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Vital Signs Monitoring Plan
Southwest Alaska Network

Inventory and Monitoring Program

September 2006

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Acronyms:

ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
ALAG	Alagnak Wild River
ANIA	Aniakchak National Monument and Preserve
ANILCA	Alaska National Interest Lands Conservation Act
ARO	Alaska Regional Office
ASC	Alaska SeaLife Center
GIS	geographic information system
I&M	Inventory & Monitoring (Program)
KATM	Katmai National Park and Preserve
KEFJ	Kenai Fjords National Park
LACL	Lake Clark National Park and Preserve
NMFS	National Marine Fisheries Service
NPS	National Park Service
OASLC	Ocean Alaska Science and Learning Center
SWAN	Southwest Alaska Network
USFS	U.S. Forest Service
USGS-BRD	U.S. Geological Survey-Biological Resources Division
USFWS	U.S. Fish & Wildlife Service
WRD	Water Resources Division

Cover Photo:

The glaciated west flank of Devil's Desk, the volcanic neck of a former stratovolcano in Katmai National Park and Preserve. Location: 58.5° N, 154.3° W. Elevation: 6,409 feet (1,954 meters). Photo was taken June 2005 by Alan Bennett, SWAN Program Coordinator.

Vital Signs Monitoring Plan
Southwest Alaska Network

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In Memory
Richard Proenneke
1917–2003

In 1968, at the age of 51, Richard (Dick) Proenneke constructed a log cabin at Upper Twin Lakes and lived there alone for almost 30 years. In 1980, Twin Lakes became part of the Lake Clark National Park and Preserve, and Dick became a volunteer backcountry interpreter and naturalist. A diesel mechanic by trade, decades of living in wilderness would transform Dick into what some might call a landscape ecologist. A keen observer and meticulous recorder, Dick was fascinated by weather phenomena, annual phenological events, cyclic natural fluctuations in animal abundance, and plant-animal interactions. Inquisitive and deliberate, he not only observed and recorded but also asked the question, "Why?" A wolverine carcass found one spring at the head of a valley would be systematically probed for weeks. What was its sex and age? Was there evidence of emaciation or broken bones? Was the carcass in an avalanche zone?

In *A Sand County Almanac* Aldo Leopold wrote: "*Keeping records enhances the pleasure of the search, and the chance of finding order and meaning in these events*." At Twin Lakes, Dick found order and meaning by recording natural events. He began recording his observations and measurements in 1968 and continued to do so until 1995, the last full year he spent at Twin Lakes. He wrote most of his notes on wall calendars, the type that rural Iowa hardware stores give to loyal customers at the start of the new year. Entries included dates of lake freeze-up; lake ice break-up; den entry and den emergence by brown bears; first calving by moose; first lambing by Dall sheep; and nest initiation by gray jays. Dick also recorded daily high and low air temperatures; monthly winter snow pack and lake ice thickness; and random events such as severe storms, earthquakes, and landslides. Dick had a special interest in wolves and annually recorded winter pack size, number of kills, and composition of kills.

Sustained and simple like the monitoring program we aspire to build, Dick's calendars and journals are among the longest continuous data sets for any Alaska national park. Trends in the duration of lake ice cover on Upper Twin Lake plotted from Dick's records (1969–95) parallel those of other Northern Hemisphere sites and provide evidence that freshwater ecosystems are responding to a warming climate. Dick's love for wilderness, passion for observing and understanding the natural world around him, and dedication to keeping records are an inspiration to all of us as we develop and implement long-term monitoring in the Southwest Alaska Network.

Preface

In 2001, a network of five national park units in southwest Alaska began the process of planning a long-term vital signs monitoring program. This report completes the three-phase process used in designing this monitoring program and constitutes a first draft of the monitoring plan. Phases I and II, completed in 2003 and 2004, respectively, involved evaluating and synthesizing existing data; defining monitoring questions and preliminary objectives; developing conceptual ecosystem models; and identifying and ranking a draft list of vital signs. Phase III, completed in 2005, involved development of sampling designs; monitoring protocols; data management procedures; and an administration and implementation framework.

The overall process that this network has followed in planning, designing, and implementing its vital signs monitoring program is described in more detail at the NPS Inventory and Monitoring Web site (http://science.nature.nps.gov/im/). We encourage readers of this plan to visit that site to obtain additional background information on the history and evolving stages of the National Park Service's Inventory and Monitoring Program (I&M). This report, along with all appendices and supplemental information, is available on the Southwest Alaska Network Web site. (http://www.nature.nps.gov/im/units/swan/index.cfm?theme=Overview).

Executive Summary

Chapter 1

Chapter 1 provides background for the proposed monitoring program. In order to protect national parks for future generations, it is vital that the National Park Service (NPS) observes and understands the condition of natural resources in our parks. To address this need, NPS implemented a strategy known as "vital signs monitoring" to develop scientifically sound information on the status and long-term trends of park ecosystems and to determine how well current management practices are sustaining those ecosystems. The Southwest Alaska Network (SWAN) consists of five Alaskan park units (Aniakchak National Monument and Preserve, Alagnak National Wild River, Katmai National Park and Preserve, Kenai Fjords National Park, and Lake Clark National Park and Preserve). Collectively these units comprise 9.4 million acres or 11.6 percent of the total land area managed by the National Park Service. Network parks encompass climatic conditions, geologic features, near pristine ecosystems, natural biodiversity, freshwater, and marine resources equaled few places in North America. This network of relatively untouched wilderness parks is a unique resource and offers unparalleled opportunities to study and monitor ecological systems minimally affected by humans. In recognition of this, the SWAN monitoring framework will emphasize (i) establishing reference conditions representing the current status of park, monument, and preserve ecosystems; and (ii) detecting ecological change through time. The Network's conceptual foundation addresses the interplay of multiple forces that occur at a variety of spatial and temporal scales, and identifies climate/landform, natural disturbance, biotic interactions, and human activities as the most important drivers in determining regional ecosystem structure and function.

Chapter 2

Chapter 2 contains an overview of conceptual models used during the planning phases of vital signs monitoring. The character of SWAN parks is largely determined by the complex and dynamic physical, geological, and chemical interactions of marine, aquatic, and terrestrial subsystems. Therefore, a basic understanding of atmosphere-land-ocean interrelationships is important for us to comprehend how physical and biological drivers influence ecosystems. Climate influences on SWAN ecosystems are strongly tied to conditions in the North Pacific, especially location and strength of the winter Aleutian Low and the shift in storm track direction that occurs in summer. SWAN ecosystems are also shaped and maintained by disturbances. Infrequent large-scale disturbances (volcanic eruptions, earthquakes, tsunamis) and more frequent, small-scale disturbances (insect outbreaks, floods, and landslides) maintain a shifting mosaic of landscape patterns. Important biological interactions in SWAN include the transport of nutrients by mobile species, herbivore-predator interactions that maintain a heterogeneous distribution of resources, and the presence of "ecosystem engineers" that structure habitats and influence the distribution and abundance of other species. Ecological links between the coastal, freshwater, and terrestrial subsystems involve the flow of water, nutrients, and energy. Salmon play an extremely important role in Network ecosystems and provide a link between marine, terrestrial, and freshwater subsystems. Human activities acting as stressors in SWAN ecosystems stem from far-field influences related to global industrialization and near-field influences related to regional development and park visitation. The most important far-field influences are climate change, invasive species introductions, and effects on migratory fish and birds outside of Network parks. Near-field influences include a variety of activities, but all act in similar ways to affect fish and wildlife via disturbance, habitat loss or fragmentation, and overharvesting.

Chapter 3

Chapter 3 describes the selection of a final list of vital signs. Candidate vital signs were chosen during a series of scoping workshops held between August 2002 and April 2003. The initial list that emerged from the scoping workshops included 61 vital signs. This list was reduced to 38 after similar indicators were merged under a single vital sign, or duplicate entries or weakly supported vital signs were removed. Technical Committee members reviewed each vital sign for why it was selected, how it relates to conceptual ecosystem models, and how it contributes to the Network's goals and objectives for monitoring. Committee members numerically ranked each of the vital signs based on ecological significance and relevance to park resource management and protection issues. The Board of Directors reviewed the selection process and rankings, and approved the list of vital signs in March 2004.

Chapter 4

Chapter 4 discusses specific sampling designs relevant to long-term monitoring in SWAN parks. The SWAN I&M program's approach to developing sampling designs is to (i) identify existing monitoring programs and set up a protocol to acquire data that meet our objectives, (ii) collect data from satellite or aerial platforms on a parkwide scale when feasible, and (iii) develop ground-based designs only for those vital sign metrics for which remote sensing or aerial measurement provide data at an inadequate spatial resolution to meet SWAN monitoring objectives. We will use a combination of random and nonrandom sampling designs for those vital signs whose protocols are developed by SWAN alone. The random sampling design will primarily utilize a generalized random-tessellation stratified (GRTS) and systematic sample with a random start. When necessary, we will incorporate accessibility and prioritization components into these designs, where prioritization criteria will be heavily influenced by park staff. High-priority, easily accessible units or sites will be sampled more frequently than other ones.

Chapter 5

Chapter 5 outlines the requirements and timeline for protocol development. Protocols consist of a narrative, standard operating procedures, and supplementary materials. The protocol narrative describes why a particular vital sign and metric(s) were selected; specifies objectives and details of the proposed sampling design to meet those objectives; identifies field methods that will be used to gather data; explains how these data will be managed, analyzed, and reported; discusses personnel requirements and training procedures; and describes operational requirements such as scheduling, equipment, and budget. Standard operating procedures provide detailed instructions on how to accomplish every topic mentioned in the narrative. Protocol development summaries (PDSs) have been prepared for 31 SWAN vital signs for which monitoring will be implemented within 3–5 years. Each PDS briefly addresses key elements of sampling protocols and includes a justification and list of measurable objectives. A schedule has been established for the development and testing of protocols for vital signs monitored by SWAN, monitored in partnership with SWAN parks, or with other federal and state agencies.

Chapter 6

Chapter 6 summarizes the contents of the SWAN Data Management Plan. The goal of data management is to ensure the quality, interpretability, security, longevity, and availability of vital signs monitoring data. To achieve this goal it is crucial that monitoring staff understand and perform data stewardship responsibilities in the production, analysis, management, and end use of data as described in the Data Management Plan and the specific monitoring protocols. The SWAN uses a project tracking database to document and support the progress of information collected for vital signs monitoring.

Chapter 7

Chapter 7 discusses avenues for data analysis as part of the SWAN monitoring program. Various descriptive statistics (e.g., means and standard deviations) and graphs will be generated frequently to provide information on status of a given vital sign. The frequency of analysis will depend on the vital sign and metric. We will use empirical Bayes models to estimate trends. These models allow specification of different covariance structures, removal of the estimated sampling variance component, and incorporation of additional variables thought to influence trends in the response variable (e.g., abundance). When appropriate, we will build a candidate set of trend models that includes variables thought to most influence a given vital sign metric, use information-theoretic approaches to choose the best-fitting covariance structure and model, and, if necessary, model average over the candidate models. Bayesian belief networks (BBNs) will be used to link monitoring data to decisions regarding the current "state of the park." Information will be reported in numerous formats using language that simultaneously fits within both scientists' and nonscientists' frames of reference, such that progress and findings are technically accurate and understandable.

Chapter 8

Chapter 8 outlines the proposed administrative framework for the SWAN monitoring program. The "network concept" is based on the principle of park and Network staff working cooperatively to plan, coordinate activities, share resources, leverage additional resources, and implement operational monitoring. Programmatic integration of monitoring with park operations such as protection, interpretation, maintenance, and stewardship is crucial. A key

challenge for SWAN is to secure the range of technical specialists needed to implement the monitoring program without overcommitting the Network budget to staff salaries. We plan to meet this challenge by strategic sharing of positions with the Network parks, Alaska Regional Office, and outside agency partners.

Chapter 9

Chapter 9 establishes a schedule for implementation of the monitoring program. Operational monitoring for vital signs will be phased in over 5 years beginning in 2006. Throughout the implementation phase, draft protocols will be written, field tested for 1–2 years, submitted for peer review, and finalized. Vital signs that can be monitoring by remote sensing, such as landscape processes, glacial extent, and land cover/land use, will be implemented first because they provide important context for ground-based monitoring that will follow.

Chapter 10

Chapter 10 presents the proposed budget for the first year of implementation (FY 2007). Vital signs monitoring is intended to fill gaps in what parks are already doing by augmenting existing park personnel and base funds. In SWAN, allocation of vital signs monitoring and water resources funding reflects this intent. A greater proportion of Network funding will be directed to program areas that parks currently and historically have not had financial or staff resources to sustain, i.e., terrestrial vegetation, physical resources, and marine nearshore resources. Lesser funding will be directed to program areas for which parks have ongoing monitoring and existing staff, i.e., terrestrial fauna.

Chapter 1
Introduction and Background

In this chapter, we provide a summary of legislation, NPS policy and guidance, Service-wide and Network-specific strategic goals for performance management, and park-enabling legislation relevant to vital signs monitoring. The monitoring framework adopted by SWAN is outlined, along with monitoring questions that drove the selection of vital signs.

1.1 The Importance of Long-Term Monitoring

Park managers entrusted with stewardship of our public lands have long known that decisionmaking related to protecting these ecosystems is complex. They need relevant, up-to-date information to understand how the condition of park resources is changing over time in response to natural processes and human activities. In 1992, the National Research Council (1992) reviewed the natural resource management program of the NPS and concluded that "if the National Park Service is to meet the scientific and resource management challenges of the twenty-first century, a fundamental metamorphosis must occur within its core." Indeed, that metamorphosis materialized when the NPS implemented a strategy to standardize inventories and monitoring of natural resources on a programmatic basis throughout the agency. The effort was undertaken to ensure that the approximately 270 park units with significant natural resources possess the resource information needed for effective, science-based, managerial decision making and resource protection. The national strategy consists of a framework having three major components:

1. Completion of basic natural resource inventories in support of future monitoring efforts;
2. Creation of experimental Prototype Monitoring Programs to evaluate alternative monitoring designs and strategies; and
3. Implementation of operational vital signs monitoring in all natural resource parks.

A fundamental goal of the NPS is to protect or maintain natural ecosystem structure and function in national parklands. Alaska national park units are among the last remaining wilderness areas in the world—large enough to support naturally occurring ecological and evolutionary processes. These parks have been viewed as ecological baseline controls that provide us with unique insights into the functioning of ecosystems, in which the effects of humans are minimized (Arcese and Sinclair 1997).

> *"And so we might continue to ask questions, the answers to which would be sought by National Park Service scientists were there a formal, continuing, and sufficiently massive program of ecological and systematic monitoring."*
> *(Cain 1959)*

Knowing the condition of natural resources in national parks is crucial to the Service's ability to protect and manage parks. National park managers across the country confront increasingly complex and challenging issues and are asked to provide scientifically credible data to defend management actions. Many of the threats to park resources, such as invasive species and air and water pollution, come from outside the park boundaries, and so require a landscape approach (see Section 1.8.1) and integrated long-term monitoring to understand and protect the park's natural resources.

In this plan, we define vital signs monitoring as "the collection and analysis of repeated observations or measurements to evaluate ecological changes in the condition of park resources" (see Glossary). In theory, by monitoring a wide range of variables at long-term sites, it is possible to gain an understanding of how

ecosystems function and respond to change (Bricker and Ruggiero 1998). Coupling monitoring with research and modeling may make it possible to predict what will happen in the future and, if necessary, devise appropriate response strategies.

Ecological monitoring is vital to park management for a variety of reasons:

- Ecological monitoring can provide important understanding and insights into long-term ecological phenomena and the functioning of complex ecosystems across park and Network boundaries.
- Ecological monitoring is necessary to evaluate objectively whether the NPS is achieving mandates and policies of protecting park natural resources. One of the major shortcomings of most natural resource management and conservation plans has been the absence of a comprehensive ecological monitoring program (Kremen et al. 1994).
- Ecological monitoring is necessary to detect and evaluate the long-term adverse effects of human activities on park ecosystems. Because of the delay between a human disturbance and a subsequent response, long-term ecological monitoring is necessary to detect change.
- Information that flows from ecological monitoring elevates the stature of park ecosystems, organisms, and ecological processes to stakeholders, park visitors, and the public.

1.2 NPS Policies and Mandates that Link Monitoring and Management of Parks

The enabling legislation establishing the NPS and its individual park units clearly mandates, as the primary objective, the protection, preservation, and conservation of park resources, in perpetuity for the use and enjoyment of future generations (NPS 1980). NPS policy and recent legislation (National Parks Omnibus Management Act of 1998) require that park managers know the condition of natural resources under their stewardship and monitor long-term trends in those resources to fulfill the NPS mission of conserving parks unimpaired (Figure 1-1; see Summary of Laws, Policies, and Guidance). The laws and management policies that follow provide the mandate for inventories and monitoring in national parks.

The mission of the NPS (NPS Organic Act, 1916) is:

> "*...to promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental*

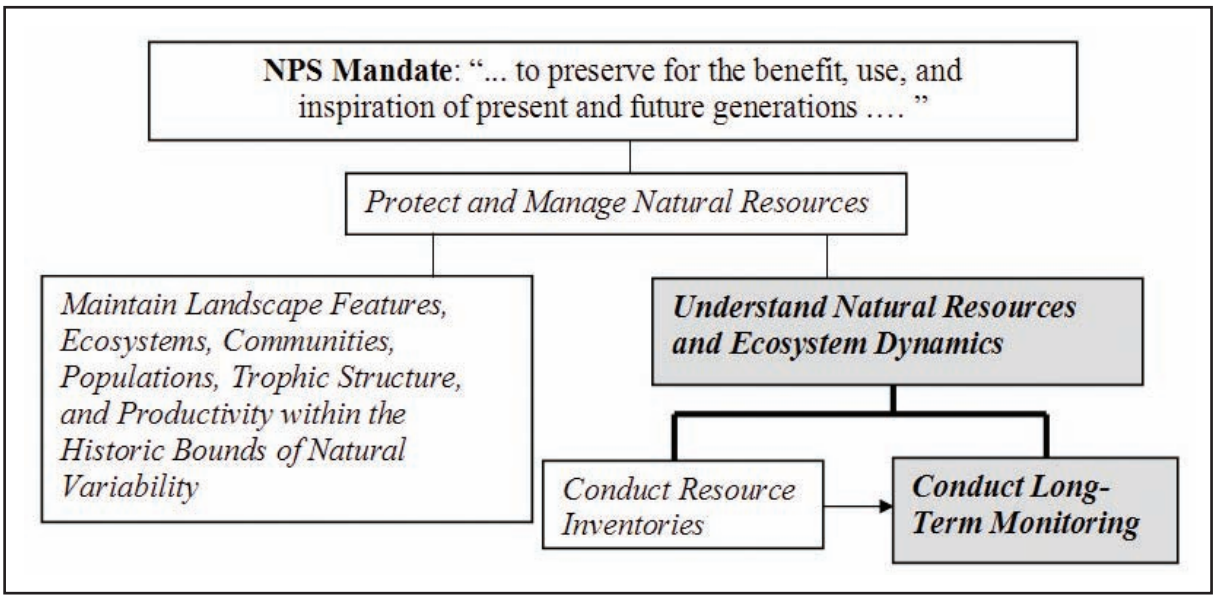


Figure 1-1 *Relationship between park mandates, resource protection, and long-term monitoring.*

purposes of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."

