NPS vital signs program (Mortenson 2006). The following outlines elements to be included in the data management plan and provides steps for implementation of the plan. The specific goals of the data management plan are:

1. Ensure accuracy and maintain integrity of the data as gathered by investigators.

2. Provide for an efficient exchange of information among nearshore vital sign investigators, and between these investigators and NPS staff.

3. Provide a mechanism by which data and reports can be archived.

4. Provide a framework by which analyses presented in reports can be traced to methods used to collect data and to the underlying data obtained during the initial data collection.

5. Provide a mechanism by which managers and the public can gain access to the information obtained.

There are several keys to the successful implementation of such a plan. First, the plan must be a written document. Second, there must be a management framework that clearly defines responsibilities for the plan's implementation. Third, all scientific investigators and their staffs must be trained to ensure that all data are obtained and transferred as specified by the plan.

Here we provide a framework by which a more complete plan can be produced and implemented as the project progresses. The complete plan will include the standard operating procedures, data sheets to be used in data collection, a complete description of all metrics included in the data, and an outline of the database structure. Attached are standard operating procedures that include field data sheets and examples of raw data files. A final database structure and design is yet to be completed. Also, the details of procedures and mechanisms for information storage and transfer have not been fully developed.

The data management plan is intended to be a "living" document that will change as procedures are modified according to the needs of each investigator. While we have attempted to anticipate all of the possible permutations, there are almost always changes required. One seldom is able to anticipate all of the potential problems associated with field studies, and the subtleties of the data being gathered.

4.1.2 Data managers and information flow

The data manager for the vital signs program will be a Park Service staff member who is responsible for the overall design and maintenance of vital signs databases. After collection and timely review, all data files will be submitted by investigators to the vital signs data manager for inclusion in the vital signs database. It will also be the responsibility of the data manager to ensure that hardware and software are provided for the transfer and archiving of information, and for the development of transfer protocols. It will also be the responsibility of the data manager to maintain the central database, to maintain an updated index or metadata database, and provide a means of disseminating information in the database to the other investigators, and the public.

It will be the responsibility of each investigator to ensure that the data presented to the data manager is in an appropriate, pre-determined format, and is an accurate representation of the data as collected. The investigators will designate specific persons on her/his staff who have authority to submit data or request data from the data manager.

4.1.3 Written documentation

Written documentation will primarily be provided in the form of the monitoring protocol provided here, standard operating procedures, and reports. All procedures, including field operations, laboratory analyses, data management, data distribution, report production, and the archiving of files will be provided in SOPs. All SOPs will contain the author's name, the draft number, the effective date of the SOP, a brief statement of its purpose, and the specific training required to use the SOP. The format will follow that outlined by Oakley et al. (2003). SOPs are to be reviewed every year and updated as required. New SOPs are to be written as new procedures are adopted.

4.1.4 Training

Before an SOP can be used, all of those persons who will utilize the procedure must be trained. The level of training will be dependent on the procedure and will be at the discretion of the principal investigator in charge of that particular task. At a minimum, all users will be required to have read the SOP, and to have demonstrated their understanding of it. More elaborate training procedures involving hands on training and proficiency testing may be required in some instances and will be defined in individual SOPs.

4.1.5 File structure and databases

An outline for a suggested file structure for the nearshore data management program is given below. Files are to be organized under major file-folder headings and subfolder headings including the following:

Administrative
Protocols
Bibliography_Documents
Graphics
Photos: not site ID photos
Data_Sampling (data used for site/transect selection process

Data_Collection: Data is organized by the data collection method and year. Once the data has been deemed clean, a copy is made for the 540_Data_QAQC directory.

\SOP1_Coastline_Surveys (sea otter carcasses)

\SOP2_Sea_Otter_Forage

\SOP3_Mar_Bird_Mammal_Surveys

\SOP4_Inverts_Rocky_Shores

\SOP5_Sea_Otter_Aerial_Surveys

\SOP6_Inverts_Gravel_Sand_Beaches

\SOP7_Black_Oystercatcher

\SOP8_Mussels_Beds

Data_Analysis

Data_QAQC: validated & verified seasonal data. (Staging area prior to import into master datasets).

Data_Master: master datasets. Lookup tables as well as field data.

Data_Design: Staging area for developing database applications.

Samples_Collected: Sample tracking database for collection, storage, analysis….

Reports_and_Presentations:

\Field trip

\Annual

\Final

\Presentations

\Posters

Field or laboratory data that are initially recorded in 'hard copy' form and later transferred to electronic form should be maintained by individual investigators. Raw data files are access, excel or similar files that may be entered and edited hard copy field or laboratory data sheets. Analysis files are those used to manipulate or provide summaries of statistical analyses of the raw data. Metadata files describe the contents of each raw or analysis file. With the exception of hard copy raw data files, all files are to be in electronic format and are to be maintained by the data manager.

Analysis flow diagrams describe procedures used to obtain a particular result (figure, table, or descriptive result) given in a report. Any presentation of data in a report will be accompanied by an appendix that lists an analysis flow diagram that describes the steps taken in producing the table or figure. This flow chart will allow one to trace the summary presentation back to field or laboratory data sheets and allow for efficient data audits. The diagram will indicate all the names of any intermediate databases used in the production of the final table or figure, as well as the names of all analysis files.

Sampling locations are to be described using latitude and longitude (degrees, decimal degrees) and the NAD 83 datum.

4.1.6 Acronyms and abbreviations

The database management system will use the following standardized abbreviations and acronyms:

Vital Signs:

- KELP = Kelp & Eelgrass
- MAII = Intertidal Invertebrates
- MBM = Marine Bird & Mammals (live)
- BLOY = Black Oystercatcher
- SEOT = Sea Otter
- MADE = Marine Debris
- MACA = Marine Carcasses
- MAWQ = Marine Water Quality

Park/Location Codes:

- KATM = Katmai
- ANIA = Aniakchak
- KEFJ = Kenai Fjords
- LACL = Lake Clark
- ALAG = Alagnak Wild River
- SWAN = Southwest AK Network

Status Codes

- Raw = raw
- Draft = draft

- QAQC = ready for import into a final database, verified, validated
- Final = final product (image, illustration, analysis, etc)
- InProg = a step or steps up from Raw, but QAQC not completed yet (data files), basically a 'work in progress' for other file types.

4.1.7 File naming

Files and directories are to be named according to the following naming standards. File names will use date for versioning as YYYYMMDD. Names are to be kept as short as possible, using abbreviations or acronyms as indicated above where applicable. Spaces and unusual characters (e.g. % or &), or reserved words (e.g. DATE) are to be avoided in both folder and file names. Conventions for commonly used file types are as follows:

- Reports
  AuthorLastNameFirst Initial_YEAR_CODE_Title_YYYYMMDD.doc
  (e.g. BodkinJ_2004_AK_Forage_Depths_SeaOtters_200401.doc)

- SOP Files
  SOPNum_VitalSign_Method_Title_YYYYMMDD.doc
  (e.g. SOP01_SeaOtter_Forage_DataCollection_200603.doc)

- Field Data Sheets
  SOPNum_VitalSign_Num_Title_YYYYMMDD.doc
  (e.g. SOP01_SeaOtter_Forage1_FieldDataSheet_200603.doc)

- Spreadsheets, Analysis Files (SAS Programs, Sigmastat, etc), GIS Files, etc:
  SOPNum_VitalSign_Num_Title_Status_YYYYMMDD.xxx
  (e.g. SOP01_SeaOtter_Forage1_Block10_ForageData_RAW_20061025.doc)

- Images (non-data):
  Code_YYYY_Description_###.jpg
  (e.g. KATM_2006_BrownBear_and_Cub_001.jpg)

4.1.8 Metadata

Metadata will be created per Executive Order 12906 (1994) requiring the creation of metadata for all data sets as well as allowing metadata to be available to the public. Metadata structure will follow the Biological Data Profile of the Content for Digital Geospatial Metadata or the Metadata Profile for Shoreline Data for FDGC CSDGM standards, depending on data type. FDGC CSDGM standards as well as the above mentioned profiles may be found at the following website: http://www.fgdc.gov/metadata/geospatial-metadata-standards. Metadata databases will be developed to facilitate access to information in raw files, intermediate databases, and analysis files. Separate metadata databases will be developed for geospatial data (GIS coverages) and for non-geospatial data. These will contain at least the minimum requirements described in the FDGC CSDGM standards which are: Identification information (contain data entry fields that ask for citations, spatial domain, keywords, access constraints and analytical tool use) and Metadata Reference Information (contains data entry fields that ask for metadata date, metadata contact, metadata standard name and metadata version). Geospatial and non-geospatial metadata

will be created using ArcCatalog (ESRI) and Metavist. Creation of metadata will allow for efficient searching of data not only for the proposed project participants, but for ease of data distribution and collaboration across disciplines and reduce the possibility of duplication. Investigators will be responsible for updating metadata information sheets associated with each file and forwarding these to the data manager.

4.1.9 Information transfer

It is anticipated that the data will be housed and served in a web accessible form. A website for this purpose has yet to be developed, but it is anticipated that this website will serve the following functions.

1. Provide general project information to other scientists and the public. This would include contact numbers, project descriptions, biographies of key personnel, a schedule of events, descriptions of new and exciting findings, and access to reports.
2. Provide a web-based server that will house all of the nearshore data, documents, etc. and will provide a means of accessing the data by project personnel as well as non-project persons. It is anticipated that some files (e.g. raw data files or certain correspondence files) will be accessible only to investigators. Others will be publicly available.
3. Provide a means of accessing the data in a linked and searchable fashion. For example, provide a means of obtaining information relating to a specific location such as: data on mussel abundance at a particular site, maps of the site based on GIS coverages, and shoreline aerial video of the site. Other important aspects include providing linkages between a particular data set with an SOP under which the data were collected or linking numerical data with images.
4. Create and maintain records of edits to data files and archive older versions of files.
5. Create a "community forum" bulletin board where members of coastal communities can record observations of significance. These might include observations regarding particular events such as when and where the first herring spawn occurred in a given year, unusual weather, or unusual occurrences of dead animals in the nearshore.

4.2 Analysis of monitoring data

4.2.1 General guidelines

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. Specific types of analyses to be performed will vary with metric and are detailed in specific standard operating procedures. The following provides a generic discussion of types of analyses to be used. In large part, the discussion focuses on changes (primarily declines) in the density or other important demographic measures (e.g. survival or size structure) of species that are currently relatively abundant. However, our sampling designs (especially for intertidal algae, intertidal invertebrates, and marine birds) are inclusive of both rare and abundant species. Therefore, we should also be able to detect increases in rarer species that may occur over time.

4.2.2 Selection of primary metrics

The number of potential metrics to be used in the evaluation of vital signs is large and not all metrics provide the same degree of information with respect to insights as to trends in vital sign

resources. For example, over 70 taxa of invertebrates and algae were identified in 2006 and 2007 surveys of sheltered rocky intertidal sites at KATM. However, the majority of these are relatively rare and indices of abundance for many are highly variable over time. As a result, indices of abundance for most of the taxa encountered are not suitable as vital sign indicators. Therefore, we have chosen to limit the number of primary metrics used to evaluate various vital sign resources on a routine basis. In general, we selected metrics that were deemed to be of ecological importance and that could provide reasonable power to detect trends over time. A preliminary list of these metrics is given in Table 4 and the rationale for their selection is given below. Other "secondary" metrics will be maintained in the databases and used on an ad hoc basis to evaluate change. For example, the sudden dominance by an intertidal invertebrate species in surveys of rocky shorelines or in the diet of sea otters might be deemed important and evaluated as an indicator of change in the future.

Table 4. Primary vital sign metrics to be analyzed to detect changes in the nearshore system on a routine basis. Also given are preliminary guidelines for degree of change deemed ecologically important (as discussed in Section 4.2.6 below).

Vital sign	**Metric**	**Degree of change deemed ecologically important**
Kelps and seagrass	Km of coastline with canopy forming kelp (based on shorezone surveys)	50% reduction
	Km of coastline with eelgrass (based on shorezone surveys)	25% reduction
	Area with eelgrass present	25% reduction
Intertidal communities-rocky	Number of algal and invertebrate species	30% change
	Percent cover bare substrate	80% change
	Percent cover barnacles	80% change
	Percent cover *Fucus distichus*	80% change
	Percent cover *Alaria* sp.	80% change
	Percent cover *Neorhodomela/Odonthalia* spp.	80% change
	Density of *Nucella* spp.	80% change
	Density of *Katharina tunicata*	80% change
	Density of sea stars	80% change
	Density of *Evasterias troschelii*	80% change
	Size distribution of *Lottia persona*	50% change

Vital sign	**Metric**	**Degree of change deemed ecologically important**
Intertidal community-soft	Density of *(Leucoma staminea)*	80% change
	Density of *Saxidomus gigantea*	80% change
	Density of *Macoma* spp.	80% change
	Size distribution of *(Leucoma staminea)*	50% change in mean size
	Size distribution of *Saxidomus gigantea.*	50% change in mean size
	Size distribution of *Macoma* spp.	50% change in mean size
Intertidal Community – mussel beds	Density of *Mytilus trossulus* >20 mm	80% change
	Total biomass of *Mytilus trossulus* >20 mm mussels	50% change
Marine birds	Number of bird species - summer (including rates of local extinction, colonization, and turnover)	50% reduction
	Number of bird species – winter (including rates of local extinction, colonization, and turnover)	50% reduction
	Abundance of harlequin ducks in winter	50% reduction
	Abundance of Barrow's goldeneye in winter	50% reduction
	Abundance of black-legged kittiwakes in summer	50% reduction
	Abundance of glaucous-winged gulls in summer	50% reduction
	Abundance of pigeon guillemots in summer	50% reduction
	Abundance of cormorants in summer	50% reduction
	Abundance of scoters in summer	50% reduction
	Abundance of harlequin ducks in summer	50% reduction

Vital sign	**Metric**	**Degree of change deemed ecologically important**
Black oyster catcher	Density of active nest sites	50% reduction
	Number of chicks or eggs per nest site	50% reduction
	Species composition of prey remains (proportion of *Mytilus trossulus* , *Lottia persona*, *Lottia scutum*, and *Lottia* spp.)	Not determined
	Size distribution of remains of dominant prey (*Mytilus trossulus* and *Lottia persona*)	Not determined
Sea otter	Abundance (Number per region based on aerial surveys)	40% change
	Proportion of dominant prey in diet (proportion of clams, mussels, crabs, and "other")	35% change
	Hours required to obtain energy required for maintenance.	20% increase; 33% decrease
	Proportion of carcasses in young, prime age, and aged age classes	40% change in any class
Water quality	Mean yearly air temperature, water temperature, and salinity	None
	Average daily range in air temperature, water temperature, and salinity	None
	Minimum and maximum air temperature, water temperature, and salinity	None
	Concentration of PAHs, PCBs, DDTs, Chlordanes, Total HCH (organopesticides), and selected heavy metals in mussel tissue.	Concentrations that exceed the mean of all sites sampled in the U.S. mussel watch program (see Table 5 below).