Congress strengthened the NPS's protective function and provided language important to recent decisions about resource impairment when it amended the Organic Act in 1978 to state that "*the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established….*"

More recently, the National Parks Omnibus Management Act of 1998 established the framework for fully integrating natural resource monitoring and other science activities into the management processes of the National Park System. The act charges the Secretary of the Interior to "*continually improve the ability of the National Park Service to provide state-of-the-art management, protection, and interpretation of and research on the resources of the National Park System,*" and to "*assure the full and proper utilization of the results of scientific studies for park management decisions*." Section 5934 of the act requires the Secretary of the Interior to develop a program of "*inventory and monitoring of National Park System resources to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources*."

Congress reinforced the message of the National Parks Omnibus Management Act of 1998 in its text of the FY 2000 Appropriation Bill:

> *"The Committee applauds the Service for recognizing that the preservation of the diverse natural elements and the great scenic beauty of America's national parks and other units should be as high a priority in the Service as providing visitor services. A major part of protecting those resources is knowing what they are, where they are, how they interact with their environment and what condition they are in. This involves a serious commitment from the leadership of the National Park Service to insist that the superintendents carry out a systematic, consistent, professional inventory and monitoring program, along with other scientific activities, that is regularly updated to ensure that the Service makes sound resource decisions based on sound scientific data."*

The 2001 NPS Management Policies updated previous policy and specifically directed the Service to inventory and monitor natural systems:

> *"Natural systems in the national park system, and the human influences upon them, will be monitored to detect change. The Service will use the results of monitoring and research to understand the detected change and to develop appropriate management actions."*
>
> Further, "*The Service will:*
>
> - *Identify, acquire, and interpret needed inventory, monitoring, and research, including applicable traditional knowledge, to obtain information and data that will help park managers accomplish park management objectives provided for in law and planning documents.*
> - *Define, assemble, and synthesize comprehensive baseline inventory data describing the natural resources under its stewardship, and identify the processes that influence those resources.*
> - *Use qualitative and quantitative techniques to monitor key aspects of resources and processes at regular intervals.*
> - *Analyze the resulting information to detect or predict changes, including interrelationships with*

visitor carrying capacities, that may require management intervention, and to provide reference points for comparison with other environments and time frames.

- *Use the resulting information to maintain-and, where necessary, restore the integrity of natural systems" (2001 NPS Management Policies).*

Additional statutes that provide legal direction for expending funds to determine the condition of natural resources in parks, and specifically guide the natural resource management of Network parks include the following:

- Taylor Grazing Act 1934;
- Fish and Wildlife Coordination Acts, 1958 and 1980;
- Wilderness Act 1964;
- National Historic Preservation Act 1966;
- National Environmental Policy Act of 1969;
- Clean Water Act 1972, amended 1977, 1987;
- Endangered Species Act 1973, amended 1982;
- Migratory Bird Treaty Act, 1974;
- Forest and Rangeland Renewable Resources Planning Acts of 1974 and 1976;
- Mining in the Parks Act 1976;
- American Indian Religious Freedom Act 1978;
- Archaeological Resources Protection Act 1979;
- Federal Cave Resources Protection Act 1988;
- Clean Air Act, amended 1990; and
- Wild and Scenic River Act 1990.

1.3 Applications of Information Gained from Monitoring: Who Is Interested in the Information Provided by Monitoring and Why?

The most widely identified application of monitoring is that of enabling managers to make better informed management decisions (White and Bratton 1980, Croze 1982, Jones 1986, Davis 1989, Quinn and van Riper 1990). For example, monitoring rates of coastal shoreline erosion and accretion can help park managers assess risks to archeological sites or aid in decisions regarding the placement of backcountry cabins or other structures.

Monitoring provides a tool to address issues that occur at multiple sites in a park or multiple parks within a network, rather than addressing site-specific problems individually. From such a holistic view, managers can develop general principles and guidelines that can be applied broadly to a particular type of issue.

In large wilderness park units, an important application of monitoring information is simply to gain insight into how complex park ecosystems function (Croze 1982). By gathering data over long periods, correlations between different attributes (such as predator and prey populations) become apparent, and resource managers gain a better general understanding of the ecosystem. In turn, this knowledge may support future decisions concerning existing or proposed harvest levels for a species.

Similarly, some authors suggest that it is important to document changes for the sake of familiarity with the resources (Halvorson 1984, Croze 1982). The responsibility of resource managers includes an awareness of changes in resources under their stewardship, even if no specific management decisions or actions are involved. For example, a park may want to monitor succession in areas where glaciers are retreating even if resource managers do not contemplate active management of the vegetation.

Another use of monitoring information involves convincing others to make decisions benefiting national parks (Johnson and Bratton 1978, Croze 1982). Some aspects of monitoring may focus on documenting specific internal or external threats. For example, parks and neighboring coastal landowners may monitor concentrations of hydrocarbons in benthic invertebrates to document the effects of offshore oil and gas activities on nearshore intertidal communities. In that case, the information may convince local governments, Native corporations, industries, or even courts of law to make decisions benefiting national parks.

Monitoring sensitive species, wilderness-dependent species, or entire communities in relatively undisturbed wilderness park units can provide park managers, stakeholders, and the public with a kind of "canary in the mine"—an early warning of the effects of human activities before they become noticeable in more impacted areas (Davis 1989, Wiersma 1984). For example, locations initially free from local sources of pollution may show a more pronounced response to the effects of long-range transport and deposition of air pollutants than adjacent developed areas.

Finally, a monitoring program can provide basic background information that is needed by park researchers, public information officers, interpreters, and those wanting to know more about the area around them (Johnson and Bratton 1978). Data such as basic weather information, plant phenology, and records of major disturbances, such as volcanic eruptions and landslides, are useful on a periodic basis to those working or visiting in the parks.

1.4 Southwest Alaska Network—Environmental Setting and Park-Specific Mandates: What Physical and Biological Features Make These Park Units Special?

The Southwest Alaska Network (SWAN) consists of five units of the NPS (Figure 1-2, Appendix I-1). Katmai National Park and Preserve (KATM) (6,409 mi^2 [16,599 km^2]), Alagnak Wild River (ALAG) (48 mi^2 [124 km^2]), and Aniakchak National Monument and Preserve (ANIA) (942 mi^2 [2,440 km^2]; Appendix I-2) are managed as one administrative unit by staff based in King Salmon. Lake Clark National Park and Preserve (LACL) (6,254 mi^2 [16,198 km^2]) is managed by staff based in Anchorage, Homer, and Port Alsworth, and Kenai Fjords National Park (KEFJ) (1,047 mi^2 [2,712 km^2]) is managed by staff based in

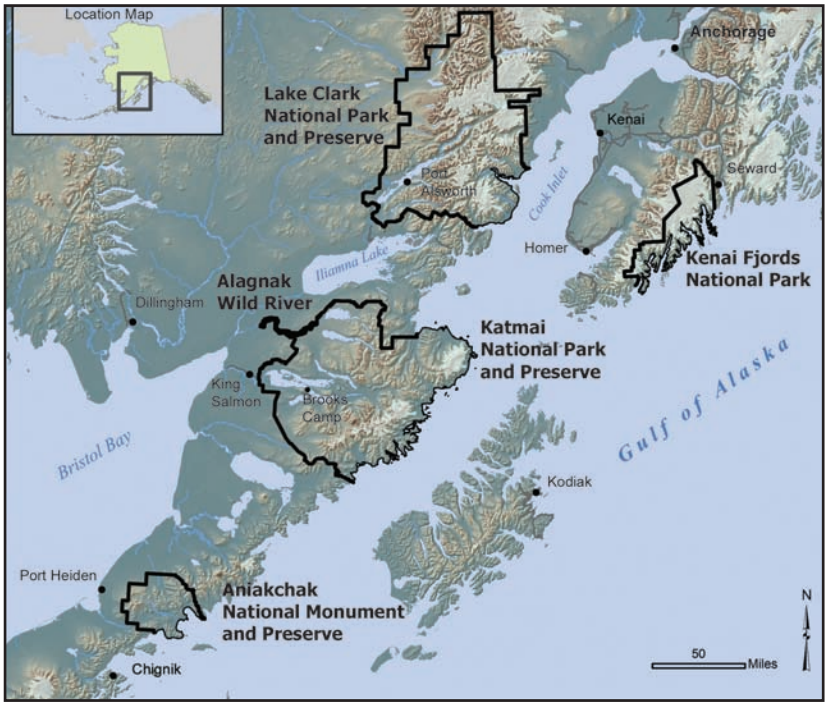


Figure 1-2 *National Park Service units in SWAN.*

Seward. Collectively, these units comprise 9.4 million acres (3.8 million hectares), 11.6 percent of the land managed by the NPS, or 2 percent of the Alaska landmass, and include a diversity of geologic features, ecosystems, wildlife, and climate conditions that are equaled few places in North America (Appendix II).

> ***Mandate: Aniakchak National Monument and Preserve*** -
> *"To maintain the caldera and its associated volcanic features and landscape, including the Aniakchak River and other lakes and streams, in their natural state; to study, interpret, and assure continuation of the natural processes of biological succession; to protect habitat for, and populations of, fish and wildlife, including, but not limited to, brown/grizzly bears, moose, caribou, sea lions, seals, and other marine mammals, geese, swans, and other waterfowl…." (Alaska National Interest Lands Conservation Act* [ANILCA]).

1.4.1 Dynamic Landform Processes and Patterns

From steep glaciated fjords in the east to steaming volcanoes on the western horizon, SWAN parks occur in one of the most geologically active regions of the continent. The Network is located on the shelf of the North American Plate, one of the most seismically active regions of the United States. During the 1964 earthquake, lands within KEFJ subsided three to six vertical feet (0.9 to 1.8 meters), whereas in LACL and KATM, coastal lands rose by that amount. The Network contains at least 17 active volcanoes. Katmai National Monument was created to preserve the Valley of Ten Thousand Smokes, a spectacular 40-square mile, 100-to-700-foot-deep, pyroclastic ash flow deposited by the 1912 eruption of Novarupta. Aniakchak National Monument was created in recognition of the unique geological significance of its 6-mile-wide, 2,000-foot-deep caldera formed 3,500 years ago by the explosive eruption of a 7,000-foot mountain.

Approximately one-fifth of the landmass of this Network is covered by ice or permanent snowfields. Valley and tidewater glaciers radiate from massive snowfields along the coastal mountains of the three northernmost parks. Ten of the 34 tidewater and hanging glaciers that emanate from the Harding Icefield are in KEFJ.

Volcanic eruptions, tectonic forces, and glacial processes combine to make this Network an important laboratory for both geologic research and long-term ecological studies of how landscapes respond to infrequent, large-scale disturbances. For example, a unique opportunity exists to observe pattern and relative timing of ice retreat, primary and secondary plant succession, patterns of animal colonization, and evolutionary processes.

> ***Mandate: Kenai Fjords National Park*** –
> *"To maintain unimpaired the scenic and environmental integrity of the Harding Icefield, its outflowing glaciers, and coastal fjords and islands in their natural state; and to protect seals, sea lions, other marine mammals, and marine and other birds and to maintain their hauling and breeding areas in their natural state, free of human activity which is disruptive to their natural processes."* (ANILCA)

1.4.2 Marine Coastline

SWAN parks contain almost one-third of the marine coastline in the National Park System. This coastline spans 1,200 miles in the northern Gulf of Alaska, from the heavily glaciated KEFJ on the Kenai Peninsula to sparsely glaciated Aniakchak on the Alaska Peninsula. The Network's varied coastline, numerous freshwater drainages, and diverse geomorphology generate many combinations of physical factors, creating a microcosm of the northern Gulf of Alaska. KEFJ's rocky headlands with extreme wave exposure place in sharp contrast the protected low-energy beaches and broad intertidal flats at KATM and LACL.

SWAN coastal waters are one of the most biologically productive nearshore ecosystems in the world (Sambrotto and Lorenzen 1986). High tides, frequent storms, and upwelling produced by the Alaska Coastal Current bring essential nutrients to the surface euphotic zone, where they support growth and productivity along the continental shelf (Burbank 1977, Lees et al. 1980, Hood and Zimmerman 1986).

Important ecological features of the Network coastline include (i) sheltered salt marshes and tidal flats that support lush vegetation and large populations of benthic organisms and serve as important feeding and resting areas for brown bears (*Ursus arctos horribilis*), shorebirds, and fish; (ii) cliffs, headlands, and islands that support seabird rookeries and marine mammal haul outs; (iii) eelgrass, surfgrass, and kelp beds that provide herring spawning areas and a nursery substrate that supports the base of the nearshore food chain; and (iv) tidally influenced coastal freshwater streams that support wild stocks of anadromous salmon.

1.4.3 Aquatic Systems, Anadromous Fish, and Ecological Interrelationships

> ***Mandate: Lake Clark National Park and Reserve*** *– "To protect the watershed necessary for the perpetuation of the red salmon fishery in Bristol Bay; to maintain unimpaired the scenic beauty and quality of portions of the Alaska Range and the Aleutian Range, including volcanoes, glaciers, wild rivers, lakes, waterfalls, and alpine meadows in their natural state; to protect habitats for and populations of fish and wildlife, including, but not limited to caribou, Dall sheep, brown/grizzly bears, bald eagles, and peregrine falcons."* (ANILCA)

Wild anadromous fishes link the ocean, freshwater, and land in important functional ways, supporting a complex food web that crosses the land-water interface (Willson et al. 1998). The interrelation-ships among salmon (*Oncorhynchus* sp.*)*, brown bears, and the structure and function of both aquatic and terrestrial ecosystems are flagship ecological resources of the Network and of national and international significance.

Network parks contain some of the largest and most pristine freshwater resources in the National Park System. These include the two largest lakes, Naknek Lake and Lake Clark, numerous multilake systems, and thousands of miles of rivers, including five designated Wild Rivers. Surface water covers approximately 432,000 acres (12 percent) of KATM. Aquatic systems in the western portions of KATM and LACL are so extensive that they form the template upon which biological systems at all levels are organized.

Aquatic systems in the Network are pristine in the sense that (i) natural watershed processes are operating, including disturbances such as floods and seasonal changes in flow; (ii) water quality is, by national standards, unimpaired (there are no designated [303(d), Clean Water Act] surface waters, although near-field and far-field influence have in all likelihood introduced small but unknown amounts of contaminants; and (iii) aquatic fauna diversity and productivity vary naturally in both time and space. Aquatic and terrestrial animals have likely had a very long, and probably coevolutionary, relationship with salmon in each of these parks (Willson et al. 1998, Gende 2002, Schindler et al. 2003), as higher growth rates or reproductive successes in eagles, bears, and mink have been attributed to salmon availability (Hansen 1987, Ben-David 1997, Hilderbrand et al. 1999b). The magnitude of salmon-wildlife-ecosystem relationships calls attention to the consequences of loss or severe depletion of anadromous fish stocks, and the role that long-term monitoring can play in documenting these changes.

1.4.4 Wilderness-Dependent Large Mammal Species and Species Interactions

> ***Mandate: Katmai National Park and Preserve*** *–*
> *"for the protection of the ecological and other scientific values of Naknek Lake and the existing monument…; to protect habitats for, and populations of, fish and wildlife, including, but not limited to, high concentrations of brown/grizzly bears and their denning areas; to maintain unimpaired the water habitat for significant salmon populations; and to protect scenic, geological, cultural, and recreational features."* (ANILCA)

Despite hunting and other human activities, all parks in the Network possess intact, naturally functioning terrestrial ecosystems with their historic complement of species, including large apex carnivores and predator-predator, predator-prey interactions. Intact, functioning ecosystems with historic levels of biodiversity are becoming extremely rare globally and supply a resource of great value locally and internationally.

Some key wilderness-dependent mammals in SWAN are wolverines *(Gulo gulo*), brown bears, wolves *(Canis lupus*), and lynx *(Lynx rufus*). These species do not require wilderness

habitats per se, but they require wilderness to avoid conflicts with humans and to avoid human-caused mortality. They also depend on populations of free-roaming, naturally cycling prey. Wilderness-dependent interactions include wolf-ungulate, brown bear-ungulate, carnivore-carnivore, predator-scavenger, and cyclic lynx-snowshoe hare (*Lepus americanus)* interactions.

Davis and Halvorson (1988) considered national park ecosystems to be "miner's canaries," and nowhere is this con-cept more appropriate than when applied to wilderness-dependent species (Peek 1999). Because such species are sensitive to human disturbance and need large tracts of wild land or wilderness to survive, their status signals impending environmental change across broad geographic areas. For example, wolverines are a classic wilderness-dependent species because they require large home ranges with a full array of seasonal habitats, intact populations of prey, larger apex predators that provide scavenging opportunities, and refugia from human influences. Banci (1994) found that the persistence of wolverines in southwestern Alberta is due entirely to the presence of large refugia in the form of national parks. As wild ecosystems are progressively compromised by a variety of human activities, such as mining, logging, recreation, and settlement, what is left becomes increasingly valuable as laboratories of natural ecological processes.

1.4.5 Ecoregion and Biological Diversity

> ***Mandate: Alagnak Wild River** – "To protect and enhance the values which caused it to be included in said system.…These values are the river's outstandingly remarkable scenic, fish and wildlife, and recreation attributes."* (ANILCA)

Southwest Alaska parks are places where land and water meet. LACL is often called "one park, four Alaskas," referring to the diversity of landscapes relative to area (Appendix I-2, I-3, and I-4). Although not as dramatically, this diversity feature is shared by each of the Network parks, which collectively span three Alaska climatic zones and 11 ecoregions (Appendix I-5).