Kelp and seagrasses – Monitoring of kelp and seagrass (eelgrass) requires estimation of changes on several different spatial scales. We will examine larger temporal- and spatial- scale changes in the distribution of canopy forming kelps and eelgrass by examining the changes in the km of shoreline occupied by kelps and eelgrass based on shorezone mapping surveys (Morris and Harper 2004) conducted every 10 to 12 years. For eelgrass, we will estimate the area covered by eelgrass and categorical estimates of eelgrass density in selected eelgrass beds.

Intertidal community - Algae and Invertebrates on sheltered rocky shorelines – For intertidal invertebrates and algae, we will examine number of species present and rates of local extinction, colonization, and turnover based on the presence or absence of species (Nichols et al. 1998) using COMDYN software (Hines et al. 1999). We will also examine changes in abundance of selected species. Species selection was based on surveys conducted at 5 sites in KATM in 2007 and 2008 (Bodkin et al 2007, 2008), at KEFJ in 2008 (Bodkin et al. unpublished data), and at KEFJ in 1989-1991 (Highsmith et al. 1994). In these surveys, over 70 taxa of invertebrates and algae were identified, but most were rare and offer little power to detect changes in their abundance over time. As a result, we choose to limit the number of metrics we will examine as vital sign indicators to the percent cover of bare substrate (indicating the absence of sessile invertebrates and algae), the total number of sessile and small motile species encountered, the total number of sea stars species, and the percent cover or number per unit area of several relatively abundant and ecologically important taxa. Indices of abundance (either based on percent cover or density) will be evaluated for five taxa of sessile invertebrates and algae: barnacles, *Mytilus trossulus*, *Fucus distichus* susp. *evanescens*, *Alaria* sp., and *Neorhodomela/Odonthalia* spp. These taxa are widely distributed, dominate the intertidal in terms of percent cover (together contributing over 90% of cover), and are important as the primary structural and energetic components in the rocky intertidal community. For larger motile invertebrates, we will evaluate the abundance of 4 sea star species (*Evasterias troschelii*, *Pisaster ochraseus*, *Pycnopodia helianthoides*, and *Dermasterias imbricata*), the large chiton *Katharina tunicata*, the predatory snail *Nucella* spp. *Katharina* is an important grazer in this community (O'Clair and O'Clair 1998) and sea stars and *Nucella* spp. are important keystone predators (O'Clair and Rice 1985, O'Clair and Zimmerman 1987, Carroll and Highsmith 1996, O'Clair et al. 1999). We will also examine size distributions of *Lottia persona* that are abundant and are important prey for higher trophic levels (especially black oystercatchers) (O'Clair and O'Clair 1998).

Intertidal community - Invertebrates on sand-gravel beaches - For intertidal invertebrates on sand/gravel beaches, we will examine changes in abundance and size distribution of selected species. Species selection was based on surveys conducted in KATM and KEFJ (Lees and Driskell 2006, Coletti et al. 2009) that focused on the abundance, size distribution, and diversity of clams. A total of over 25 species were found, most of which were rare (fewer than 10 individuals in 12 – 0.25 sq. m. quadrats per site) and offer little power to detect change in their abundance over time. As a result, we choose to initially limit the number of metrics we will examine as vital sign indicators to the density and size distribution of three dominant taxa (*Leucoma staminea*, *Saxidomus gigantea*, and *Macoma* spp.). The three taxa selected for consideration are also important prey for sea otters (Calkins 1978, Estes et al. 1981, Kvitek et al 1992, Dean et al. 2002). While we will focus on these more abundant species at present, all

larger bivalves are counted and measured and could be included in future analyses should their abundance increase over time.

Intertidal community- mussel beds – We define mussel beds as sites with relatively high densities of Pacific blue mussels, *Mytilus trossulus*. Specifically, mussel beds are defined as areas with greater than 10% cover by mussels within contiguous 0.25 sq. m quadrats over areas of 100 sq. m. or greater. Metrics used to evaluate changes in mussel beds will include the average density of large (greater than 25 mm in length), and the mean biomass of mussels greater than 25 mm in length (the minimum size generally taken by black oystercatchers and sea otters). Biomass will be estimated based on density and size distribution data gathered at each site, and on previously established relationships between size and biomass (O'Clair et al. 1999).

Marine birds – Evaluation of marine birds rely primarily on summer and winter boat based surveys that provide indices of density for each species encountered. We will examine number of species present and rates of local extinction, colonization, and turnover based on the presence or absence of species in each season (Nichols et al. 1998). We will also examine changes in estimates of abundance of selected species chosen based on their relative abundance and ecological importance. In summer surveys conducted in KATM and KEFJ in 2006 and 2007, more than 30 species of birds were identified and counted. Most of these were rare. While we may include these species in our analyses should they become more abundant over time, we will focus only on relevant species that currently provide more statistical power to detect changes in abundance over time. The taxa selected for evaluation include three that nest in the nearshore and feed primarily on schooling fishes (black-legged kittiwakes, glaucous-winged gulls, and pigeon guillemots) and five that are more reliant on nearshore benthic food resources (harlequin ducks, goldeneye, mergansers, cormorants, and scoters). We elected to examine genera instead of species for some birds (goldeneyes, mergansers, cormorants, and scoters) because of occasional difficulty in distinguishing between closely related species within these genera during field surveys. Previous boat-based surveys in Prince William Sound (Irons et al 2000) found that abundance estimates for all of these taxa provided reasonable power to detect changes (greater than 50% power to detect a 50% reduction or a doubling in abundance between oiled and unoiled areas based on a sample size of 123 transects).

Black oystercatchers – Oystercatcher density will be estimated in summer boat-based surveys. We will also estimate nest site density and will use this as a primary vital sign metric. In addition, we will evaluate nest site productivity as estimated based on the average number of eggs or chicks per nest, and will evaluate the composition of remains of prey brought to nest sites. Metrics to be evaluated for prey composition will include the proportion of the predominant prey items (primarily mussels and several limpet species) as well as the size distributions of these predominant prey.