Landscape diversity, the product of diverse bedrock types and climatic and disturbance regimes, provides the template for relatively high biological diversity. Coastal Aleutian, low Arctic, interior-boreal, and Pacific coastal floras and faunas converge in southwest Alaska, with SWAN parks supporting 60% of the state's vascular plant flora. Vascular plant communities in the region continue to undergo changes in composition, and the shift in species distributions since the Last Glacial Maximum, primarily in the movement of species south and southwest, is readily observed today. For example, Sitka spruce (*Picea sitchensis*) is migrating from the upper Alaska Peninsula west toward the Aleutians and southwest toward the Kodiak Island Archipelago (Capps 1937), while alder (*Alnus sinuata*) has increased dramatically in the region over the last several centuries (Heusser 1983, Nelson 2004). Numerous species of animals, such as Dall sheep *(Ovis dalli)*, black bear *(Ursus americanus*), and trumpeter swans *(Olor buccinator),* also reach the limits of their statewide range in SWAN parks.

Climate change and its influence on the distribution of plants and animals in the Network have broad implications for long-term monitoring. The geographic ranges of most plant and animal species are limited by climatic factors, including temperature, precipitation, soil moisture, humidity, and wind. Peninsular landmasses are likely to respond to climate change more rapidly and severely than mainland interior areas because of a greater coast/interior ratio (Suffling and Scott 2002). Colonization by new species, changes in the distribution of existing species, or changes in the timing of critical life stages or patterns of migration all have implications for park management and resource protection.

1.5 Approach to Planning a Monitoring Program

SWAN staff have followed the basic three-phase, five-step approach to designing a monitoring program (Table 1-1), described in detail in the Recommended Approach for Developing a Network Monitoring Program (http://science.nature.nps.gov/im/monitor/index.htm):

Table 1-1 *Overall timeline for the SWAN to complete the entire three-phase planning and design process to develop a monitoring program.*

	FY01 Oct-Mar	FY01 Apr-Sep	FY02 Oct-Mar	FY02 Apr-Sep	FY03 Oct-Mar	FY03 Apr-Sep	FY04 Oct-Mar	FY04 Apr-Sep	FY05 Oct-Mar
Data Gathering, Internal Scoping									
Inventories to Support Monitoring									
Scoping Workshops									
Conceptual Modeling									
Vital Sign Prioritization and Selection									
Protocol Development, Monitoring Design									
Monitoring Plan Due Dates Phase 1, 2, 3					Phase 1 Oct 03		Phase 2 Oct 04		Phase 3 Dec 05

Phase 1

1. Define the purpose and scope of the monitoring program.
2. Compile and summarize existing data and understanding of park ecosystems.
3. Develop conceptual models of relevant ecosystem components.

Phase 2

4. Select vital signs and specific monitoring objectives for each.

Phase 3

5. Determine the appropriate sampling design and sampling protocols.

During March and May 2002, the SWAN Technical Committee held a series of meetings to develop a strategy for breaking the three-phase planning process into manageable pieces that could be addressed sequentially. Considerations in developing this strategy were (i) the relatively small size of the natural resources staff in the Network parks (at the onset of planning the combined natural resources staff of the three administrative units numbered seven); (ii) logistical challenges of meeting as a group because park staff are based in three different remote Alaska locations; and (iii) a desire by Technical Committee members to participate collectively as a single team throughout the planning process.

1.5.1 Scoping Workshops

The Technical Committee used a series of mini scoping workshops to review and discuss the current state of knowledge concerning park ecosystems, resource protection issues, and potential options for monitoring. The objectives for workshops were to (i) review/refine conceptual ecosystem models and monitoring questions drafted by the Technical Committee and Network staff; (ii) identify drivers of change and discuss why it is important to understand them; and (iii) identify candidate attributes to monitor that provide reliable signals about ecosystem condition. The Technical Committee, NPS staff from other networks and the Alaska Regional Office, and scientists from universities, State of Alaska agencies, and other federal agencies attended the workshops.

Figure 1-3 *Participants identify candidate attributes to monitor during the Terrestrial Ecosystems Workshop in 2003.*

Most workshops had a community or ecosystem focus, and workshops were ordered in sequence: coastal⇨ freshwater⇨ terrestrial (Figure 1-3, Table 1-2). The coastal workshop was held first because in this Network the ocean influences structure and processes in freshwater and terrestrial ecosystems. Similarly, the freshwater workshop identified many key terrestrial linkages, such as nutrient transfer. The cascading sequence also allowed many of the same participants to progress through the process in a logical order. The workshop summaries comprised a growing base of information that enhanced efficiency of successive workshops and integration of components. Pre-workshop preparation involved assembling extensive background material on Network parks and developing objectives and monitoring questions This background material was mailed to participants 1 month before the workshop to familiarize them with the landscape and to stimulate discussion.

Table 1-2 *Scoping workshops held in FY 2002–2003 to identify ecosystem drivers and other agents of change, resource management and scientific issues, and monitoring options for parks in the SWAN.*

DATE/PLACE	PARTICIPANTS[1]	SUBJECT	PURPOSE
May 2, 2002, in Anchorage, AK	Network Park Staff, Subject Matter Expert(s): Karen Oakley, USGS	Network Landscape Ecosystems	Identify: Dominant Resource Management Issues; Focus Areas for Long-term Monitoring, Physical and Human-related Agents of Change, and Landscape Sub-components to be Addressed by Subsequent Workshops
August 26–28, 2002, at Kenai Fjords National Park	Network Park Staff, Subject Matter Expert(s): Charles Peterson, Univ. North Carolina; Carl Schoch, Kachemak Bay Research Reserve-ADF&G; Vernon Byrd, Alaska Maritime NWR-USFWS; Karen Oakley, USGS; Peter Armato, NPS	Marine–Coastal Nearshore Ecosystems	Review: Modify Ecosystem Conceptual Models; Identify Ecosystem Drivers of Change; Identify Key Resources, Their Ecological Importance, and How They Are Affected by Drivers of Change; Identify Candidate Resources and Attributes for Monitoring
November 4–6, 2002, at Cooper Landing, AK	Network Park Staff, Subject Matter Expert(s): John Magnuson, Univ. Wisconsin; Robert Stallard, USGS-WRD, Joe Margraf, Univ. Alaska Fairbanks; Jim Larson, USFWS; Phil North, EPA; Karen Oakley, USGS; Nancy Deschu, NPS	Freshwater Ecosystems	Review: Modify Ecosystem Conceptual Models; Identify Ecosystem Drivers of Change; Identify Key Resources, Their Ecological Importance, and How They Are Affected by Drivers of Change; Identify Candidate Resources and Attributes for Monitoring
December 12, 2002, in Anchorage, AK	Network Park Staff, Subject Matter Experts: Michael Shephard, USFS; Karen Oakley, USGS	Physical Landscape Drivers	Review: Modify Landscape Conceptual Models; Identify Key Physical Drivers of Change and How They Are Manifested as Gradients of Temperature and Precipitation; Identify Catastrophic Disturbances
April 16–17, 2003, in Anchorage, AK	Network Park Staff, Subject Matter Expert(s): Robert Gill Jr., USGS; David Duffy, Pacific CESU; Rob DeVelice, USFS; Gerald Tande, ANHP; Ed Berg, USFWS; Torre Jorgenson, Alaska Biol. Research; Karen Oakley, USGS; Terry DeBruyn, NPS	Terrestrial Ecosystems—Fauna and Flora	Review: Modify Ecosystem Conceptual Models; Identify Ecosystem Drivers of Change; Identify Key Resources, Their Ecological Importance, and How They Are Affected by Drivers of Change; Identify Candidate Resources and Attributes for Monitoring
November 13, 2003, in Fairbanks, AK. Jointly held with Central Alaska Network	Network Park Staff, Subject Matter Expert(s): Bruce Molnia, USGS; Dennis Trabant, USGS; Rod March, USGS; Daniel Lawson, CRREL; Keith Echelmeyer, UAF-GI; Martin Treuffer, UAF-GI; Roman Motyka, UAF-GI; William Harrison, UAF-GI; Matthew Sturm, CRREL; Adam Bucki, UAF-GI	Glaciers and Icefields	Review: Modify Ecosystem Conceptual Models; Identify Ecosystem Drivers of Change; Identify Key Components of Glacier Systems that are Effectively Monitored; Identify Potential Partnerships for Glacier Monitoring.

1. ADF&G - Alaska Department of Fish and Game; USFWS - U.S. Fish and Wildlife Service; USGS - U.S. Geological Survey; USFS - U.S. Forest Service; EPA - Environmental Protection Agency; CESU - Cooperative Ecosystems Study Unit; ANHP- Alaska Natural Heritage Program

Scoping workshop discussions were recorded and compiled into a workshop summary report that was sent to participants and posted on the Network Web site. Workshop notebooks and summary reports also were circulated for technical review and comment by scientists who did not attend the workshops (Table 1-3). Review comments were not used to revise the summaries, but were added as an attachment and were considered by the Technical Committee during Phase II planning.

Table 1-3 *Technical reviewers of SWAN scoping workshop summaries.*

Technical Reviewer and Affiliation(s)	Area(s) of Expertise
Ginny L. Eckert Assistant Professor of Biology University of Alaska, Southeast School of Fisheries and Ocean Sciences Juneau, AK	Marine Intertidal Ecology and Monitoring; Population Dynamics of Benthic Marine Invertebrates
Mark W. Oswood Professor of Zoology University of Alaska - Institute of Arctic Biology Bonanza Creek LTER Fairbanks, AK	Freshwater Ecology, Especially of Rivers and Streams; Limnology; Entomology; Biodiversity of Aquatic Invertebrates
Andrea Woodward Research Ecologist USGS FRESC Olympic Field Station Seattle, WA	Development of Long-Term Ecological Monitoring Plans; Plant-Animal Interactions; Effects of Climate Change on Subalpine Plant Communities
Michael Shephard Ecologist US Forest Service State and Private Forestry Anchorage, AK	Community Ecology; Dynamics of Coastal Rainforests; Ecoregion Mapping; Invasive Exotic Plants
John N. Schoen Senior Scientist National Audubon Society - Alaska State Office Affiliate Professor of Wildlife Biology University of Alaska Anchorage, AK	Large Mammal Population Dynamics; Forest Wildlife Habitat Relationship; Conservation of Landscape Biodiversity

1.5.2 Data Mining

The purpose of data mining was to find and catalog information relating to natural resources in the park or its vicinity to support the development of a monitoring plan. Products from data mining primarily consisted of two types of documentation: a bibliography and metadata. The bibliography documented formal and informal reports, articles, and books, whereas metadata information documented databases, geographic information system (GIS) data, and spreadsheets. Results from data mining are searchable using the SWAN Information Discovery and NPS NatureBIB (http://www1.nature.nps.gov/im/units/swan/).

1.5.3 Review of Monitoring by Others

To help us develop partnership opportunities or benefit from monitoring efforts conducted by other federal and state agencies, we reviewed global, national, regional, and local monitoring efforts that may be relevant to natural resources monitoring in our Network. A portion of this survey was accomplished using a questionnaire that was mailed to principal investigators. We compiled information into databases of existing and planned research and monitoring within ecoregions encompassed by the Network. Other partnership opportunities were identified during scoping workshops.

1.6 Water and Air Quality Monitoring

Issues affecting water quality, the role of water quality monitoring in an integrated ecosystem context, Water Resources Division (WRD) core variables, and other water quality parameters were discussed at the coastal, freshwater, and other scoping workshops. The Network's strategy for water quality monitoring (funded by the NPS WRD) is to fully integrate the design and implementation of water quality monitoring with the Network-based vital signs monitoring. Steps taken toward developing a water quality monitoring component include (i) identifying and evaluating existing monitoring efforts, historic data, and information needs; (ii) developing a list of biological, chemical, and physical parameters for monitoring; and (iii) determining watershed and water body features (Appendix I-6).

As part of these efforts, the Network has determined that no 303(d) waters are present in any of the parks, although several have been designated on tributaries to the Naknek River downstream of the park boundary. The State of Alaska does not designate Outstanding National Resource Waters. Water quality data collection within these parks has been sporadic, and trend analysis was not possible. In general, Network waters are low in nutrients and show little evidence of human impact. Some water bodies (e.g., Battle Lake, tributaries to Surprise Lake, and streams within the Valley of Ten Thousand Smokes) are naturally low in pH or are enriched in dissolved constituents due to volcanic inputs.

All parks within SWAN are classified as Class II air quality areas. Limited monitoring of fine particulates (< 2.5 µm) in KATM from 1987 to 1992 indicated sources from long-range transported anthropogenic aerosol, sea-salt aerosol, and local soil dust, and high concentrations of lead and bromide, indicative of fossil fuel emissions (Polissar et al. 1998). Potential air pollution threats include oil and gas development in Cook Inlet, mining, coal-fired power production, and long-range transport of air pollutants. The U.S. Fish and Wildlife Service has established two coastal Interagency Monitoring of Protected Visual Environments (IMPROVE) stations in the SWAN region, one along the coast of LACL, and a second in the Shumagin Islands, which should provide regional data on aerosol concentrations. In addition, the Western Airborne Contaminants Assessment Project (WACAP) has been initiated to determine the risk to ecosystems and food webs in western national parks from the long-range transport of airborne contaminants.

1.7 Monitoring Goals, Objectives, and Questions

The overall goals of natural resource monitoring in parks are to develop scientifically sound information on the current status and long-term trends in the composition, structure, and function of park ecosystems, and to determine how well current management practices are sustaining those ecosystems (http://science.nature.nps.gov/im/monitor/GoalsObjectives.htm#GoalsObj).

NPS Service-wide Vital Signs Monitoring Goals

1. *Determine status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.*
2. *Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management.*
3. *Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.*
4. *Provide data to meet certain legal and congressional mandates related to natural resource protection and visitor enjoyment.*
5. *Provide a means of measuring progress toward performance goals*

The long-term monitoring program of SWAN will be designed around the five broad, Service-wide goals. Service-wide goals 1 and 3 establish the primary framework for the monitoring in SWAN because they emphasize (i) the establishment of baseline reference conditions representing the current status of park and preserve ecosystems; and (ii) an understanding of the range of natural variation in park ecosystems and detecting changes through time.

Within coastal, freshwater, and terrestrial ecosystems, preliminary monitoring objectives and questions were nested within this framework of understanding ecosystem behavior and detecting change (Table 1-4). Objectives and questions were developed by the SWAN Technical Committee and revised based on review of conceptual ecosystem models, suggestions from scientists who participated in the scoping workshops, and comments from technical reviewers of the workshop summaries. These general monitoring questions served as the basis for framing more specific monitoring questions and measurable objectives that were incorporated into protocol development summaries after vital signs were selected.

Table 1-4 *SWAN monitoring objectives and questions.*

Climate and Weather

Objective 1. Understand the natural range of variation in weather patterns across the SWAN parks.

- What is the annual variability in quantity, timing and form of precipitation in network park ecoregions?
- What are the patterns of direction, strength, and timing for storm tracks and wind? How do these affect storm surges on coastal systems?
- What are the ranges and timing of seasonal temperature fluctuations?

Objective 2. Understand general climate trends in network parks, including changes due to Pleistocene ice retreat and global climate change.

- How are current climate trends contributing to glacial retreat (and possible advances)?
- Are there general trends in warming (cooling) and/or increased (decreased) precipitation? Are these trends affecting volume and timing of river flows and coastal storms?

Dynamic Landform Processes and Patterns

Objective 1. Understand how movements of the North Pacific and North American plates are affecting park terrains.

- How do ongoing earthquake activity and resultant uplift and subsidence affect park lands, especially coastal beaches and intertidal areas?

Objective 2. Understand effects of Pleistocene and Little Ice Age glaciations on SWAN ecosystems.

- How rapidly are glaciers retreating now, relative to former eras? How are icefields changing in area and extent?
- How are refugia and nunataks affecting patterns of plant and animal colonization?

Marine Coastline - Fjords and Estuaries

Objective 1. Understand long-term changes in the physical and chemical features of coastal habitats.

- What are annual trends in salinity and other nearshore marine water quality parameters?
- How is the relative composition of nearshore marine habitats changing (physical morphology and biotic communities)?

Objective 2. Understand how key marine species and communities are responding to changes in habitat.

- Is the distribution of coastal salt marshes changing, or are vegetation zones within salt marshes migrating?
- How does the distribution and relative abundance of marine mammals fluctuate spatially or temporally?
- How are species that live in the supratidal but forage in estuaries and the intertidal changing with respect to distribution and abundance?
- Are key species successfully reproducing?

Aquatic Systems - Large Rivers and Lakes

Objective 1. Understand long-term changes in the physical and chemical features of large rivers and lake systems.

- How is water quality, including temperature, dissolved oxygen, conductivity and pH, changing spatially and temporally within large lake systems?
- How are the thermal dynamics of large lakes changing in relation to the duration or lack of winter ice cover?
- How are seasonal discharge and sediment regimes of rivers shifting? (i.e., higher winter flows and lower spring and summer flows?)

Objective 2. Understand how ecological relationships are changing in rivers, lakes, and wetlands.

- How are lake processes responding to climatic warming?
- How is anadromous salmon abundance and spawning distribution changing?
- How is the composition and abundance of resident lake fish changing?

(continued on next page)

Table 1-4 (continued)

Ecoregion and Biological Diversity
Objective 1. Document rates and types of change in vegetation in response to environmental factors and human effects. • How are plant and animal communities changing across the SWAN region in response to the primary environmental drivers of climate, natural disturbances, biotic interactions, and human activities? **Objective 2. Observe and understand ecological relationships and how the occurrence and distribution of fauna species and communities are changing.** • Are species range shifts occurring, and are they occurring evenly among habitats? • Do nonnative species occur, and is their distribution increasing? • How is the composition of bird and mammal communities changing?
Wilderness Dependent Wildlife and Species Interactions
Objective 1. Understand how species sensitive to humans are responding to habitat fragmentation, harvest, and increased human presence within or near parks. • How are the distribution and/or relative abundance of large and medium sized carnivores changing? • How are assemblages of carnivore prey species and vegetation communities changing temporally and spatially? • How is habitat connectivity changing for wide ranging wilderness species such as wolves?
Human Activities
Objective 1. Understand how park and preserve ecosystems are affected by local and regional human activities. • How are methods and locations of human access changing? • How are visitor numbers and activities changing, and which resources are at risk from these changes? • What land developments are occurring near and on park lands, and how do these affect park resources? • Are hydrocarbons and other toxins bioaccumulating in marine invertebrates or freshwater fish? **Objective 2. Understand how park and preserve ecosystems are affected by global human development activities.** • How are network ecosystems responding to global climate change? • How are far field human development activities affecting air and water quality in and surrounding network parks? • Are atmospherically deposited or biotransported pollutants, such as PCB's and methyl mercury accumulating in fish; and do their concentrations show geographic gradients?

1.8 Conceptual Foundation for Monitoring

SWAN embodies a vast, diverse, and dynamic landscape that changes through space and time in response to inputs of energy, natural events, and the influence of humans. Monitoring at such large geographic scales requires a framework for understanding relationships between components and processes of interacting ecosystems and the human activities that affect them. For example, to understand how park ecosystems respond to adverse effects arising from human activities we need to be able to distinguish between changes that fall within and outside the range of natural variability. This requires scientifically sound information on ecosystem status and trends acquired through long-term monitoring. Short-term monitoring provides an incomplete picture because annual fluctuations may reflect variables that cycle through decades such as precipitation patterns, temperature regimes, or predator and prey populations. This is particularly true in subarctic regions, such as in southwest Alaska, where biological processes are relatively slow. In consideration of this, our conceptual foundation provides a guide for monitoring and research.

Conceptual Foundation for Monitoring
SWAN and its surrounding landmass, glaciers, lakes, rivers, and marine coastline are an interconnected landscape. Within this interconnected whole, at time scales of years to decades, climate, natural disturbance, biotic interactions, and human activities are the most important driving forces in determining ecosystem structure and function. Consequently, our monitoring program must address the interplay of multiple forces, which occur at a variety of spatial and temporal scales, in order to understand the structure and function of network ecosystems.

1.8.1 Landscape-Based Monitoring: Why Is It Important to Have a Landscape Perspective?

Theories developed to support studies of ecosystems are different from those that form a basis for studies of the ecology of landscapes (Sanderson and Harris 2003). A key difference is that time and space are rarely independent variables in ecosystem studies, even in watersheds. The SWAN landscape is a heterogeneous land area composed of interacting ecosystems that differ structurally in the distribution of species, communities, energy, and materials. This perspective is important for park managers in that the organisms that can exist (including their movement patterns, interactions, and influence on ecosystem processes) are constrained by the sizes, shapes, and patterns of interspersion of habitat across the landscape.

"Anyone who has visited a national park would agree that although a rotting log might be an ecosystem, it hardly qualifies as a landscape." (Sanderson and Harris 2003)

Landscape ecology is a science that explores how a heterogeneous combination of ecosystem attributes is structured, functions, and changes. Four principles of landscape ecology have particular importance for long-term monitoring in large Alaska national parks. These landscape principles deal with *time*, *place*, *disturbance,* and *species.*

a) Time Principle—Ecological processes function at many time scales, some long, some short; and ecosystems change through time. The time principle has several important implications for monitoring. First, the current composition, structure, and function of park ecosystems are, in part, a consequence of historical events or conditions that occurred decades to centuries to millennia earlier. Second, the full ecological effects of human activities often remain unseen for many years because of the time it takes for a given action to propagate through components of the system. Finally, the imprint of natural disturbance or a land use may persist

"Because we are unable to directly sense slow changes . . . processes acting over decades are hidden and reside in 'the invisible present.'" (Magnuson 1990)

on the landscape, constraining processes or species occurrence and abundance for decades or centuries (Dale et al. 2000).

We need to understand how the temporal dynamics of landscape change in parks affects ecological structure and processes. Short-term ecological events that we see every day often have their origins in transient, rare, slow, or subtle processes. Similarly, ecosystem response to natural and human-induced events may be cyclical, directional, episodic, or catastrophic. It is extremely difficult for humans to sense changes occurring over decades. Magnuson (1990) coined the term "the invisible present" to refer to the loss of information and tendency for misinterpretation when we fail to observe the present in appropriate time scales.

In the invisible present one finds time scales of the invasion of nonnative plants and animals; bioaccumulation of toxins, such as mercury; shifts in metapopulation dynamics of large mammals; and carbon dioxide-induced global climate change. These and other events move too slowly to be appreciated in real time, yet their accumulation results in real change over decades.

In the past, natural resource research and management in Alaska parks has been characterized by short-term (1–3 year) projects, and in most cases, frequent staff turnover. Short-term projects or breaches in continuity associated with park staff turnover confound interpretation of annual fluctuations in populations that may reflect such variables as precipitation patterns, temperature regimes, predator populations, or natural cycles.

***b) Place Principle*—**Local climatic, hydrologic, edaphic, and geomorphologic factors as well as biotic interactions strongly affect ecological processes and the abundance and distribution of plants and animals at any one place. Local environmental conditions reflect location along gradients of elevation, temperature, salinity, longitude, and latitude and the multitude of mesoscale physical, chemical, and edaphic factors that vary within these gradients. Hence, a rocky shoreline in KEFJ looks very different and has a different biotic community structure than a rocky shoreline at LACL.

> *"Even though . . . site-specific trends enhance our ecological insights, they rarely answer many questions of significance about larger . . . systems."*
> (Urquhart et al. 1998)

Ecological systems are characterized by multiple drivers acting at multiple scales, complex patterns of spatial variability, and unidentified thresholds. Because ecological processes and responses depend on the spatial context of an observation as well as on its temporal context, the analogy of an "invisible place," as with the invisible present, may be appropriate.

Park resource studies are often conducted at small spatial scales due to logistical constraints and costs, and often in response to management issues that are perceived to be localized. In field surveys, park biologists often make observations at different sites with the aim of relating biological response variables (i.e., the abundance of a species or the structure of an ecological community) to environmental variables. However, the ability to take a Network-wide view is important because when the same system is observed at several spatial scales, completely different characteristics in the distribution of organisms can be revealed (Turner et al. 1989).

Reciprocal relationships often exist among landscape structure and composition and ecological processes (Dale et al. 2000). To understand the relation between pattern and process requires that we move beyond simple descriptions at local scales to an assessment at multiple spatial scales. For example, monitoring programs that target a few parameters or a single entity, such as moose (*Alces alces*) distribution or seasonal snow cover, have limited value for understanding ecological processes, modeling, forecasting change, and developing scenarios to protect park resources. By monitoring a range of physical, chemical, and biological variables through time, it is possible to gain an understanding of how ecosystems function and respond to change. Additionally, coupling monitoring with research and modeling makes it possible

to predict what might happen in the future and, where possible, devise appropriate management response strategies.

c) Disturbance Principle—It is imperative that we understand, and in some cases quantify, the drivers of change in ecological systems. These drivers include both ongoing natural processes, such as weather and interannual climatic variability, and random disturbances. Understanding the importance of the influence and magnitude of different drivers of change, the collective influence of multiple stresses, the ecological consequences of the changes, and the feedbacks between ecosystems and their physical environments (e.g., composition of the atmosphere or ocean, land use, water quality, sediment flux) is critical to the development of strategies for monitoring.

Figure 1-4 *Eruption of Mount Redoubt in LACL in 1990.*

A disturbance is an event that disrupts ecological systems, changes landscape patterns, and can impose both temporal and spatial heterogeneity on ecological systems. Disturbance events are usually episodic, such as avalanches or wildfires, or stochastic (random), such as earthquakes or volcanic eruptions (Figure 1-4). Episodic disturbances are part of the natural variability of a system, whereas stochastic disturbances change the trajectory of a system and may promote changes outside natural variability.

Disturbance has many important effects on communities and ecosystems, including enhancing or limiting biological diversity, initiating succession, and creating landscape patterns that influence many ecological factors, from movements and densities of organisms to functional attributes of ecosystems (Forman 1995).

Major natural disturbances, such as earthquakes and volcanic eruptions, can have sudden and widespread effects on Network parks. The concept of *geoindicators* describes common earth processes that, in less than a century, are liable to change in magnitude, direction, or rate, enough to affect ecosystem condition and landscape structure (Berger and Iams 1996). Twenty-three of the 27 earth system processes and phenomena named as geoindicators are operative in SWAN. In addition, human-induced disturbances, such as oil spills, have similar potential to exert sudden, widespread, and long-lasting change.

Figure 1-5 *The recent discovery of giant kelp (Macrocystis pyrifera) along the Kenai Fjords coast during 2002 is an example of the importance of the "species principle." Giant perenial kelp is a north Pacific endemic limited in distribution by winter sea surface temperatures. The species may have been transported from Southeast Alaska on commercial herring nets and accidentally introduced. Its survival may indicate winter warming in the northern Gulf of Alaska. This species can act as a keystone in rocky shore communities by providing structure and food for a variety of other species.*

d) Species Principle—Species respond to change, signal change, or directly affect ecological systems and landscapes in diverse ways (Figure 1-5). *Indicator species* (such as harbor seals, *Phoca vitulina*) are important because their condition indicates the status of a larger functional group of species, reflective of the status of key habitats, or symptomatic of the action of a stressor. *Keystone species* (such as sea otters, *Enhydra lutris*) have greater effects on ecological processes than would be

predicted from their abundance or biomass alone (Power et al. 1996). *Ecological engineers* (such as beavers, *Castor canadensis*) alter the habitat and, in doing so, modify the fates and opportunities of other species (Naiman and Rogers 1997). *Umbrella species* (such as brown bears) either have large area requirements or use multiple habitats and thus overlap the habitat requirements of many other species. *Link species* (such as sockeye salmon, *Oncorhynchus nerka*) exert critical roles in the transfer of matter and energy across trophic levels or provide critical links for energy transfer within complex food webs. Trophic cascades occur when changes in the abundance of a focal species or guild of organisms at one trophic level propagate across other trophic levels, resulting in dramatic changes in biological diversity, community composition, or total productivity.

Changes in the abundance and distribution of focal species are diverse and can affect ecosystems through such processes as competition, mutualism, dispersal, pollination, and disease and by modifying habitats and abiotic factors. For example, brown bears are an important vector for transferring marine nutrients to riparian forests, through dissemination of partially eaten salmon carcasses and salmon-enriched wastes (Ben-David et al. 1998, Hilderbrand et al. 1999a). To the extent that this process affects productivity and species composition in riparian forests, interactions of salmon and bears may be characterized as keystone interactions controlling the long-term structure and dynamics of riparian communities (Helfield and Naiman 2002).

Because effects of keystones are diverse and involve multiple steps, they are often unexpected despite their fundamental importance to biological diversity and ecosystem dynamics (Paine 1995, Power et al. 1996). The depletion or removal of a keystone species can radically change the diversity and trophic dynamics of a system. Changes in land use that affect keystone species may spread well beyond the boundaries of a land-use unit. Because SWAN parks adjoin state, Native American, and private lands, developments or management actions taken outside parks may create habitats unfavorable to some species and favorable to others, create barriers to movement or dispersal, introduce new predators or competitors, or change existing trophic relationships.

A nonnative species can assume a focal-species role when introduced into an ecosystem and produce numerous effects on it. Nonnative species have altered community composition and ecosystem processes via their roles as predators, competitors, pathogens, or vectors of disease and through effects on water balance, productivity, and habitat structure (Drake et al. 1989).

1.8.2 Issues-Oriented Monitoring: What Are the Most Important Management and Scientific Issues in the Network?

To achieve success and continued support, long-term monitoring must provide data that are both useful and widely used. The data must be relevant to topics of widespread interest, as well as those of specific management concern. Most importantly, the information generated from the monitoring program needs to assist park managers in clarifying and addressing resource protection issues.

As used in this plan, “issues-oriented monitoring” implies that some park resources by virtue of legislative mandate, importance to stakeholders, or risk from a specific threat may receive attention beyond that which would emerge from their ecological position of importance in the landscape. It *does not* imply that monitoring will only focus on a narrow range of issues perceived to be relevant to today’s management challenges. The Network’s monitoring program simply cannot address every resource management interest. Limitations exist because institutional resources devoted to monitoring practices are often constrained by time, finances, and personnel.

The intent of the program is to monitor a select set of ecosystem processes and components that reflects the status of Network ecosystems and is relevant to resource protection issues. This information will

collectively provide a foundation for understanding the parks and building a more flexible monitoring program. Future issues may emerge as monitoring proceeds and our understanding of ecological processes is enhanced.

As part of this process, past and current monitoring efforts within the parks were summarized (Table 1-5). Network park resource protection issues were compiled from former and current management plans, review of published and unpublished literature, and interviews with current and former park staff. Additionally, park resources staff developed a list of natural resource management issues or natural resources of special concern (current and anticipated). They also identified the basis for concern, if known, by identifying human-caused or environmental threats with the potential to affect park resources adversely. Issues were compiled and summarized under the headings of *Physical Change, Biological Resources, Pollution, and Human Use* (Table 1-6). This matrix was presented and discussed at scoping workshops attended by Regional NPS staff and scientists from other state and federal agencies. A recurring theme among issues is a lack of information. This is not surprising, given the vast size and complexity of the park units, brief history of their resource management programs, and relatively small staff and budget.

Park units in the Network share many of the same resource protection issues because of similarity in landscape features, geographic proximity, type and magnitude of public use, and enabling legislation. Most protection issues are linked to human population growth and the many ways that human activities are manifested in ecosystem response at the global, regional, network, and park scales. In Chapter 2, resource protection issues and concerns of Network parks are discussed under the headings of *far-field* (global/regional) and *near-field* (network/park). Conceptualizing near-field and far-field human effects is a challenging task because the scales are linked and environmental changes are not evenly distributed across the earth. Far-field human-related issues are manifested as climate change, long-distance air pollution, and demand for fossil fuels and other minerals. Near-field human-related issues are manifested as harvest of plants and animals, recreational use, and private lands development.

Table 1-5 *Summary of past and current monitoring in SWAN parks.*

	ANIA/ALAG/KATM	KEFJ	LACL
Air and Climate			
IMPROVE	NSF, NPS		**USFWS**
Weather		**Park**	**Park, NWS**
Snow	**Park**	**Park**	**Park**
Geology and Soils			
Glaciers		**Park, USGS**	CRREL
Water			
Stream Gauge		**Park, NWS**	**USGS***
Water Quality			**USGS***
Biological Integrity			
Insect and Disease	**ADNR**		**ADNR**
Salmon	**ADF&G**	**ADF&G**	**ADF&G, USFWS**
Bald Eagle	Park	Park	**Park**
Landbird	Park		
Trumpeter Swan			Park
Oystercatcher		Park	
Snowshoe Hare	Park		
Beaver			Park
Moose	**Park**		**Park**
Bear	**Park**		
Dall Sheep			Park
Mountain Goat		Park	
Stellar Sea Lion	**NMFS**		
Harbor Seal	**NMFS**	**Park, ASC**	
Vegetation		Park	
Human Use			
Visitor Use		**Park**	

Bold are currently monitored
* Park or Network funded

ADF&G = Alaska Department of Fish and Game
ADNR = Alaska Department of Natural Resources
ASC = Alaska Sealife Center
CRREL = United States Army Cold Regions Research and Engineering Lab
NMFS = National Marine Fisheries Service
NSF = National Science Foundation
NWS = National Weather Service
USFWS = United States Fish and Wildlife Service
USGS = United States Geological Service, Water Resources Division

Table 1-6 *Summary of natural resource protection and management issues in SWAN parks.*

	ANIA	KATM/ALAG	KEFJ	LACL
Pollution				
Airborne pollution or visibility	X	X	X	X
Noise pollution		X	X	X
Water pollution: bacterial, fuel emissions, fuel spills	X	X	X	X
Biological Resources				
Internal and external and developments that threaten habitat connectivity and animal movement corridors	X	X	X	X
Loss of community diversity, especially sensitive species and consumptive harvests (sport and subsistence)	X	X	X	X
Wildlife disturbance and displacement	X	X	X	X
Insect outbreaks	X	X	X	X
Exotic species introductions	X	X	X	X
Disruption of natural predator/prey interactions	X	X	X	X
Degradation of aquatic ecosystems	X	X		X
Alteration of trophic interactions in large lake systems	X	X		X
Depletion of salmon populations and effects on aquatic and terrestrial ecosystems	X	X	X	X
Changes in the composition, structure and function of intertidal biota related to climate change and pollution	X	X	X	X
Physical Change				
Soil erosion—human effects	X	X	X	X
Change in water chemistry	X	X	X	X
Change in climate: glacier changes, soil temp/permafrost changes	X	X	X	X
Volcanic eruptions	X	X		X

Chapter 2
Conceptual Models

The purpose of this chapter is to explain our understanding of how drivers of change and ecological interactions affect selected natural resource components and processes of SWAN parks. The models serve as pictorial illustrations of the conceptual foundation for monitoring presented in Chapter 1 and support the identification and selection of ecological vital signs for monitoring. Models also provide scientists and managers from different disciplines a common view of landscapes and ecosystems and provide an objective hierarchical framework for identifying attributes to monitor.

2.1 Introduction

We prepared conceptual models of coastal, freshwater, and terrestrial subsystems for each scoping workshop. Model development required extensive literature review and consultation with research scientists and landscape ecologists familiar with subarctic ecosystems. In some cases, published or unpublished models of ecosystems similar to southwestern Alaska were used. In the scoping workshop notebooks, conceptual models were presented in a hierarchical format focusing on the broadest view of the Network and then zooming into subcomponents. The broad perspective is useful to illustrate geoclimatic setting and regional scale processes responsible for the evolution of landforms. A second level of organization, such as a trophic food web, is useful to illustrate the processes responsible for the formation of habitat types and ecological functions. Specific models produced for scoping workshops included the following:

- Physical forces and energy flow—to describe the environmental context and most important abiotic factors influencing the subsystem;
- Trophic interactions (i.e., food webs)—to identify the "cast of players" in each subsystem, clearly identify the food base for each level of the subsystem, and see the connections between producers, consumers, and decomposers.
- Habitat types—to identify the most widely recognized types of habitats within each subsystem (e.g., lake types, intertidal communities, vegetation associations).
- Human activities—to characterize the human activities of current importance in the subsystem and identify activities of future concern.

Throughout the scoping workshops and other phases of planning, Network staff consulted these models to examine how processes may be linked across space and time. In some cases, workshop participants refined or created new ecosystem models. Models were also used to help formulate specific testable questions to be answered through long-term monitoring (Chapter 1, Section 1.6).

Models created for scoping workshops played an important role in the ongoing process of building the holistic models presented here. However, because coastal, freshwater, and terrestrial ecosystems in SWAN are tightly linked by geoclimatic forces, energy exchange, and biotic processes, it would be redundant to repeat each set of models three times. A common view of all three major systems facilitates understanding of the most important drivers of change in SWAN ecosystems.

Common themes about the drivers emerged and were reinforced throughout the workshop series. Workshop participants and researchers who have expert knowledge of subarctic landscapes repeatedly ranked climate/landform, landscape-scale disturbance, biotic interactions, and human activities as the four interactive drivers having the greatest relative impact on Network parks. A holistic model (Figure 2-1) depicts these four major drivers that affect the Network at the landscape-scale. They control the structure and processes important in the primary subsystems (coastal, freshwater, and terrestrial).