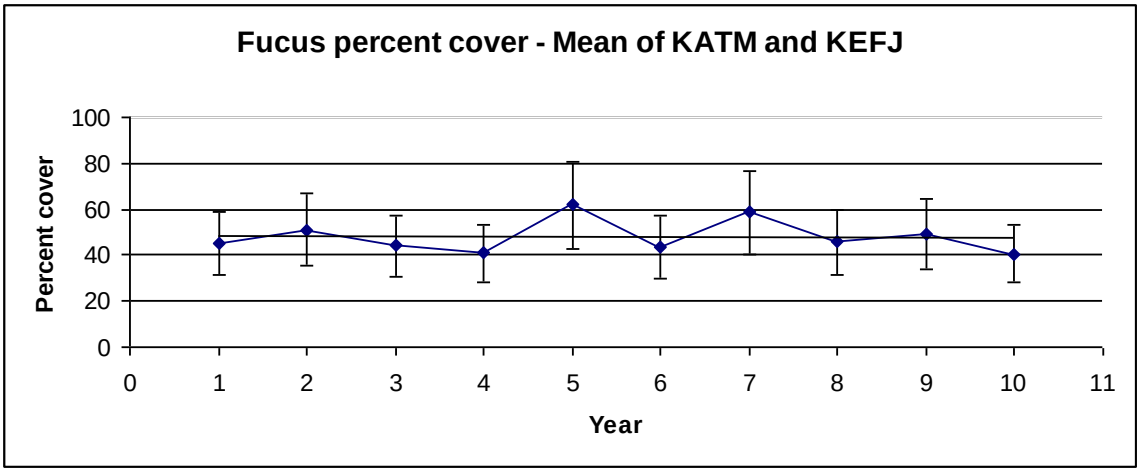
Sea otters – We will examine changes in number of sea otters (based on aerial survey estimates) as a primary metric of interest in evaluating changes in sea otters. However, sea otters are relatively long-lived marine mammals (generally reaching 15 years of age or greater) with relatively low birth rates and changes in abundance may not be the most sensitive indicators of long-term trends in abundance. Nor will changes in abundance offer any clues as to the causes for change. As a result, we will also evaluate trends in age-specific mortality rate (as indicated

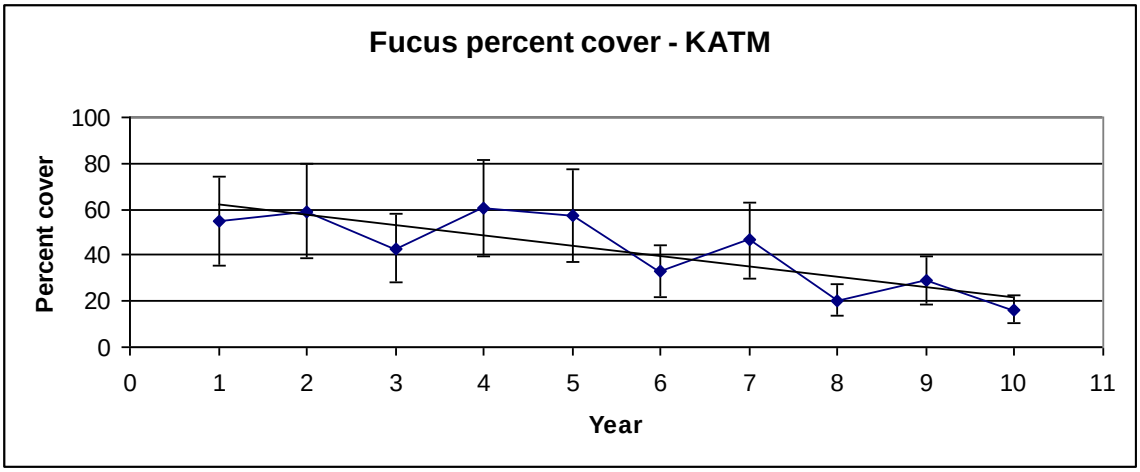
by the proportion of carcasses in each of three age classes: 0 to 3, 4 to 8, and >8 years of age). In addition we will evaluate changes in diet over time. Metrics to be evaluated will include the proportion of predominant prey items in sea otter diets (proportion of mussels, clams, crabs, and other prey). We will also estimate the total prey energy obtained per hour of feeding by sea otters. The latter is used to estimate food availability (Dean et al. 2002) and incorporates data on the composition and sizes of prey as well as dive times and times of intervals between dives.

Marine Water Chemistry and Water Quality – Water quality will be evaluated by measuring temperature and salinity in the intertidal zone and the concentration of various metal and organic contaminants in the tissue of mussels. For both we will evaluate changes in yearly mean, mean daily range in temperature, and minimum and maximum yearly values. We will focus on ranges and extreme values because these are often important disturbance events that can regulate community structure of intertidal algal and invertebrate communities (e.g. Carroll and Highsmith 1996). A total of over 120 organic compounds or isomers and ten metals were measured in the tissue of mussels. For organics, we will evaluate several summary metrics including total PAHs, total chlordanes, total DDTs, total PCBs, and total HCHs) as indicators of exposure to contaminants in the nearshore.

4.2.3 Routine annual analyses

Annual reports will include primarily descriptive analyses that present means and confidence intervals for each primary metric over various spatial scales. The plots of means over time will be made to examine trends over the spatial scales of the region (means for both KATM and KEFJ), within parks (e.g. KATM) and in the case of metrics in which multiple sites are examined, for sites within parks (Figure 3).





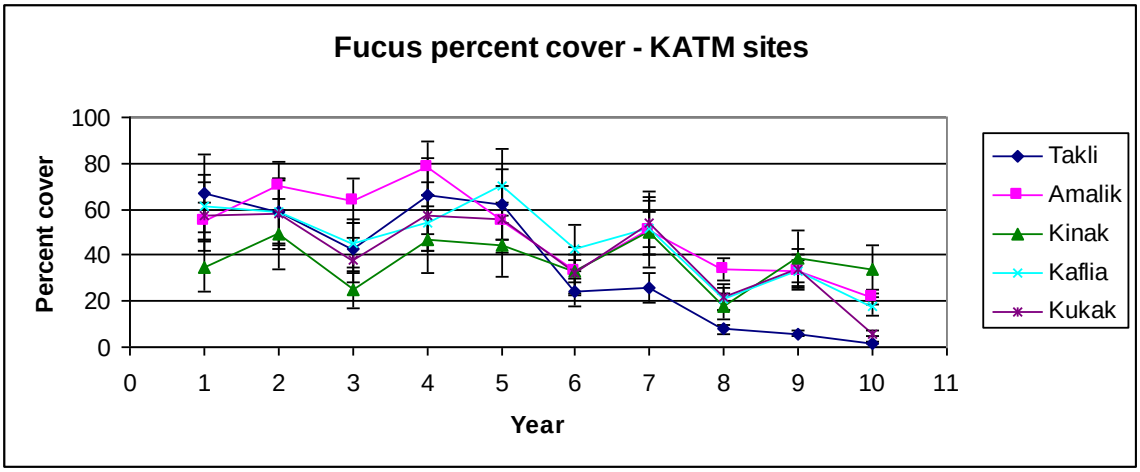


Figure 3. Example plot of mean and confidence intervals over time for hypothetical data for percent cover of Fucus for regions, parks, and sites within parks.

4.2.4 Analyses to detect trends

Analyses to detect trends in the data will be conducted after five years of data have been collected for a given metric, and at 2 to 5 year intervals thereafter. The specific analyses performed will depend in part on the metric and on the pattern of observed trends. The following provides a general discussion of types of analyses that are being considered.