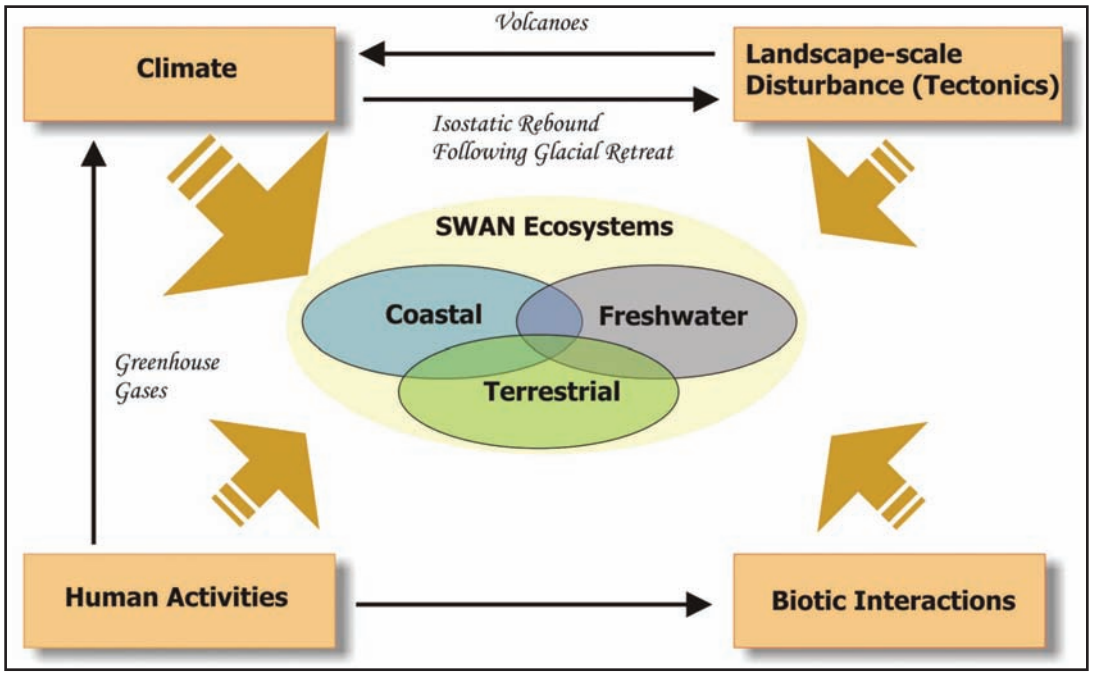
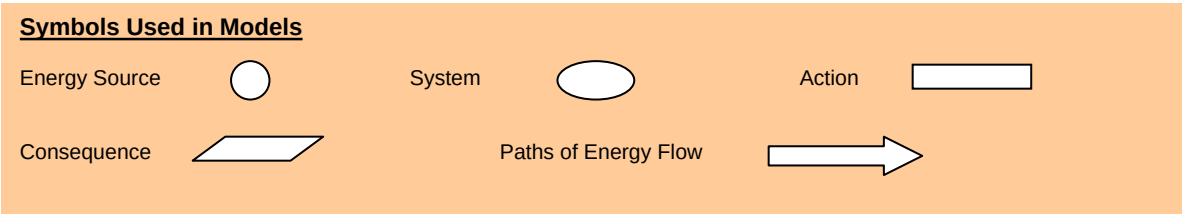


Figure 2-1 *Holistic model. Major driving forces shaping park ecosystems are climate, landscape-scale disturbance, biotic interactions, and human activities. The model depicts the close linkages between the primary subsystems (coastal, freshwater, terrestrial) of park ecosystems and feedbacks between the drivers. Drivers can act independently and interactively. For example, volcanic eruptions are tectonic disturbances that can lower air temperatures.*



Any number of more detailed models for various components or processes can be nested within this holistic model, without losing the broad view. The holistic model provides perspective and a forum for discussion of the relative strength of various forces acting in this Network.

In this chapter, we present a nested set of models for SWAN that depicts geoclimatic setting, ecosystem interactions, and interactive drivers of change. Understanding the influence and magnitude of drivers of change, the collective influence of multiple drivers, the ecological consequences of the changes, and the feedbacks between ecosystems and their physical environments is crucial to developing strategies for long-term monitoring.

2.2 Landscape Drivers of Change

2.2.1 Climate and Landform

Climate is considered to be the most important broad-scale factor influencing ecosystems. In Alaska, climate patterns reflect latitude, surrounding oceans, topography, and the interactions of these with global circulation (Simpson et al. 2002). The hydrologic cycle is the primary ecosystem driver, affecting both aquatic and terrestrial plants and animal communities, as well as the physical processes within the landscape. Understanding the inputs, storage, movement, and export/loss of water is therefore central to understanding climate as a driving force in SWAN ecosystems.

SWAN parks are aligned along the northern Gulf of Alaska, where the climate is dominated by maritime influences. Low annual temperature flux, a relatively warm average annual temperature (above freezing), and high amounts of precipitation characterize the region. Important features of the climate-hydrological cycle in Network parks include winter storms generated by the Aleutian Low, summer storms generated in the Bering Sea, the presence of glaciers, and seasonal snow cover generally persisting from October to April—more than half the year.

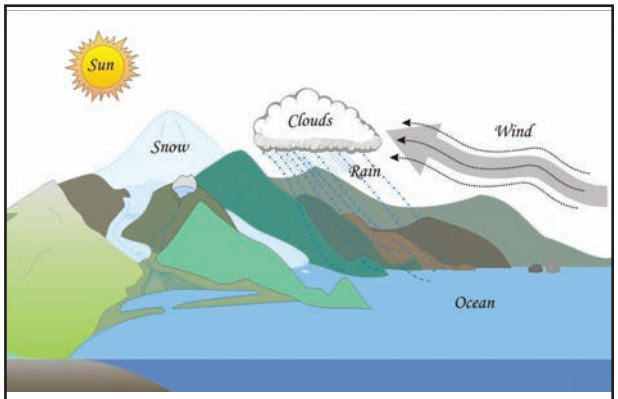


Figure 2-2 *Interaction between topography and maritime air masses along the northern Gulf of Alaska.*

Maritime influences interact with topography to create patterns of precipitation and wind. Network parks are dominated by steep mountains built as the Pacific Plate slides under the North American Plate. This creates mountains that rise abruptly from the ocean in the path of the prevailing winds (Figure 2-2) and results in orographic uplift and high precipitation on the windward side of the mountains, and rain shadows on the leeward side.

Coastal mountain ranges along the northern Gulf of Alaska are distinguished by being some of the snowiest places (mean annual precipitation 39–197 in [1,000–5,000 mm]) on the planet. Coastal areas of KATM, KEFJ, and LACL have the necessary combination of winter precipitation and oceanic air currents, as well as steep temperature and elevational gradients, to generate impressive snowfall and mild winters (mean annual temperature 25–43 °F [-4–6 °C]) (Redmond et al. 2005). Wind, topography, and snowfall create a heterogeneous snow distribution that affects local biotic processes by determining water availability and growing season length.

Climate interacts with landform to play a fundamental role in governing ecosystems by influencing four major processes:

Microclimate

Landform affects temperature and precipitation via elevation and affects radiation via topographic position relative to incident insolation. Microscale topography has an important influence on snow distribution.

Topographic control of water inputs to lakes

Topographic position of lakes within a drainage system determines the relative importance of precipitation and groundwater flow as inputs to lakes. This, in turn, has implications for water chemistry and associated biological processes.

Wind-mediated disturbances

Many disturbance agents are influenced by terrain as it interacts with wind. For example, wind throw is more common in mountain passes and on high windward slopes.

Landform-mediated disturbances

Other disturbances are mediated directly by landform and slope position. For example, susceptibility to small-scale landslides or slumping depends on terrain shape (e.g., slope concavity).

Long-term weather data from representative sites in the region (Walter 1963) demonstrate the annual climate patterns that result from these interactions between air circulation patterns and topography. Seward, located on the windward side of the prevailing winter storm track, is wet and warm, and receives most of its precipitation in winter months. Port Alsworth, located on Lake Clark, is cold and dry and has a continental climate similar to sites in Interior Alaska.

While the Aleutian Low storm track is the predominant climate driver in the Network throughout most of the year, in summer, the Arctic High retreats, the location of the low pressure systems shifts, and the storm track changes direction (Simpson et al. 2005). Instead of moving southeast to northwest, the storms now originate in the west and move east. Within SWAN, this shift in storm track direction changes what is leeward and windward and explains the somewhat surprising drop in precipitation that occurs in Seward in June and July. The Alaska Peninsula appears to be located at the fulcrum of this winter-summer storm track shift. This is an important feature of SWAN climate and explains much of the variation in climate among sites in the Network, particularly with respect to the timing and amount of precipitation.

Because climate is such an important determinant of the ecological setting, changes in climate act as drivers of ecological change. Climate changes occur at multiple scales of space and time. At very long time scales, SWAN is being affected by post-Pleistocene warming. The entire Network was glaciated during the Pleistocene (Hamilton et al. 1986). The current pattern of glacier distribution in Network parks reflects widespread retreat during the Holocene (the most recent geologic period). ANIA, located at the southern end of the Network, has one small glacier on the interior caldera wall. Farther north in KATM, glaciers are restricted to the higher mountains. LACL includes both mountain and valley glaciers, whereas KEFJ has large icefields and numerous valley and mountain glaciers.

At shorter time scales, the climate of the region is affected by primarily oceanic factors, such as the Pacific Decadal Oscillation (PDO) and El Nino/Southern Oscillation (ENSO). The PDO and ENSO are produced by patterns in sea surface temperature driven by changes in the tropics. PDO events have a strong influence on precipitation patterns. During positive PDO events, winter storm tracks that would normally go to southeast Alaska are diverted into the Cook Inlet region, enhancing precipitation in coastal central Alaska, including much of the Network (Simpson et al. 2002). ENSO events involve mainly temperature and their effects can be widespread, influencing conditions in Interior Alaska, as well as coastal areas.

2.2.2 Landscape-Scale Natural Disturbances

Natural disturbances are important drivers of change (Chapter 1) and are defined as any relatively *discrete* events in space and time that disrupt ecosystem, community, or population structure and change resources, substrate, or the physical environment (White and Pickett 1985). The key parts of this definition are that disturbances are *discrete* in time, in contrast to chronic stress or background environmental variability, and that they cause a notable change (a *perturbation*) in the state of the system.

We examined historical, geomorphologic, hydrologic, and ecological research to develop an integrated understanding of how natural disturbances have shaped landforms and ecological processes. In addition, paleoecological studies recently initiated by the Network (2003–05) will broaden our understanding of how current ecological conditions developed. Alaska ecosystems, especially those of southwestern Alaska, are shaped and maintained by disturbances. Infrequent large-scale disturbances (volcanic eruptions, earthquakes, tsunamis) and more frequent smaller scale disturbances (insect outbreaks, floods, avalanches, and landslides) create and maintain a shifting mosaic of landscape patterns (Figure 2-3).

SWAN parks lie on the border where two continental plates meet. The Pacific Plate is moving in a northwest direction at a rate of 2–3 in (5–8 cm) per year, and is being subducted (overridden) by the North American Plate. This action results in numerous earthquakes and contributes to the many active volcanoes in the region. There have been over 100 earthquakes of magnitude 6.0 or greater during the last century on the Alaska Peninsula and there are 17 active volcanoes in or near SWAN parks. Explosive volcanic eruptions, such as KATM's Novarupta in 1912, can catastrophically disturb hundreds to thousands of square miles of landscape, profoundly affecting fluxes of water and sediment. Vegetation can be defoliated, buried, or removed, and the landscape can be mantled with tephra (airborne volcanic ejecta ranging from ash to small blocks of rock). Rivers, lakes, and valleys can be partly or completely filled with pyroclastic debris, or massive deposits from debris avalanches and pyroclastic flows.

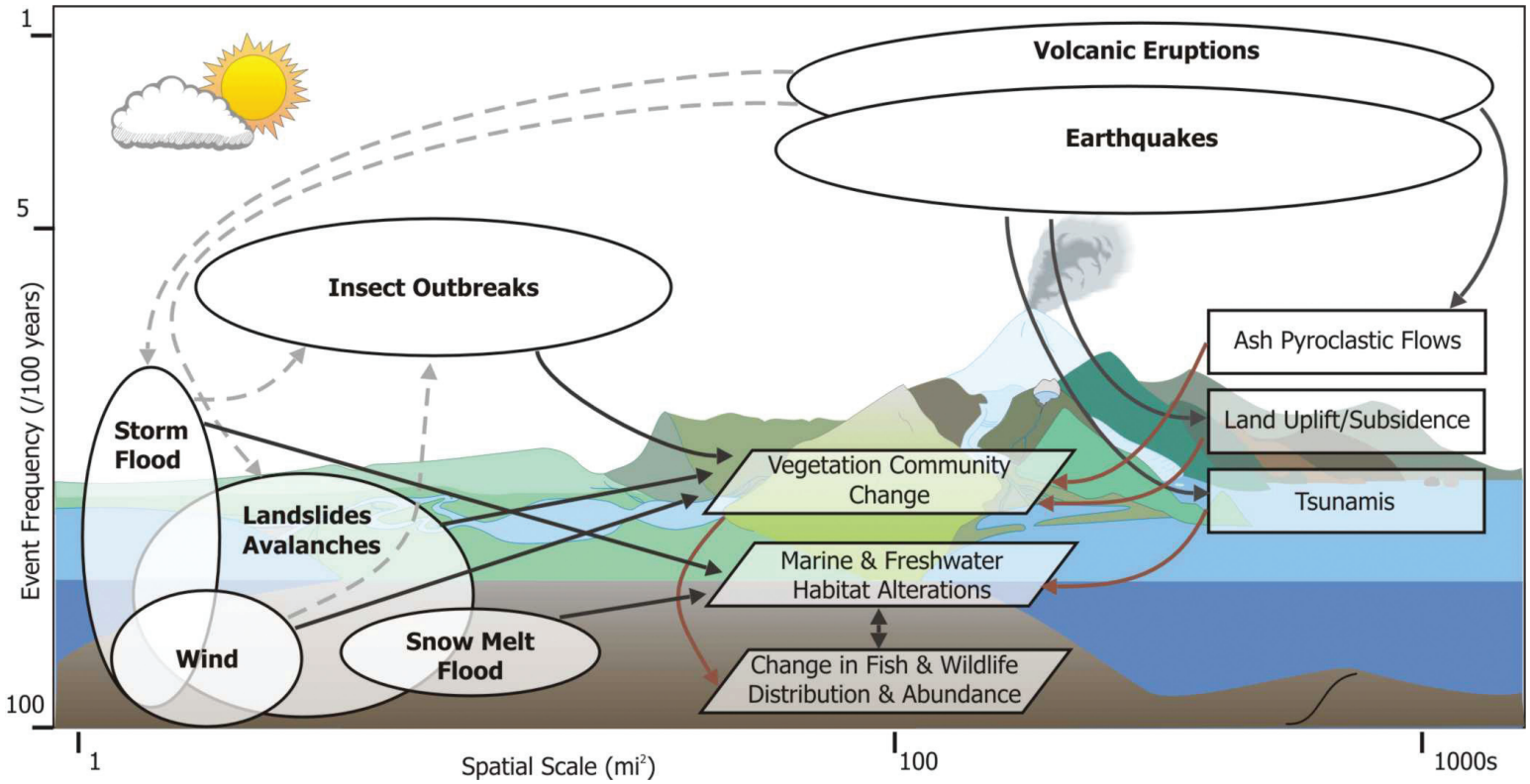


Figure 2-3 *Landscape disturbance model. Frequency, scale, and consequences of natural disturbances in SWAN. Large-scale disturbances (volcanic eruptions, earthquakes, tsunamis) and more frequent smaller scale disturbances (insect outbreaks, floods, and landslides) create and maintain a shifting mosaic of landscape patterns.*

During the 1964 Alaska earthquake, some portions of the LACL, KEFJ, and KATM coastline subsided by more than 6 ft (1.8 m). To the east of Seward, uplift as much as 30 ft occurred seaward of the subsidence zone, which means a large expanse of land changed elevation significantly in just a few minutes. Since 1964, some of the sunken areas have rebounded, and others have been buried in silt. In addition, some coastal lands in this region may be experiencing isostatic rebound caused by glacier retreat.

The tectonically active history of SWAN parks indicates that potentially catastrophic changes (e.g., major volcanic eruptions, major earthquakes) could occur in the future and have widespread effects on park ecosystems. These landscape-scale disturbances have the ability to modify landforms and reorder successional processes. The slower, smaller changes in land height due to rebound are also important, especially for the coastal zone. Although the annual changes might be small (measured in millimeters), the long-term changes can be ecologically significant.

On the annual/decadal scale, smaller scale disturbances such as flooding, windstorms, landslides, avalanches, and insect outbreaks can be major drivers of ecosystem structure and function. Fire, which is a major disturbance elsewhere in Alaska, is currently a rare event in SWAN parks. Fluvial processes, such as snowmelt and storm floods, can reconfigure channels, erode portions of the floodplain, and deposit sediment within and outside the floodplain. These disturbances can remove existing vegetation and create new islands, bars, or flats where soil and vegetation can develop.

Similarly, catastrophic winds (exceeding 100 mi/hr) cause large-scale forest blowdown in LACL, KEFJ, and portions of KATM. Depending on intensity, they can create single-generation stands of trees with uniform canopies or multigeneration stands with diverse canopy and size structures. Site productivity may be altered through the uprooting of trees and mechanical disturbance of soil, exposure of mineral soil seedbeds, and establishment of early successional stands favored by herbivores such as moose and snowshoe hares.

Landslides are common in coastal areas due to steep slopes, unstable substrate, and frequent rainfall. Landslides may cover a small proportion of the land area in the Network parks, but are important centers of biodiversity as they provide temporary refugia for pioneer species not found elsewhere. Landslides also promote downslope movement of nutrients and soil organic matter.

The native spruce bark beetle (*Dendroctonus rufipennis*) is the most significant agent of insect mortality in high latitude and high elevation spruce forests in Alaska (Ford 1986). Large-scale infestations have a significant influence on fish and wildlife habitats by changing forest structure and function. Bark beetle-caused tree mortality provides important habitat for some species of wildlife, provides coarse woody debris to streams, and affects biogeochemical cycles. Outbreaks can also affect park management objectives, particularly in high-use recreation areas.

Large- and small-scale natural disturbances often interact to produce patterns of landscape change. For example, volcanic eruptions and earthquakes commonly trigger landslides. Many spruce bark beetle outbreaks in standing spruce originate in wind-thrown trees and emerge from this highly productive breeding material to move into standing trees.