Different types of analyses may be required if trends are gradual and occur at a relatively consistent rate over time or are episodic (e.g. extreme shifts in a given year based on an extreme event such as an earthquake or particularly hard freeze). Trends that result form extreme events will be modeled using either change-point or segmented regression (Seber and Wild 1989, Küchenoff and Carol 1997). More gradual changes will be examined using linear or log-linear regression models.

The general approach to be used in trend analysis is as follows. Several hypotheses (models) will be selected a priori that might provide reasonable explanations of trends in the observed data, and we will use an information-theoretic (I-T) criterion to rank these models based on their relative support and select the best-fitting model to generate our trend estimate (Burnham and Anderson 2002, 2004; Lukas et al. 2007). If more than one model is reasonably supported, we will use model averaging to generate our estimates (Burnham and Anderson 2002). In the simplest form, models used to examine trends in various vital signs (e.g. sea otter abundance) will include explanatory variables of time (e.g. survey year), location (e.g. park), and the interaction of time and location. (This would result in the simultaneous testing of 6 models with parameters of year; location; year and location; year and the interaction of year and location; location and the interaction of year and location; and year, location, and the interaction of year and location.) Where appropriate, models examined will also include terms that might account for potential biases in the data, such as the years of observer experience or observer identity for a given sea otter aerial survey. Terms that might further explain trends over time (e.g. mean annual temperature, location relative to a particular local disturbance, or time period relative to a particular disturbance event) will also be included where appropriate. Terms such as observer identity that are likely to lack independence in influencing dependent variables in successive years be will be treated as random effects. The regression analyses are to be performed using the Proc Mixed function in SAS (SAS 2000) or comparable software.

4.2.5 Analyses to provide insights as to causes

Causes for observed environmental changes can only be determined by use of specific experimental designs. However, we can gain some insights as to possible causes for change 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 locations (a time effect of ecological importance, 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 (e.g. a release of a toxicant from boat harbors). Second, inclusion of explanatory variables in models might also suggest cause. For example, if inclusion of the

concentration of contaminants in mussels helps to provide a better fit of temporal trends in black oyster catcher abundance, then this might suggest that a decline in oyster catchers was related to an increase in contaminants.

It should be stressed that we will not be able to definitively assign causes for changes based solely 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 cannot be designed or carried out until there is sufficient observational or correlative evidence produced to detect a change and suggest a possible cause.

4.2.6 Ecological thresholds and management trigger points

The objective of the nearshore Vital Signs program is to examine trends in various metrics that are indicative of changes in the health of the nearshore community. However, the ultimate goal of the program is to provide resource managers with the tools that will allow them to take actions to protect resources. Therefore, in addition to identifying trends, it is also necessary to provide some guidance as to what levels of change are ecologically important and to identify "trigger points" that warrant consideration of action on the part of managers (Nichols and Williams 2006).

Determining when a trend is ecologically important is not a straightforward process. There is currently no standard by which to measure ecological importance, and there are no clear guidelines to determine "trigger points" for action by resource managers. Various models have been proposed to evaluate threats to extinction of threatened or endangered species (e.g. IUCN 2002), but these are generally not appropriate for our use. Few of the species we are monitoring as vital signs are in danger of extinction, and our hope is that we can identify trends of ecological importance and inform managers so that actions can be taken to protect resources prior to them reaching the status of threatened or endangered. Furthermore, the geographic scale of concern is different. For example, it is possible to have declines in abundances of a particular species that is of concern to park managers, but relatively insignificant to the continued survival of the species. There is currently a NPS funded study to help identify a process that may help to determine these trigger points based on structured decision making and on models of park system behavior (Nichols et al. 2007). Our intent here is to provide some interim guidance for ecologically important trends for each metric we are considering. We stress that these are preliminary. While such values are needed to guide analyses and interpretation of results, there is little precedent for establishing ecological thresholds. It is anticipated that these will be modified over time based on further empirical and theoretical analyses.

Our preliminary guidance on possible trigger points is based largely on our understanding of the species within the nearshore system of the parks and interactions between these species. In general, we deem important changes that are likely to have system-wide effects, through predator –prey interactions for example. This is based largely on our conceptual understanding of the system and not on a more rigorous systems model. Where possible, we will rely on two types of data to help identify trends of ecological importance. The first is the range in natural variation that has been observed in what are considered healthy populations. These variations represent the bounds to be placed on any reasonable trigger point. The second is the range in variation, generally expressed as a level of change that has been considered ecologically important in past

studies of impacts to nearshore ecosystems, and especially those that have been shown to have larger system-wide effects. We will rely heavily on observations made following the *Exxon Valdez* oil spill since the spill is widely recognized as having significant long-term impacts on the nearshore ecosystem. The spill affected nearshore communities in KATM, KEFJ, and more strikingly in similar nearshore systems in Prince William Sound, and was widely studied over a period of several decades. In some cases, there is an absence of data on levels of natural variation in healthy systems or examples of the levels of change that have proved to be of ecological importance. In these cases we make use our best professional judgment to estimate levels of change that are of ecological importance.

It is unlikely that we will ultimately rely solely on any one metric to evaluate the health of the nearshore system. Instead, we will likely rely on changes in a suite of metrics viewed in the context of a community or systems model. For example, reductions in intertidal mussel populations coupled with a reduction in mussels as a component of the diet in sea otters and black oyster catchers would provide stronger evidence of an important ecological change than would reductions in mussels alone. However, it is important to provide trigger points for each metric as an initial step in this process.

The guidance provided is given in terms of absolute levels of change from current conditions. However, in some instances it may be appropriate to also examine trends in the relative levels of change at one location compared to others. Tracking relative changes may be important in identifying locations that are changing in response to a site specific disturbance event, especially in cases where there are larger geographic-scale temporal changes that are occurring in response to normally occurring climatologic or oceanographic changes. For example, relatively small absolute declines in abundance at a given location might be deemed important if abundances elsewhere are increasing, and relative changes at that given location are large in relation to other locations. We assume that the magnitude of relative change that is ecologically important is the same as the level of absolute change. For the sake of simplicity, we discuss only absolute changes below. However, it should be recognized that relative levels of change may be of interest and will be similarly evaluated.

The actions that might be undertaken by mangers when a trigger is exceeded cannot be determined and will be resource and event dependent. Actions might range from continued or more detailed study to more specific conservation measure such as limiting of visitation to sites where declines are observed or removing potential sources of contamination. It is likely that future consideration of possible management decisions will be made based on a weight of evidence provided.

Preliminary guidance on changes deemed to be of ecological importance for each vital sign metric is as follows:

Kelps and seagrasses – The natural variation in the cover of canopy forming kelps in the Gulf of Alaska is largely unknown. However, kelp canopies in the GOA and elsewhere are known to fluctuate in response to oceanographic conditions (e.g. storm activity, water temperature, light, and nutrient availability), grazing, competition, and human disturbance (North 1964, Neushul 1981, Dayton 1985, Foster and Schiel 1985). Therefore, we will recognize only

relatively large (greater than 50%) reductions in canopy cover within a park (based on aerial shorezone mapping) to be of ecological importance.

Dramatic changes in the abundance of eelgrass have been observed over the past several hundred years (Costa 1988, Short and Wylie-Echeveria 1996). Changes are generally associated with disease and human disturbance. While some eelgrass beds along exposed coastlines are subject to high inter-annual variability due to storms, those in more sheltered habitats (like most in KATM and KEFJ) display relatively little variation from year to year (Costa 1988, Short and Wylie-Echeveria 1996, Ward et al. 1997). Longer-term (5 to 10 yr.) declines of 25% or more in these beds in these types of sheltered habitats are generally attributable to human disturbance and are considered to be of ecological importance. We have no data on the trends in abundance of eelgrass at KATM or KEFJ, but based on the relative lack of annual variation made in sheltered eelgrass beds elsewhere in Alaska (Ward et al 1997), we consider reductions 25% or greater in the km of coastline occupied by eelgrass or in the area covered by eelgrass at selected eelgrass beds to be of ecological importance.

Algae and Invertebrates on sheltered rocky shorelines -Inter-annual patterns of abundance of intertidal invertebrates and algae on rocky shores are highly variable. Most of the species have high mortality rates due to intense grazing or predation and because of their susceptibility to natural disturbances including wave action freezing, and desiccation. In what are regarded as healthy systems in the Gulf of Alaska, it is not unusual to see inter-annual changes in estimates of percent or abundance of dominant intertidal invertebrates and algae that are 50% or greater (Highsmtih et al 1994, Skalski et al. 2001). At sites impacted by the *Exxon Valdez* oil spill, only larger changes (on the order of 80 to 90%) were deemed to be of ecological importance. Based on these results, we consider changes in abundance of selected dominant taxa of 80% or greater be of ecological importance. Changes in the number of species present are somewhat less variable, and inter-annual variation in the number of species detected is generally less than 20%. Impacts from the *Exxon Valdez* oil spill caused changes in number of species of algae detected that were on the order of 30% or greater. We consider changes of 30% or greater ecologically important. Based on 3 years of data from KATM, size distributions of limpets, *Lottia persona*, appear to vary relatively little over time. Median sizes at any one site varied less than 20% over the three year period. We have no data on longer-term changes in limpet size, but suspect that changes in median size on the order of 50% or greater are ecologically important.

Invertebrates on sand-gravel beaches – In the Gulf of Alaska, there are relatively few data regarding the normal range of variability in clam assemblages on sand-gravel beaches or on levels of change that are ecologically important. Additionally, the sampling methods are by necessity destructive and preclude sampling at high frequency. As a result variation in mean density values within clam beds over time are generally high. Within clam beds sampled in multiple years in Glacier Bay, mean densities of dominant species varied by as little as 10% and as much as 300%. (J. Bodkin, unpublished data). Similarly, Houghton et al. (1996) found relatively high inter-annual variability in clam densities in Prince William Sound (at sites unaffected by the Exxon Valdez oil spill). Because of the lack of data from sites within SWAN Parks and the anticipated high spatial and temporal variance, we will use values for

clam densities of 80% to represent changes that are deemed ecologically important. Reductions on the order of 80% or greater were observed at sites that were washed after the Exxon Valdez spill and were deemed ecologically important (Houghton et al. 1996). We also lack size data for dominant intertidal clams from SWAN Parks, but expect variation in mean sizes to vary much less than density. As a consequence we expect a 50% change in mean size of dominant intertidal clams to be ecologically important.

Intertidal community- mussel beds – Little is known about the persistence of beds of Pacific blue mussels (*Mytilus trossulus*) or changes in density, sizes, or biomass of mussels within beds over time. A two-year study in Price William Sound indicated that year to year variations in density and biomass were as high as 50%. Longer-term studies of closely related species California mussels (*Mytilus californianus*) and blue mussels (*Mytilus edulis*) suggest that mussel beds can persist for decades but that the boundaries of the bed and changes in biomass of mussels within a bed can change appreciably. Studies indicate that while beds can persist for a decade or more, occasional episodic large disturbance events (storms associated with El Nino events or ice scour associated with extremely cold winters) can cause local extinctions of some beds (Paine et al 1985, Seed and Suchanek 1992, Petraitis and Dudgeon 2004). Without specific information on the persistence and inter-annual variation in beds of Pacific blue mussels, it is difficult to set meaningful boundaries on changes that might be considered ecologically important. Until more data are provided we consider park-wide (within KATM or KEFJ) changes of 80% or greater in the average density and 50% change in the biomass of mussels to be ecologically important.

Marine birds –After the Exxon Valdez oil spill, Irons et al. (2000) found significant reductions in several bird species were on the order of 50% or higher and were deemed of ecological importance. We will consider similar reductions (on the order of 50% or greater) as ecologically important. However, for many species of birds, inter annual variation is quite high, and it is likely that we only be able to detect somewhat higher reductions. For example, in Glacier Bay National Park, inter-annual variation for commonly observed species varied between 15 and 60%, (Drew et al. 2008) and even somewhat higher inter-annual variation was observed at KATM between 2006 and 2008 (Coletti et al. 2009).

Black oystercatchers - Black oystercatchers are long-lived and have high nest site fidelity and appear to have relatively stable nest site densities and productivity over time in the absence of major disturbance events (Andres 1997, Coletti et al. 2009). Following the Exxon Valdez oil spill in Prince William Sound, comparisons of changes in black oystercatcher density and productivity at oiled and unoiled areas after the spill implied that there was greater than 60% reduction in active nest density in areas impacted by the spill and an 80% reduction in nest productivity in areas disturbed by cleanup operations. Both were considered of ecological importance. Here we consider reductions in nest density or productivity that are 50% or greater to be of ecological importance. Changes in diet, including both changes in prey frequency and sizes of select prey within the black oystercatcher chick provisioning diet, are metrics we are using to assess black oystercatcher status. There are no prior studies to suggest what specific levels of changes in diet might be of ecological importance. In surveys conducted in KATM between 2006 and 2008 there were large changes in the diets of black oystercatchers over time (a 71% and 47% reduction in the proportion of *Lottia persona* and

Mytilus trossulus respectively and a greater than 200% increase in the proportion of both *Lottia scutum* and *Lottia pelta*). However, there were no appreciable changes in either nest density or productivity of black oystercatchers over this period (Coletti et al 2009) and no obvious changes in the intertidal community at large. Therefore it is unclear as to the magnitude of change in prey size would be considered ecologically important. Thus, we will continue to monitor both prey composition and prey size to help us understand possible changes in community dynamics, but we cannot establish ecological thresholds for these metrics at present.

Sea otters – Estimates of abundance of sea otters based on aerial surveys are somewhat imprecise and in general 95% confidence intervals about estimate of mean population size in any given year are on the order of 15 to 25% of the mean. As a result of this imprecision and natural variation, population estimates for what are considered "healthy" sea otter populations with relatively stable populations can vary by as much as 25 to 30% from one year the next. However, longer-term changes on the order of 40% or larger are thought to represent changes of ecological importance. Following the *Exxon Valdez* oil spill, reductions in the sea otter population in western Prince William Sound were on the order of 50% and were clearly considered to be of ecological importance. We will use a reduction of 40% or larger as our level of change considered ecologically important. Also following the *Exxon Valdez* oil spill increases of 60% in the proportion of prime age sea otters found beach-cast (17 to 28%) with corresponding decreases in the proportions of juvenile and aged adults (44 to 42%, and 40 to 31%, respectively) were considered biologically significant, contributing to a protracted period of recovery from the spill (Monson et al. 2000). Because these proportions are not independent, we will use a change of 40% in any of the three age groups as biologically significant, assuming a minimum total sample size of 100 ages at death. Sea otter diet appears relatively consistent over long time scales at some locations. For example the proportion of clams in the diet of sea otters in Prince William Sound in the 1970's was similar to the 1990's (about 70-80%, Calkins 1978, Bodkin et al. 2002). We will consider changes in dominant prey (those contributing 35% or more to the diet) of 35% or more to be biologically significant and indicative of change in the prey base. The estimated number of hours that sea otters must spend feeding in order to obtain sufficient energy for maintenance is generally on the order of 10 hours per day in stable and healthy populations. Increases in feeding time required for maintenance that exceeds 12 hours (20%) or decreases to less than 8 hours (33%) are considered to be of ecological importance.