2.2.3 Biotic Interactions

Biotic interactions embody the species concept of landscape ecology discussed in Chapter 1. Interactions of organisms, via competition, predation, herbivory, parasitism, mutualism, and commensalism, regulate the flow of energy and nutrients in these natural systems. Because of the large number of interactions among species, we limit our discussion to interactions involving keystone species or those that affect multiple ecosystems (Figure 2-4). Wide-ranging species, especially those that influence water and nutrient dynamics, trophic interactions, or disturbance regime, affect the structure and functioning of ecosystems on broad spatial scales (Chapter 1, Section 1.6). For example, brown bears influence coastal intertidal

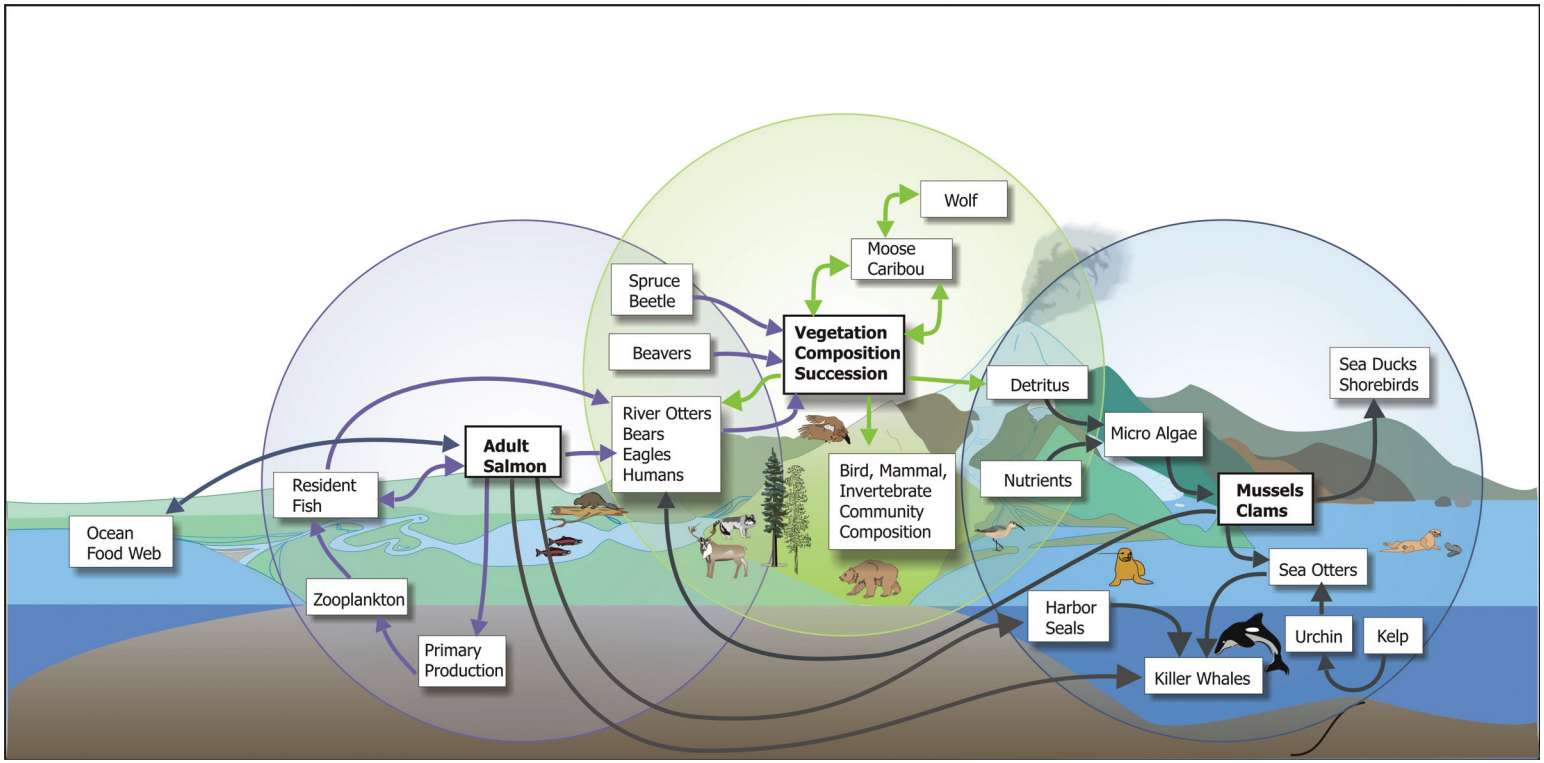


Figure 2-4 *Biotic interactions model. Some important biological interactions in SWAN involve (i) the transport of nutrients by mobile species; (ii) herbivore-predator interactions that maintain a heterogeneous distribution of resources; (iii) ecosystem engineers, such as beavers and clams, that structure habitats and influence the distribution and abundance of other species; and (iv) species, such as the spruce bark beetle, that create or modify disturbance regimes.*

community structure when they forage on salt marsh vegetation and clams, transfer nutrients from rivers to the land when they feed on salmon (Ben-David et al. 1998, Hilderbrand et al. 1999a), and influence plant distribution and nutrient availability when they dig in montane meadows (Tardiff and Stanford 1998). Moose alter successional pathways in forested ecosystems, soil chemistry, and even the local distribution and abundance of insects (Rozell 2002).

The influx of anadromous salmon dramatically affects the trophic structure and functioning of the freshwater community. Pacific salmon die after they spawn and their carcasses accumulate in streams and along lakeshores. A rich community of algae, fungi, and bacteria develops on the carcasses, and populations of invertebrates increase. These invertebrates then serve as food for fish in the streams and lakes, including juvenile salmon. More surprising are the potential fertilization effects of salmon carcasses on land. Bears and other carnivores commonly haul salmon, living or dead, onto stream banks and hundreds of yards into the forest. Eagles move carcasses into riparian areas, and ravens and crows cache salmon bits in trees and under grass and rocks. Such marine-derived nutrients have the potential to significantly affect annual nutrient budgets and to maintain the long-term productivity of coastal river systems (Helfield and Naiman 2002).

Large terrestrial herbivore-predator interactions are an intrinsic property of intact functioning ecosystems and are a flagship ecological feature of Network parks. Selective foraging by herbivores, such as caribou (*Rangifer tarandus*), can alter ecosystem functioning, change species composition, and modify nutrient cycling and plant productivity. Wolves are functionally important in this interaction because they exert top-down control of herbivores. Because caribou and wolf populations oscillate through time, herbivore-predator population cycles play an important role in maintaining a heterogeneous distribution of resources, or habitat mosaic.

In coastal ecosystems, bivalve mollusks such as mussels and clams build thick shellfish beds and mats on rocky shores and soft sediments. The structure provided by these animal communities serves to modify the nearshore environment, deposits organic matter, traps sediments, and promotes growth of marine plants. In lagoons and tidal flats, mussels and clams form the primary prey base and influence the distribution and abundance of sea otters, sea ducks, shorebirds, and other birds and mammals. Marine plants, such as grasses and kelps, form canopies of vegetation that modify water flow, entrain larvae, and provide habitat and refuge for small fish and invertebrates.

Some biotic relationships involve species that do not directly interact with each other. For example, removal of sea otters from a coastal ecosystem can result in an irruption of sea urchins (the primary prey) that can lead to overgrazing and the subsequent decline of kelp. Natural and human-related actions that create imbalances in the most basic species interactions, especially predator-prey relationships, may result in changes in the composition and structure of communities and ecosystems.

Alder (*Alnus* spp.) is a native plant that deserves special consideration in SWAN parks because of its widespread distribution and increasing abundance on the Alaska Peninsula. Alder is an early successional species that rapidly colonizes disturbed or newly exposed mineral soil. Once established, it can profoundly alter soil nitrogen availability and rates of nitrogen turnover (e.g., Hart et al. 1997), facilitating the establishment of additional species, or suppressing subdominants through competition for light. Where alder invades an existing community, very few other plants can survive under the dense canopy and its foliage and stems are avoided by most herbivores. Thus, the presence of alder may shape plant and animal communities, and may play an important role in ecosystem dynamics.

2.2.4 Human Activities (Stressors)

Human activities are important agents of change in SWAN ecosystems. During our workshops, conceptual models of human activities were refined to show relationships and interactions among stressors (Figure 2-5). For example, climate warming due to anthropogenic greenhouse gases could increase susceptibility

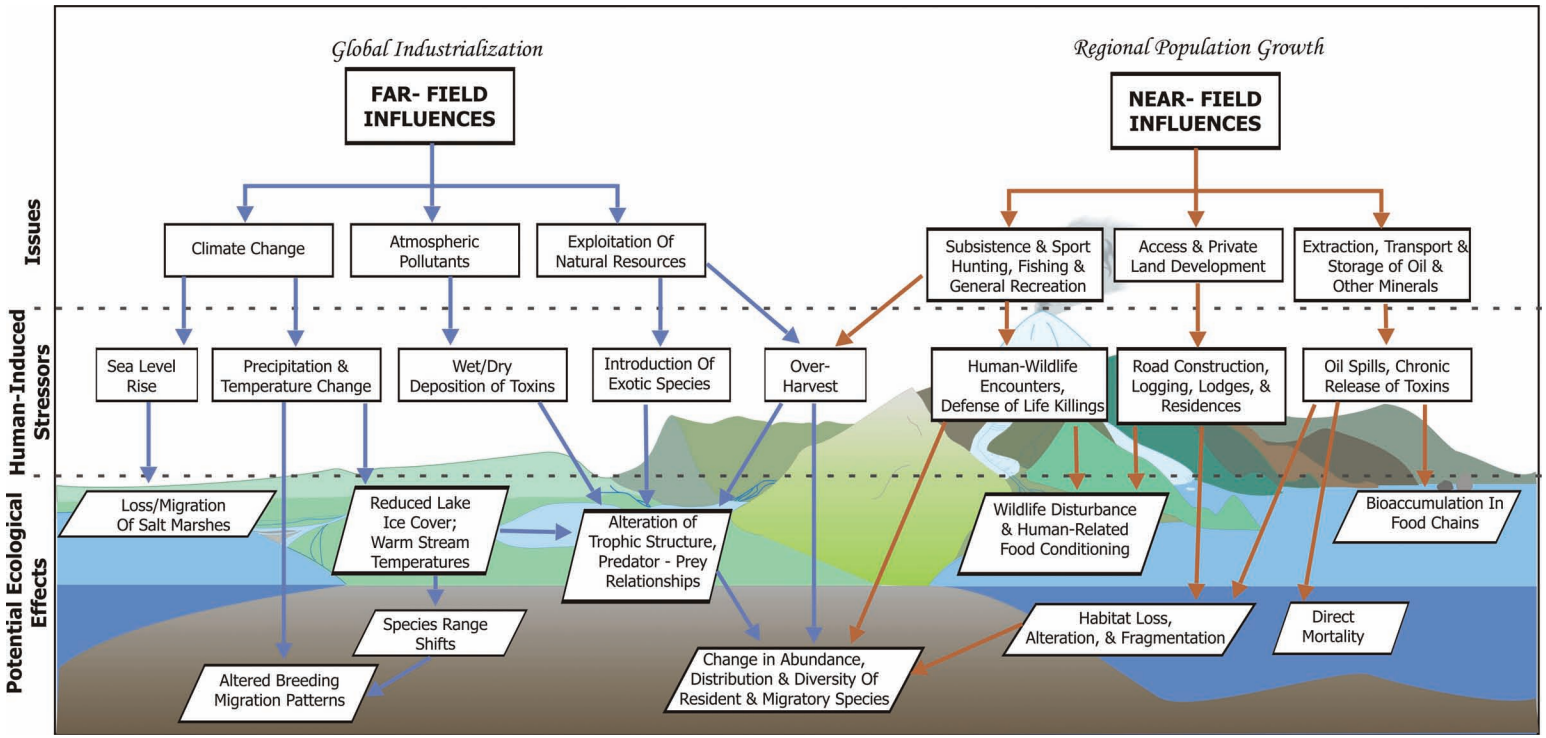


Figure 2-5 *Human activities model. Far-field and near-field issues that act as stressors to affect SWAN ecosystems. Far-field human-related issues are manifested as climate change, long-distance air pollution, depletion of migratory species, and introduction of exotic species. Near-field human-related issues are manifested as harvest of plants and animals, recreational use, private lands development, and the extraction, storage, and transport of oil, gas, and mineral resources in Bristol Bay and the northern Gulf of Alaska.*

of Network parks to invasion by exotic plants and animals, and increased visitation of parks by visitors in floatplanes would be an important pathway for introduction of exotic species. Understanding the interactions among stressors was crucial to assessing pathways of change due to human activities. For this reason, we grouped stressors into two broad categories: far-field influences and near-field influences. As stated in Chapter 1, far-field influences include human activities occurring elsewhere on the globe that could impact Network ecosystems, and near-field influences include human activities occurring in or on lands and waters adjacent to parks.

a) Far-Field Influences

The far-field human influences arise from human population growth and the general trend of human activities worldwide that might best be termed "global industrialization." Effects of global industrialization generally fall into two categories: (i) effects on biogeochemical cycling, and (ii) effects on biodiversity (Vitousek et al. 1997). For SWAN parks, biogeochemical cycling issues would most likely stem from changes in climate due to greenhouse gases and changes in atmospheric deposition patterns (e.g., pollution).

Climate Change—Projections of human-induced climate changes and evidence of past rapid climatic shifts indicate that patterns of physical and biological change are occurring on landscape scales in time frames as short as decades (Hannah et al. 2002). Gradual warming documented in the last 100 years has forced a global movement of animals and plants northward, and it has accelerated such perennial spring activities as flowering and egg hatching. In some cases, the shifts have been dramatic. For example, the common murre (*Uria aalge*) breeds on average 24 days earlier than it did decades ago (Meehan et al. 1998).

Climate change-induced shifts in park ecosystems can be manifested in many different ways, on different temporal and spatial scales (Figure 2-6). Some anticipated changes include sea-level rise, greater storm intensity and frequency, altered seasonal hydrology, accelerated glacial retreat, and shorter duration of lake ice cover. Changes in these physical parameters may not be important by themselves, but may have important effects on biological components of the ecosystem. Water availability in some regions (i.e., Bering Sea drainages) may decline because of a reduction in precipitation and because of reduced snowpack and shorter cold season. Changes in snow depth and duration will lead to significant shifts in the timing and amount of runoff in Network river basins, and may alter the release of nutrients during snowmelt (e.g., Brooks et al. 1998, Groffman et al. 2001, Sickman et al. 2003).

Along the Gulf of Alaska, warming has also been associated with an increase in precipitation of about 30% between 1969 and 1999 (Alaska Regional Assessment Group 1999). Coastal regions of SWAN may experience greater freshwater runoff from precipitation and accelerated melting of glaciers. Ultimately, runoff from the melting glaciers will cease and summer discharge will decline.

A warming climate has broad implications for park resources and long-term monitoring. Changes in temperature, precipitation, snowpack, storm frequency, and fire could affect the distribution, abundance, growth, and productivity of plants and animals. As a result of a longer growing season and higher annual temperatures, alpine areas may decrease as montane tree species migrate upward. New populations of species may move into some areas and existing populations might move out or be lost. Some animal populations may become isolated and unable to adapt to changing conditions, or they may shift ranges as the climate to which they are adapted effectively moves northward or to higher elevations.

Air Pollution—Long-distance transport and deposition of air pollutants, such as persistent organic pollutants (POP), are emerging concerns in Alaska national parks. POPs are organic, human-made, highly toxic compounds. They persist in the environment and bioaccumulate in living organisms. They are carried long distances around the globe and migrate to northern climates because of strong south-to-north air flows. The Arctic is, therefore, a potential contaminant sink. Due to a constellation of factors related to atmospheric patterns, the behavior of contaminants in the environment, temperature, and other factors

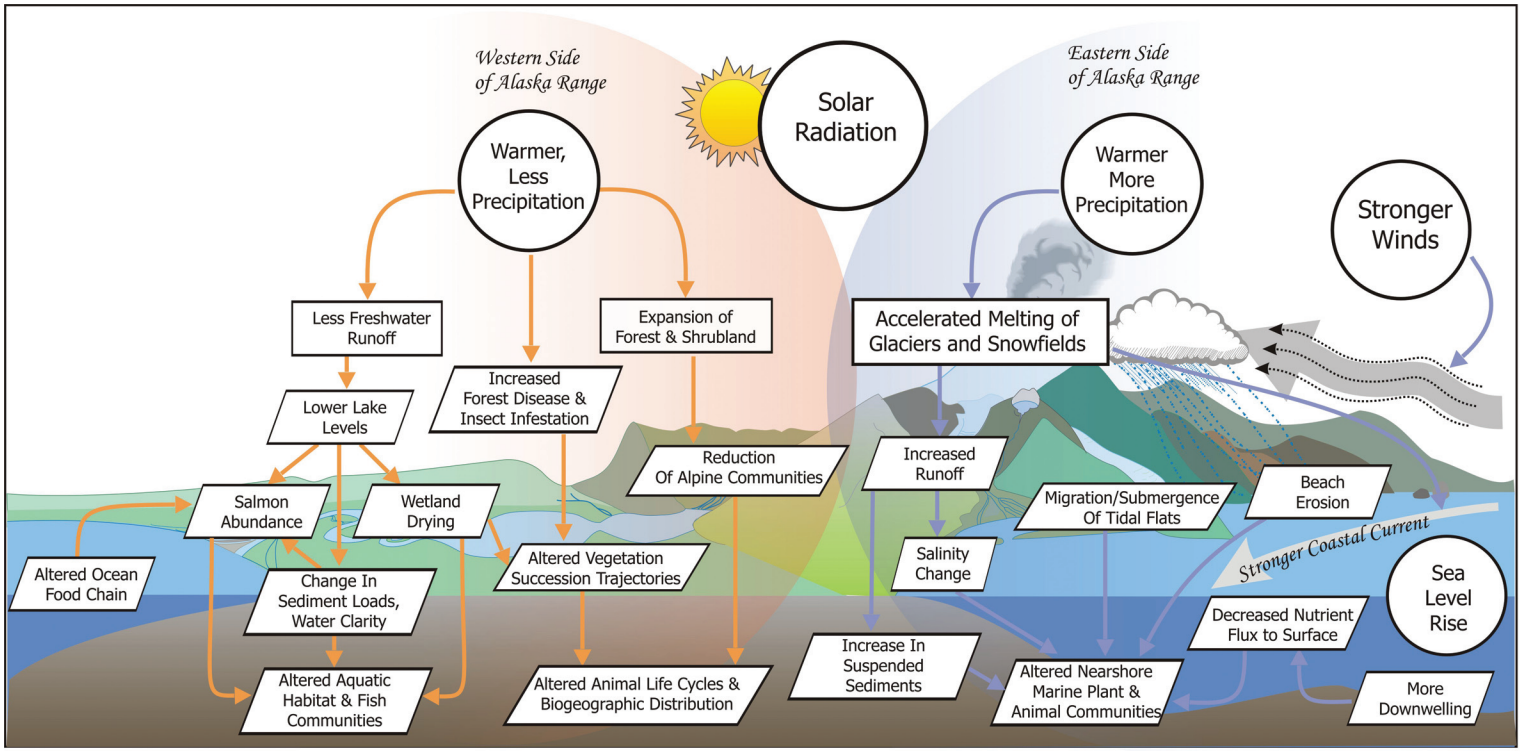


Figure 2-6 *Climate warming model. Manifestations of a warming climate on SWAN ecosystems, habitats, plants, and animals. Warming is likely to alter the hydrologic cycle in SWAN and influence processes that have created and maintained park ecosystems. Some anticipated changes include sea-level rise, greater storm intensity and frequency, altered patterns of seasonal runoff, rapid glacial retreat, and shorter duration of lake ice cover.*

unique to the Arctic setting, there is cause for concern regarding an increase in levels of contaminants in park ecosystems.