Water quality: Temperature and salinity – Variations in temperature and salinity are potentially important drivers of ecological change. Therefore, we will measure and analyze temperature and salinity on a routine basis. Variations in temperature, and especially in temperature extremes, are known to vary greatly from year to year. Less is known regarding variations in salinity, but these too are expected to vary considerably in the nearshore zone that is highly influenced by the degree of freshwater runoff. However, the longer-term variations in both temperature and salinity in the nearshore (and especially the intertidal zone) are largely unknown, as are the levels of change that are of ecological importance. Furthermore, no managerial action is anticipated even if ecological meaningful changes in these metrics are observed. Therefore, we set no thresholds for these metrics.

Water quality: Contaminants –Levels of contaminants in mussel tissue have been widely studied as an indicator of water quality. These data are used to indicate relative "hot spots" where concentrations of given contaminants are of potential concern. Relationships between concentrations of contaminants and adverse biological responses are less clear and no "threshold concentrations" indicative of adverse biological effects have been established. Therefore, we provide estimates of concentrations that are of ecological importance based on comparisons to those found elsewhere in the US. Specifically, we consider concentrations to be of ecological importance when mean for a given site exceeds mean values of all sites sampled in the US as part of the NOAA mussel watch program (O'Connor et al. 1996). We have chosen to use the mean rather than "high" values (those equivalent to one standard deviation above the mean based on log-transformed data) because the majority of sites sampled in the mussel watch program are from highly industrialized sites that are generally considered ecologically degraded relative to those in the SWAN parks. Both means and "high" values for each contaminant are given in Table 5.

Table 5. Mean concentration and "High" values (those that exceed one standard deviation of the mean for log-transformed data) of contaminants in oyster and mussel tissue samples taken from sites (generally in industrialized urban areas) throughout the United States between 1986 and 1993. For silver, copper, zinc, lead and chromium values are for mussel tissue only. All others are for oysters and mussels. Data are from O'Connor et al. (1996).

Chemical	Mean	"High"
Metals (concentrations in µg/g)		
Arsenic	10	17
Cadmium	2.7	5.7
Mercury	0.094	0.24
Nickel	1.7	3.3
Selenium	2.5	3.5
Silver	0.17	0.58
Copper	8.9	11
Zinc	130	190
Lead	1.8	4.3
Chromium	1.7	3.0
Organics (concentrations in ng/g)		
tPCB	110	470
tDDT	37	120
tCdane	14	31
tPAH	260	890

4.2.7 Interpretation of results

For the biological metrics, we consider changes to be of ecological importance if a trend is established and if the trend is such that the threshold of ecological importance has been exceeded. Trends will be deemed to be established if the 90% confidence intervals about the time coefficient in trend analysis models do not include zero. Whether that trend is of ecological importance will be determined by examining the confidence intervals in relation to the threshold levels established (Alderson 2004) (Figure 4). For example, for sea otter abundance, we deem a 40% reduction of the population estimate to be a threshold. If the mean percentage change in the population estimate (as determined by the adjusted time coefficient in trend analysis over any given time interval) is less than 40% and the lower confidence interval about that mean does not include 40%, then no effect of ecological importance would be indicated. If the confidence intervals about the mean (either upper or lower) include a 40% reduction, then the results would be considered inconclusive. If the mean decline is greater than 40% and the upper confidence interval does not exceed the 40% level, then an ecologically important decline in the sea otter population would be indicated.

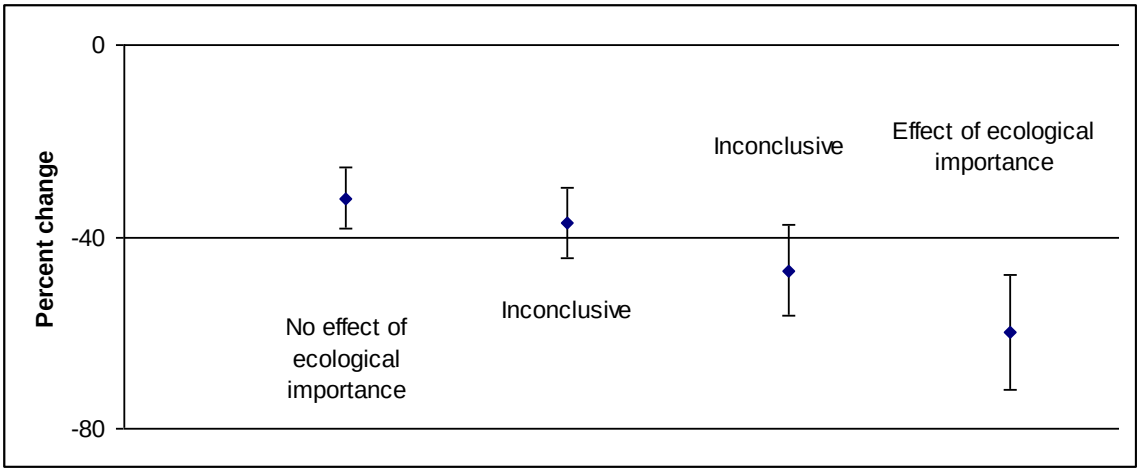


Figure 4. Interpretation of thresholds for consideration of action given means percentage change observed and 90% confidence intervals about those means. The horizontal line of no effect (-40%) is the threshold level of change deemed ecologically important

4.3 Reporting

Three different levels of reporting are to be conducted. The first are annual reports that describe the activities for the previous year, summarize results in the form of annually updated figures and tables, highlight any unusual events or trends in the data, and describe activities to be conducted in the upcoming year. More comprehensive reports will be produced every five years that provide complete statistical analyses of data gathered to date, conduct power analyses as appropriate to examine possible changes to sampling designs, suggest changes to sampling designs, and suggest possible topics for process studies needed to examine causes for change or evaluate new sampling techniques. Also, it is anticipated that there will be special reports produced on an as needed basis that address patterns of observed change that require some immediate action such as increased sampling effort, initiation of process studies, or possible regulatory intervention. Special reports might also summarize the results for a particular time specific task such as evaluation of a potential modeling effort or a synthesis of results.

5 Management Structure, Personnel Requirements, and Training

5.1 Management structure and key personnel

This project is one of several to be conducted as part of the SWAN monitoring program (Bennett et al. 2006). The SWAN program will be headed by the SWAN director (NPS) and data management functions will be directed by the SWAN Data Manager (NPS).