Various processes remove these contaminants from the atmosphere, oceans, and rivers and make them available to plants and animals. Food chains are the major biological pathways for selective uptake, transfer, and sometimes magnification of contaminants by plants and animals. In Alaska contamination has been documented in the marine and freshwater food web (Krummel et al. 2003, Ewald et al. 1998), but whether this contamination encompasses terrestrial animals to the same extent is unknown.

Invasive Species—Invited experts attending our scoping workshops emphasized the potential for invasive species to act as stressors for SWAN parks. Their recommendations are in line with recent strong concerns about species invasions raised in the scientific community (e.g., Vitousek et al. 1997, Mack et al. 2000). The State of Alaska has recently adopted an Aquatic Nuisance Species Management Plan (Alaska Department of Fish and Game 2002). This plan identifies the most important species of immediate concern for Alaska.

Of particular concern for SWAN is the potential for northern pike (*Esox lucius*) to expand from the Susitna River drainage basin southward to western Cook Inlet, where they are not indigenous. Pike prey on small salmon and trout and have the potential to restructure fish communities. An even greater threat is Atlantic salmon (*Salmo salar*) that escaped from aquaculture sites in British Columbia and Washington. This invasive species may compete with native Pacific salmon for spawning and rearing habitat. For SWAN, the main pathways of introduction are likely those that involve recreational fishing and aquaculture.

Although SWAN parks are currently assumed to be free of aquatic exotics, the same cannot be said of the invasive plants in the terrestrial environment. Parks that may be most vulnerable to invasion by exotic plants are those with moderate maritime climates (Densmore et al. 2001). In the road-accessible Exit Glacier area of KEFJ and in areas of constant human use at KATM, Densmore et al. (2001) found several exotic weeds.

Migratory Species—Another driver of change related to global issues concerns effects on migratory species when they are not in SWAN parks. The North Pacific and Bering Sea are among the most important seas for commercial salmon fisheries in the world. Depletion of salmon on the high seas could result in lower return rates to the parks with cascading effects in these salmon-based ecosystems. The rates of spawning, growth, and mortality in salmon populations are also influenced by changes in the marine environment. The fish stocks are sensitive to ocean temperatures, and small changes can result in major shifts in the geographic locations and productivity.

Migratory birds use Network parks for breeding and migration and may play important ecological roles as prey or predator. For example, rock sandpipers (*Calidris ptilocnemis*) breed on the Pribilof Islands winter in Cook Inlet and forage on coastal intertidal flats at LACL. Of the more than 150 bird species known from these parks, the majority are migratory. These species could be affected when they are at their wintering grounds in the offshore waters of the North Pacific, the continental United States, Mexico, Central and South America, the South Pacific, and Asia.

b) Near-Field Influences

The main types of near-field, human influences with potential effects on SWAN parks include regional population growth, and exploration and development of oil, gas, and mineral resources in the Cook Inlet region (Figure 2-5). Other near-field influences relate more specifically to human activities in parks. These include visitor use impacts, private land development in and near parks, and consumption of fish and wildlife. Collectively, these form the common theme of “access.”

A concept that is particularly useful for viewing park protection concerns related to near-field human activities is the “nibbling effect” (Forbes et al. 2001). This concept maintains that a slow but essentially

permanent change in ecosystem structure, components, and processes occurs from many seemingly "insignificant" human-related perturbations. Examples of *nibbling* include the liberalization of sport or subsistence harvest levels for a plant or animal, construction of a new airstrip or commercial lodge on a private inholding within a park, or issuance of 10 new incidental business permits for guided backcountry hiking. Alone, each "bite" may appear relatively insignificant, but collectively they have a cumulative and synergistic effect. Nibbling advances slowly through space and time and often along gradients radiating from rural population centers, such as Port Alsworth on Lake Clark, or attractions, such as Brooks Camp on KATM's Naknek Lake (Figure 1-2).

Oil and Other Minerals—Extraction, storage, transport, and processing of crude oil is an issue for both coastal and terrestrial resources. The Valdez Marine Terminal on Prince William Sound receives approximately 14 billion gal (53 billion L) of oil per year via the TransAlaska Pipeline System. Also, 15 oil production platforms are operating in Cook Inlet. The Drift River Marine Terminal is a privately owned offshore oil-loading platform in Cook Inlet with an onshore storage facility whose capacity is 1.9 million barrels (79.4 million gal [300.6 million L]) of crude oil. The Nikiski Oil Terminal and Refinery are located on the eastern shore of Cook Inlet. These two oil-loading facilities transfer more than 3.3 billion gal (12.5 billion L) of oil per year.

The strong Alaska Coastal Current and high local tidal ranges along the Alaska coast can quickly transport spills great distances from their source. On March 24, 1989 the tanker Exxon Valdez grounded on Bligh Reef and discharged approximately 11 million gal (41.6 million L) of Prudhoe Bay crude oil into Prince William Sound. Coastal winds and currents transported the oil slick southwest into Blying Sound and westward along the north shore of the Gulf of Alaska. The storm-tossed crude oil degraded and weathered into an oil-and-water emulsion called mousse that stranded in various concentrations along the entire length of KEFJ, KATM, and ANIA. This event highlighted the risk of anthropogenic disturbance on pristine coastal ecosystems even hundreds of miles from the origin. It also demonstrated the need for baseline information and how crucial it is to protect and restore coastal resources.

Smaller spills; leakage from storage tanks, platforms, and submerged pipelines; and ballast water discharge in Upper Cook Inlet are chronic sources of contamination. The water resources of Network parks also are threatened by the potential exploration and development of oil and gas in Lower Cook Inlet and Shelikof Strait under the Outer Continental Shelf program.

The largest gold deposit and second largest copper deposit in North America occur on state lands north of Lake Iliamna between LACL and KATM. Engineering and environmental studies began on this deposit, known as Pebble Mine, in 2003. Contingent upon feasibility and permitting issues, it may be operational in 2010. If developed, the pit would be 2 mi (3.2 km) long, 1.5 mi (2.4 km) wide, and about 1,600 ft (488 m) deep, with an area for waste rock encompassing close to 20 mi^2 (51.8 km^2). Other elements of the proposed project include an ore concentration and settling lagoon, power transmission lines, and a 90-mi haul road between the mine and a port site on the western shore of Cook Inlet.

Consumptive Harvest of Plants and Animals by Humans—Consumptive uses of plants and animals is permitted in LACL, ANIA, and portions of KATM under the Alaska National Interest Lands Conservation Act (ANILCA; http://usparks.about.com/gi/dynamic/offsite.htm?site=http%3A%2F%2Falaska.fws.gov%2Fasm%2Fanilca%2Fintro.html). This act allows for hunting, trapping, fishing, and the harvest of plant material in national parks and preserves for subsistence uses by local rural residents. In national parks and preserves, ANILCA also requires the NPS, in cooperation with the Alaska Department of Fish and Game, to manage for healthy populations of fish and wildlife species in national preserves, and natural and healthy populations in national parks. Additionally, sport fishing occurs in parks and preserves and sport hunting occurs in preserves.

Although subsistence users have access to all species that were traditionally harvested, most effort is directed at large terrestrial mammals (moose, caribou, Dall sheep, brown bear), harbor seals, and salmon.

Monitoring the harvest rate and population trends of subsistence resources is a complex challenge that frequently exceeds the capability of park managers. As a result, relationships between recruitment, annual survival, and harvest rate for many subsistence species are unknown, and local overharvest, if it occurs, may go undetected. In Alaska, the state constitution mandates that state resources be managed for maximum sustained yield. The concept of game naturally cycling between scarcity and abundance is not favorably embraced by subsistence users who desire a steady supply of resources. Of concern in recent years is a growing opinion by subsistence users that parks and preserves should also be managed for maximum sustained yield of fish and game resources.

Recreational Use—Human recreational use presents two resource protection issues: (i) direct impact to physical resources, plants, and animals from actions such as vehicle use and camping, and (ii) indirect impacts, such as the disturbance or displacement of wildlife from actions such as aircraft overflights. Coastlines, lakeshores, riverbanks, and high mountain environments are particularly sensitive to the disturbances caused by recreational use. Vehicle traffic, trampling by pedestrians, and campsites can create long-lasting impacts because natural recovery is extremely slow. As visitation increases, pressure builds to provide new trails or access opportunities into these large wilderness parks. There is also a very strong push to make these very large wilderness parks more accessible by ground transportation.

Human visitor concentration areas adversely affect animals, as evidenced by human-related food-conditioning, displacement, and introduction of exotic species. Habituation is a threat to species such as bears that may have to be relocated or killed if they lose their instinctive fear of humans. Disturbance adversely affects species if they are displaced from habitat during a critical phase of their life cycle, such as breeding. Bear viewing from both small fixed-wing aircraft and charter boat tours has increased greatly in the last decade in SWAN parks, and has the potential to affect these animals over broader areas than would fixed-point activities.

Human traffic into wilderness enhances the opportunity for exotic plants and animals to reach remote areas of the parks where they could go undetected. Avenues of entry include marine charter vessels that originate in the same Alaska harbors served by transoceanic cargo ships and floatplanes that originate in commercial floatplane bases, such as Lake Hood in Anchorage.

Private Lands Development—All parks in the Network contain private land inholdings and border private, state, and Native-owned lands. Inholdings range from 1- to 160-acre (0.4 to 64.8-hectare) parcels owned by an individual or a single business, to large contiguous parcels (> 10,000 acres [> 4,000 hectares]) that are owned by Native regional and village corporations. The network of private inholdings arose from ANILCA, the Alaska Native Claims Settlement Act, and the Homestead Act. Collectively, these acts guarantee access and the promised right of communities, landowners, and residents to continue their economic livelihood.

Inholdings are most prevalent in LACL and KEFJ. Approximately 75 percent of the shoreline of Lake Clark is privately owned, and in KEFJ private economic development potentially could occur on 42,000 acres (17,000 hectares) of predominantly coastal land owned by Port Graham Native Corporation. In some cases, the exact land status is clouded by over-selection, selection by more than one entity, and the incomplete adjudication of many small tract entries and allotments.

Residential subdivision and economic development on private lands in Network parks can conflict with the enabling legislation and NPS resource preservation objectives. Developments of greatest concern are logging, mining, and the construction of roads, airstrips, lodges, and private houses. Private land inholdings frequently coincide with areas of great ecological value and sensitivity, such as rivers, lakeshores, and coastal estuaries. Consequently, large areas of parkland adjacent to inholdings are at risk when development occurs. Most concerns of water quality are embedded in private land development.

Access—Access is a common theme among near-field influences. Access issues include the landing and

beaching of floatplanes on lake shores and riverbanks, landing of wheeled planes on beaches and gravel bars, use of snowmobiles, beaching of boats, establishment of concentrated camping sites associated with boating, and use of all-terrain and 4-wheel drive vehicles off roads. Access methods may disturb fish and wildlife, disrupt habitat, and provide the means for overharvest, poaching, and increased defense of life and property killings.

Because some Network parks are surrounded by private lands, it is not inconceivable that they could become "isolated entities," as are many parks in the continental United States. For example, the historic Pile Bay Road between Iliamna Bay on the Cook Inlet side of the Alaska Peninsula and Lake Iliamna has been upgraded to provide for year-round traffic and is targeted for future improvements. The road will be heavily used by local residents, mining industries, commercial fishermen, and to support new tourist activities. It is likely to support regional population growth between LACL and KATM. In 2003, the State of Alaska allocated $10 million to study road development, including the construction of a 182-mi (293-km) road linking King Salmon and Chignik on the Alaska Peninsula (Figure 1-2).

2.3 Ecosystem Interactions

The nature of SWAN parks is largely determined by the complex and dynamic physical, geological, and chemical inputs and interactions of marine, aquatic, and terrestrial subsystems. Therefore, a basic understanding of atmosphere-land-ocean interrelationships is important for us to comprehend how physical and biological drivers influence ecosystems. Ecosystem connectivity is a key feature of the Network and is particularly important because connectivity is one of the first attributes to be affected by natural disturbances, such as a volcanic eruption, or human activities, such as the construction of a road. Some of the critical linkages involve water movement, heat exchange, sediment and nutrient transport, and the actions of producers and consumers.

Storage and release of snowpack is pivotal in regulating linkages between the land surface, ocean, and overlying atmosphere. During the winter, higher elevations of the coastal mountain ranges collect and store large amounts of snow. During the thaw season, water runs off, transporting mass and energy through watersheds and into the Pacific Ocean and Bering Sea. This cycle recharges lakes and wetlands though runoff and transports sediments and other constituents to the ocean, where they affect nearshore physical and biological productivity. Freshwater input to the ocean also maintains and regulates the Alaska Coastal Current, which in turn influences nutrient and thermal dynamics of nearshore bays and fjords.

Changes in snow cover area and dynamics regulate thermal exchange between the land and atmosphere and influence faunal and floral distributions on land and water. Consequences resulting from alterations to surface water movement and storage include changes in flooding timing and duration, changes in flow regime, and changes in surface water storage capacity.

Freshwater systems result from the regional pattern of precipitation interacting with topography and surficial geology (Figure 2-7). Topography and geology are important for determining the gradient of streams and the configuration and depth of lakes. Most freshwater flow systems in the Network are currently of glacial origin. Permanent and ephemeral streams link glaciers and lakes during the summer melt season. These glacial meltwater streams recharge the valley lakes and are important sources of nutrients and materials to lake ecosystems. Distinct seasonal runoff patterns caused by the annual cycle of snow and ice melt change the hydrological connectivity between individual stream types and shift flows from surface dominance at summer high flow to groundwater controlled in winter.

Lakes in SWAN are created by a variety of processes, including volcanoes, glacial retreat, fluvial processes, and beavers. Most lakes that are important salmon spawning and rearing grounds occur in glacial landforms. Because of their large surface areas, wind is a significant factor, affecting productivity dynamics. The food base in these lakes is phytoplankton and zooplankton, but nutrient input from salmon carcasses may play an important role. Volcanic ash inputs to these lakes may also contribute to their high productivity.

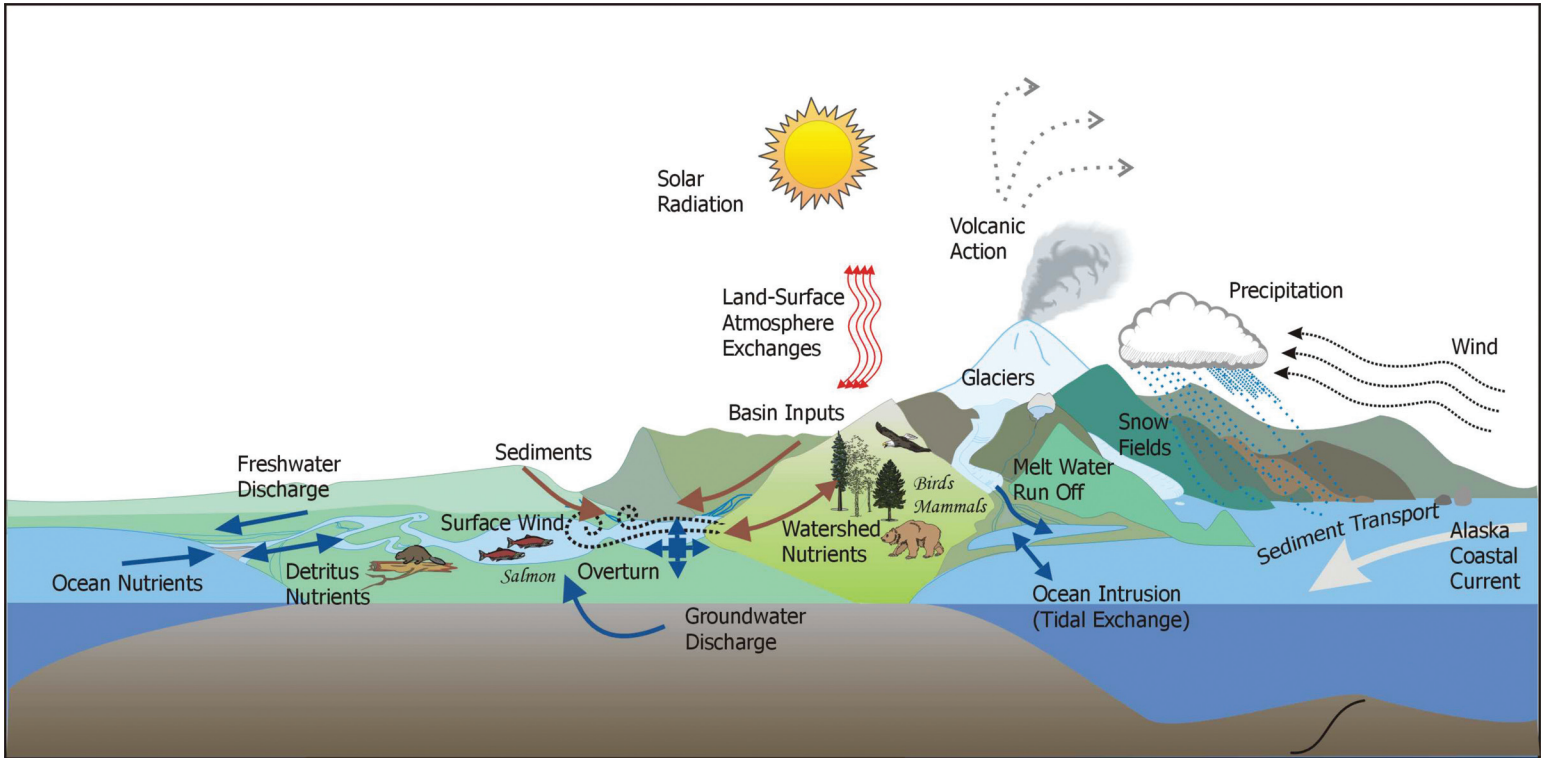


Figure 2-7 *Ecosystem interactions model. Key linkages and interactions between the atmosphere, ocean, and land in SWAN. Hydrologic and biochemical interactions with terrestrial and aquatic ecosystems control the formation of habitats and distribution of plants and animals.*

An important concept that emerged from the freshwater scoping workshop is the principle that lakes and streams comprise interconnected flow systems within the broader landscape. As collectors of water, energy, nutrients, solutes, and pollutants from the landscape and atmosphere, lakes and streams are interactive components of their environment. The flow system concept helps show relationships between the land and water and is important for understanding regional connectivity in ecosystem pattern and function.