5.2 Personnel requirements

The list of required staff and anticipated contractors and a brief description of their responsibilities and qualifications are given in Table 5. NPS staff (SWAN Network Data Manager, Biometrician, and Assistant Data are not included.

Table 6. Anticipated staffing requirements for the nearshore vital signs program.

Position and number required	**Responsibilities**	**FTEs Required**
Project Director	Oversee project - oversee staff, maintain budgets, schedule tasks, oversee contractors, oversee analysis, write reports.	0.3
Assistant Project Director	Assist in planning, field efforts, data analysis, and report preparation	0.5
USGS Data Manager	Organize data and maintain in house data bases, serve as liaison with NPS data manager	0.2
Field Supervisor and GIS analyst	Oversee field sampling and provide GIS analytical support	0.5
Field Support	Assist in field sampling and taxonomy	0.2
Field Support	Assist in field sampling	0.2
Field Support	Assist in field sampling	0.2

5.3 Training

The level of training required for each of the project personnel will depend in part on their level of experience. At a minimum, training will consist of familiarization and demonstrated proficiency in safety procedures, data management procedures, and in implementation of

standard operating procedures as required by the position. Required proficiencies for each task are outlined in standard operating procedures.

5.4 Schedule of activities

The following table (Table 7) summarizes the annual schedule for activities to be conducted in nearshore vital signs program.

Table 7. Summary of schedule of activities to be conducted over the first 9 years of the Nearshore Vital Signs program.

Field Sampling											
Vital Sign	Metric	Location	2006	2007	2008	2009	2010	2011	2012	2013	2014
Kelp and seagrass	Kelp and eelgrass cover (shorezone aerial surveys)	KATM									x
		KEFJ									x
	Eelgrass bed area	KATM			x	x	x	x	x	x	x
		KEFJ			x	x	x	x	x	x	x
Intertidal invertebrates and algae – rocky shores	Invertebrate and algal abundance and limpet size	KATM	x	x	x	x	x	x	x	x	x
		KEFJ			x	x	x	x	x	x	x
Intertidal invertebrates – gravel/sand	Intertidal invertebrate abundance and clam size	KATM		x		x		x		x	
		KEFJ		x		x		x		x	
		LACL				x		x		x	
Intertidal invertebrates and algae – mussels in mussel beds	Mussel abundance and size	KATM			x	x	x	x	x	x	x
		KEFJ			x	x	x	x	x	x	x
Marine birds and mammals	Density - summer	KATM	x	x	x	x	x	x	x	x	x
		KEFJ		x	x	x	x	x	x	x	x
	Density - winter	KATM			x			x		x	
		KEFJ			x			x		x	
Vital Sign	Metric	Location	2006	2007	2008	2009	2010	2011	2012	2013	2014
Black oystercatchers	Nest density	KATM	x	x	x	x	x	x	x	x	x
		KEFJ		x	x	x	x	x	x	x	x
	Diet – Relative abundance of prey	KATM	x	x	x	x	x	x	x	x	x
		KEFJ		x	x	x	x	x	x	x	x
Sea otter	Abundance – Aerial survey	KATM			x		x		x		
		KEFJ		x			x		x		

	Diet – Relative abundance of prey, energy obtained per dive	KATM	x	x	x	x	x	x	x	x	x
		KEFJ		x	x	x	x	x	x	x	x
	Age at death	KATM	x	x	x	x	x	x	x	x	x
		KEFJ		x	x	x	x	x	x	x	x
Water quality	Contaminants in mussels	KATM			x					x	
		KEFJ			x					x	
	Temperature	KATM	x	x	x	x	x	x	x	x	x
		KEFJ			x	x	x	x	x	x	x
	Salinity	KATM				x	x	x	x	x	x
		KEFJ		x	x	x	x	x	x	x	x
Reporting	Data Management Plan			x	x	x	x				
	Annual Reports			x	x	x	x	x	x	x	x
	Synthesis Reports						x				

6 Operational Requirements and Cost Estimates

6.1 Operational requirements

Operational requirements for specific tasks are outlined in standard operating procedures. More generic operational requirements are given here.

Facilities and Office Equipment

- Office facilities for 3 staff
- Computers for above staff
- Central server for data storage and website (specifications and location to be determined)
- Software for data management, statistical analysis, geographic information system, and office management

Field Equipment

- -2 - Inflatable vessels and associated power and safety equipment
- -16 to 24 ft vessel and associated power, electronic, and safety equipment
- -High power scopes for sea otter foraging observations
- -Ruggedized laptop computers for entry of field data
- -20 - Temperature recording devices
- -4 - GPS units
- -4 - Digital cameras
- -6- Binoculars
- -10 Salinity recording devices

Charter Vessels and Aircraft

- Minimum 45 ft vessel for charter with accommodations for 6 scientific staff
- Aircraft for aerial surveys for of sea otters
- Helicopter for access to the LACL sites

It is anticipated that many of the field equipment needs could be met using existing equipment, thereby eliminating the need for large initial capital expenditures.

6.2 Cost estimates

Cost estimates for the monitoring program are summarized in Tables 7 and 8.

Table 8. Proposed contractual costs (thousands) for SWAN Nearshore monitoring, 2007-2014. All cost estimates are in 2007 dollars and are not inflation adjusted. KATM and KEFJ summer cruise costs include one 11day cruise to KATM (37K) and one 10 day cruise to KAFJ (6K in 2007, 12K in out years). Sampling will include invertebrates and algae on rocky shores in even years and invertebrates at soft sediment sites in odd years, summer marine bird and mammal surveys, black oystercatcher surveys, sea otter skull collections for estimates of survival, and sea otter diet estimates each year. Aerial surveys of sea otter abundance will be conducted every 2-3 years. Winter marine bird and mammal surveys are to be conducted at KATM and KEFJ every 2-3 years. Contaminants include preliminary sampling of mussel tissues for metals and organics collected in 2007 at KATM and KEFJ at 5 year intervals thereafter. Lake Clark sampling includes sampling of invertebrates in soft sediment. Mussel growth includes estimates of annual growth rates of mussels. Contracts to be administered by USGS include vessel charters for KATM and KEFJ cruises. All others are to be administered by NPS.

Task				**Cost**				
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Summer Cruises, KATM and KEFJ – vessel charter	43	49	49	49	49	49	49	49
Summer LACL field work – helicopter charter	-	-	20	-	20	-	20	-
Aerial sea otter survey – plane charter	24	-	-	24	-	24	-	-
Winter marine bird and mammal survey – vessel charter	-	27	-	-	27	-	27	-
Contaminant analysis – lab costs	-	-	-	-	-	-	-	20
Total	**72**	**88**	**89**	**73**	**96**	**85**	**96**	**69**

Table 9. Annual budget estimates (thousands) with associated salary and contract, travel, and supplies and equipment costs in 2007 dollars and are not inflation adjusted.

	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Contracts	72	88	89	73	96	85	96	69
Salary	123	123	123	123	123	123	123	123
Travel	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2
Supplies and Equipment	5	5	5	5	5	5	5	5
USGS O/H 27% of 103.4	27.9	29.8	29.8	29.8	29.8	29.8	29.8	29.8
TOTAL	**237.1**	**255.0**	**256.0**	**240.0**	**263.0**	**252.0**	**263.0**	**236.0**

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National Park Service
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Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

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