The nearshore coastal ecosystem of SWAN is influenced by a host of factors, both upland/upriver processes and marine processes, both natural and anthropogenic, due to its linear configuration and proximity to coastal mountains. Factors that affect oceanic, freshwater, and terrestrial systems individually seemingly coalesce in a "great mixing bowl" to influence the coastal nearshore.

Coastal streams gather material from large land areas and concentrate it in estuaries at the land-sea interface. Consequently, inshore ecosystems and coastal ecosystems are functionally linked at multiple levels by movements of material and nutrients as sea water is mixed with freshwater. SWAN terrestrial and coastal communities are characterized by overlapping food chains as energy flows from primary producers to consumers. Many primary producers are first converted by bacterial decomposition into organic detritus, which serves as a major food source for the majority of consumers living in intertidal flats and estuaries. Carnivores (predators) occupy the highest level, obtaining energy by eating animals that feed on plankton and detritus.

In addition to inputs from the land, a variety of oceanographic processes bring cold, nutrient-rich water into the nearshore zone from offshore. These forces include wind-driven transport, tidally driven transport, and buoyancy-driven transport, such as the Alaska Coastal Current. The Alaska Coastal Current is an ever-changing feature offshore that plays many important ecological roles. For example, it supplies plankton to bays and estuaries and carries fish and invertebrate eggs from one place to another. The success of many species depends on the specific shape of the current, which is influenced by climate, season, and sea floor topography. In some coastal areas of KEFJ and KATM, locally rich habitats and plant and animal communities develop in areas where food supplies are concentrated by eddies and circular side currents that form as larger currents move around landmasses.

Heat given off by the oceans warms the land during the winter, and ocean waters help to keep coastal regions cooler during the summer. Moisture evaporated from the oceans is the ultimate source of precipitation on land. Topographic features of the land interact with the atmosphere to create mesoscale regimes of temperature and wind. This interrelationship controls phenomena such as duration of lake cover, localized patterns of snow accumulation, and distribution of plants and animals. Sea level exerts a major influence on the coastal zone, shaping barrier islands and pushing saltwater up estuaries and into aquifers.

Mobile biological organisms also transport matter and nutrients between systems. Leaves from riparian vegetation fall into streams and provide nutrients for the freshwater subsystem. Salmon returning to spawn in their natal streams bring marine nutrients to the terrestrial and freshwater subsystems. Bears, river otters (*Lutra candensis*), and other consumers transport salmon from the freshwater subsystem to the terrestrial and are the primary pathway for marine nutrients to enter the terrestrial subsystem. Similarly, birds and mammals consume intertidal marine resources, such as clams and fish, and transport nutrients from the ocean to the land. These interrelationships underscore the importance of not simply viewing ecosystems singularly, but as a set of interacting systems in the landscape.

Chapter 3
Selection and Prioritization of Vital Signs

3.1 Introduction

In this chapter we describe the process used to identify, organize, and prioritize a final set of vital signs for SWAN. As described in Chapter 1, these vital signs are intended to characterize ecosystem condition and signal change across multiple scales of space and time. We explain how the selection and prioritization of vital signs was linked to park resource management and protection issues, conceptual ecosystem models, and the Network's monitoring objectives and questions.

The NPS has defined "vital signs" as a set of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, and/or are of value to humans. These vital signs represent a subset of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations" and include water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. Vital signs may occur at any level of organization, including landscape, community, population, or genetic level, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes) (http://science.nature.nps.gov/im/monitor/glossary.htm).

Conceptual ecosystem models (Chapter 2) demonstrate that a variety of biological, chemical, and physical factors interact to control the abundance, distribution, and productivity of plants and animals in SWAN. Consequently, the overall condition of park ecosystems is determined by the interaction of all its physical, chemical, and biological components. Clearly, it is impossible to monitor all these components, and ecosystem condition, like human health, cannot be measured directly. A key challenge is identifying vital signs that characterize entire park ecosystems, yet are simple enough to be effectively and efficiently monitored (Dale and Beyeler 2001).

3.2 Vital Signs Selection

Candidate vital signs were chosen during a series of scoping workshops held between August 2002 and April 2003 (Chapter 1). These workshops were brainstorming sessions built around three objectives: (i) review and refine draft conceptual ecosystem models, monitoring objectives, and monitoring questions; (ii) identify natural and human-related drivers of change and why it is important to understand them; and (iii) identify candidate vital signs to monitor that provide informative signals about ecosystem condition. Workshop participants included a diverse group of experts (Table 1-2).

Scoping workshop notebooks were a key element of the scoping process and provided background information, context, and guidelines for vital sign selection. Although individual workshops had an ecosystem focus (i.e., coastal, freshwater lakes, and rivers), the fields of discussion and opportunities for choosing vital signs were unbounded. Redundancy was anticipated (encouraged) and both reinforced the importance of specific ecosystem drivers or components across systems and helped to generate an integrated set of vital signs.

Candidate lists of vital signs were summarized after each workshop. In October 2003, the SWAN Technical Committee (TC) assigned three members to review and merge the vital signs into a single list. The TC empowered this vital signs working group to edit candidate vital signs that were not widely supported by experts during the workshops or by technical reviewers of the workshop summaries. The working group

also revised and merged the Network's monitoring objectives and questions to incorporate suggestions by workshop participants and, in some cases, to consolidate questions.

The combined list that emerged from the scoping workshops contained 61 vital signs. This list was reduced to 38 after similar indicators were merged under a single vital sign, and weakly supported or duplicate vital signs were removed. These 38 vital signs were evaluated with respect to clarification and consistency to ensure that each was clearly stated and understandable. We considered this step important because vital signs that are confusing or not readily understood cannot be evaluated or prioritized objectively.

3.3 Vital Signs Prioritization

The SWAN TC met on December 17-18, 2003, to review and prioritize the draft vital signs. In preparation for this meeting, the vital signs working group produced several summary documents:

- List of vital signs by category
- Ecosystem conceptual models from Chapter 2 with vital signs highlighted
- Revised holistic model (Figure 3-1) with vital signs inserted
- Natural resource protection issues paired with vital signs
- Monitoring objectives and questions paired with vital signs
- One-page definition and statement of importance for each vital sign

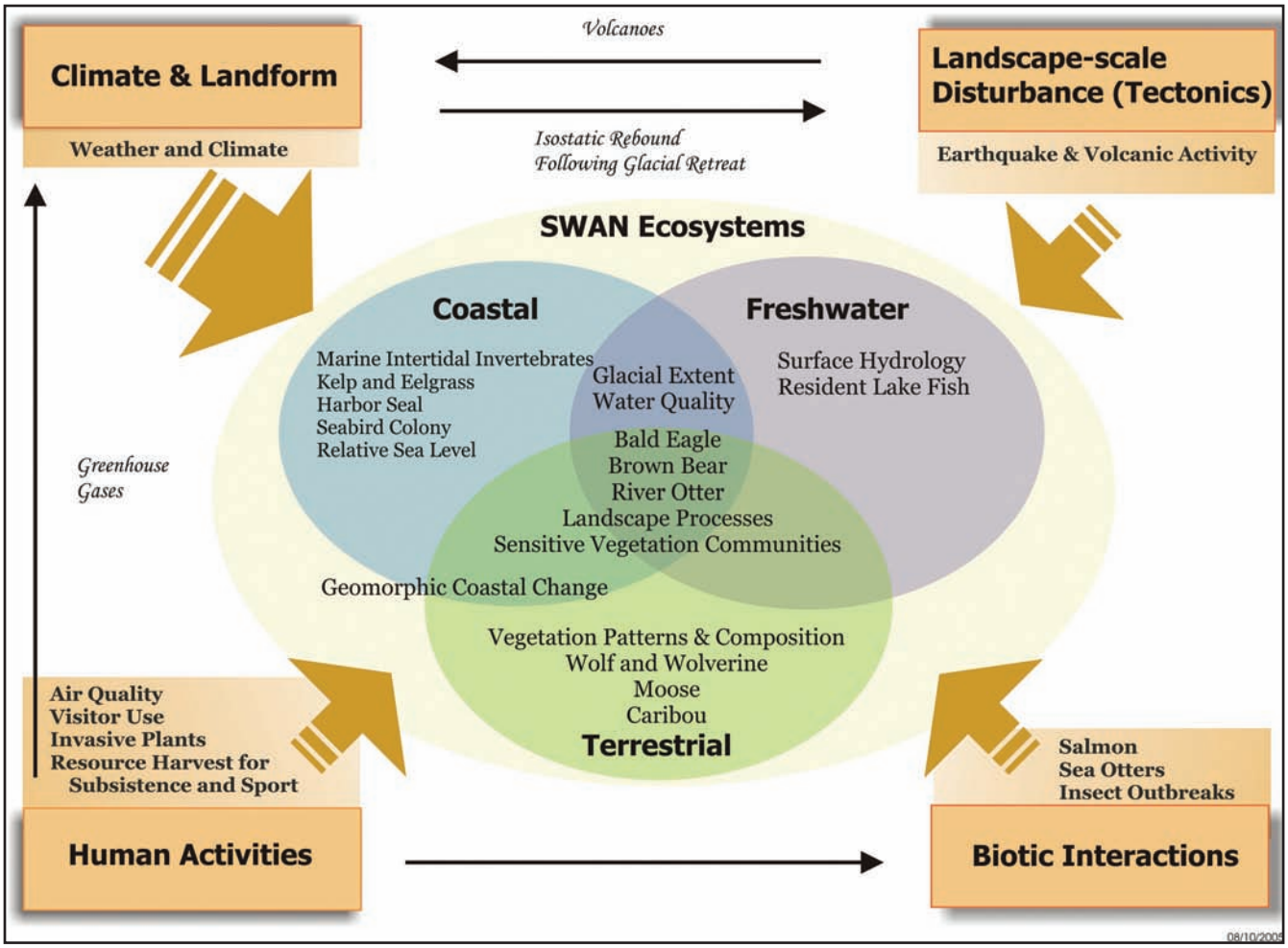


Figure 3-1 *Vital signs as they relate to drivers of change (boxes) and ecosystems (ovals) in SWAN. It is important to remember that these vital signs are not the "real system;" they are valued components of our interpretation of reality, and they may miss many subtleties, relationships, feedback, and other important considerations.*

During session one of the prioritization meeting, the TC reviewed the rationale for selecting each vital sign and how each would contribute to the Network's goals and objectives for monitoring. They also discussed candidate vital signs that emerged from scoping workshops that were not recommended by the SWAN vital signs working group. No additions or deletions resulted from this discussion, and the importance of each vital sign was reaffirmed. In some cases vital signs were renamed or merged. For example, snow cover, lake and coastal ice, and suspended sediments were combined into a single vital sign, Landscape Processes, because they will be monitored by remote sensing using a common protocol.

During session two, Committee members ranked each of the vital signs based on ecological significance and relevance to park resource management and protection. The purpose of this ranking was to identify at the onset vital signs that Network staff considered most important without considering in detail the methods of measurement or their feasibility. The ranking was not intended to establish a numerical order in which vital signs will be implemented. Prioritization criteria used by other national programs, including other NPS-Vital Signs Monitoring Networks (http://science.nature.nps.gov/im/monitor/docs/CriteriaExamples.doc), were modified for use by SWAN (Figure 3-2).

A Microsoft Access database was prepared to summarize scores and produce a numerical ranking. Vital signs were ranked overall and within the categories of drivers and ecosystems depicted in Figure 3-1. Summary statistics were generated to evaluate which vital signs accounted for the greatest deviation among committee members. During the final session (day 2), committee members reviewed and discussed the overall rankings and individual scores. Vital signs were subsequently assigned to three categories: essential, highly desirable, and optional, based on their numerical rankings (Figure 3-3). The 15 highest ranked vital signs include a mix of physical drivers, landscape processes, focal communities and species, and human-related activities. The second and third categories of vital signs primarily contain focal species and landscape processes.

Because financial limitations will restrict the scope of the monitoring program, the TC acknowledged the importance of having a core set of "essential" vital signs at the onset and a plan for building onto that core set in the future as financial resources or partnership opportunities materialize. The true costs of implementing monitoring for many vital signs is difficult to project until after protocols have been developed and tested. Costs are most uncertain for vital signs that require on-the-ground sampling. Preliminary cost estimates suggest that SWAN may be capable of implementing monitoring for the 30

Vital Sign Ranking Criteria

Ecological Significance

1. Importance as a controller or integrator: How important is the vital sign in controlling ecosystem function or structure, or how centrally is it linked to other attributes in the conceptual models? [3=high importance, 2=moderate importance, 1=low importance]
2. Usefulness as an indicator: How useful is the attribute in explaining the condition of network ecosystems; that is, how sensitive would it be as an indicator of change? [3=extremely useful, 2=moderately useful, 1=minimally useful]
3. Linkage: How closely linked is the vital sign to other attributes in network ecosystem models, or is the vital sign linked to important resources regionally? [3=many strong links, 2=few strong links or many weak links, 1=few weak links]

Park Management Significance

1. Legal/policy mandate: How important is monitoring this resource/vital sign for satisfying legal or policy mandates? [3=high importance (required), 2=moderate importance (specifically identified), 1=low importance (generally identified)]
2. Potential to support management decisions: Does monitoring this vital sign directly link to the information needed for carrying out a key management decision or evaluating the outcome of a management decision? [3=strong application, 2=moderate application, 1=weak application]
3. Importance of resource management: How important (for management) is the resource or issue represented by the vital sign, relative to other resources or issues in the park? [3=high importance, 2=moderate importance, 1=low importance]

Figure 3-2 *Criteria SWAN used to rank draft list of vital signs.*

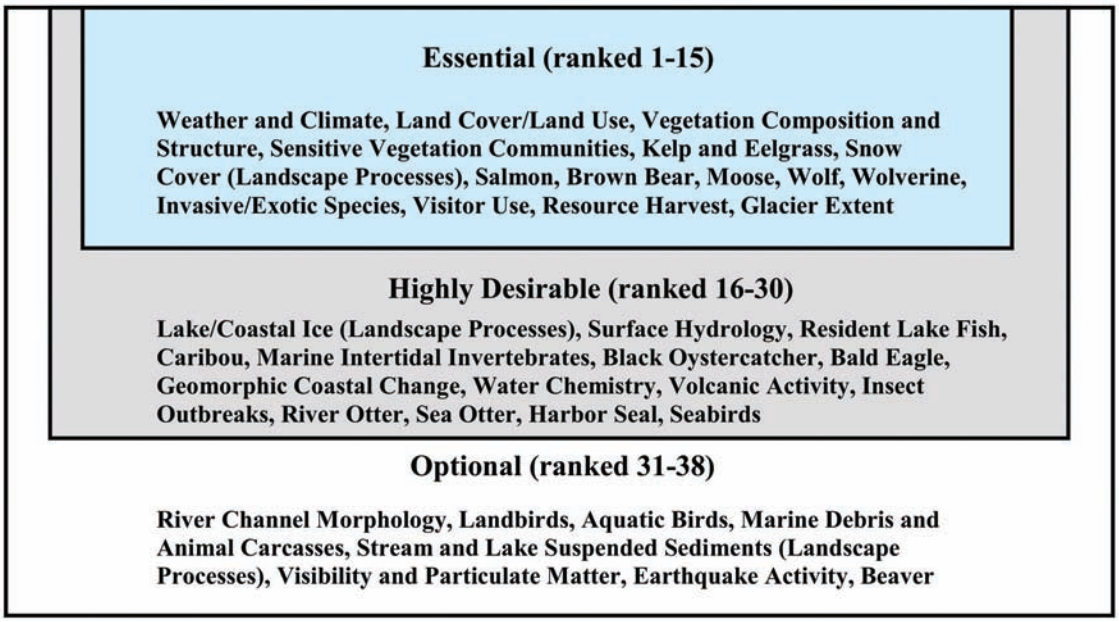


Figure 3-3 *Vital signs prioritization in SWAN. Vital signs ranked as "optional" are not being considered at this time unless the vital sign can be measured using remote sensing or it is currently being monitored by another agency.*

top-ranked vital signs. Consequently, vital signs ranked as "optional" are not being considered at this time unless the vital sign can be measured using remote sensing or is currently being monitored by another agency. For example, we are able to include Earthquake Activity, Visibility and Particulate Matter, and Stream and Lake Suspended Sediments because data can be acquired at little or no cost to the Network.

Following TC approval of the vital signs, a preliminary draft of sections 1 and 2 of this chapter were prepared, including a listing of the final (short list) SWAN vital signs within the National Ecological Monitoring Framework (Table 3-1). The NPS Ecological Monitoring Framework is a hierarchical organizational tool for promoting communication, collaboration, and coordination among parks, networks, programs, and agencies involved in ecological monitoring. SWAN vital signs are assigned to the National Level 3 category to which they most closely align.

The NPS Ecological Monitoring Framework was developed in July 2005 after SWAN had completed its final selection and naming of vital signs. As a result, some SWAN vital signs may be less definitive than a National Level 3 category title. For example, Invasive/Exotic Plants and Invasive/Exotic Animals are treated as one SWAN vital sign, Invasive Species. The SWAN vital sign Sensitive Vegetation Communities, although placed under Level 3 Wetland Communities, includes alpine and other vegetation communities not defined in the framework. A second vital signs framework built around Monitoring Projects (Table 4-1) was developed to present sampling designs and implementation schedules and allocate staff and budgets among program areas. This Monitoring Projects framework is used in tables and figures throughout Chapters 4-10. However, Tables 4-1, 5-1, and 8-4 do not list vital signs that will be monitored independently of SWAN by a park or another agency.

Both vital sign frameworks, along with descriptions of each vital sign, were provided to the Board of Directors (BOD) in early February 2004. During March, a 1-day meeting was held at each of the three parks with the superintendent, chief of resource management, and other staff. The purpose of these meetings was to review the steps that the Network followed in selecting and prioritizing vital signs, discuss individual vital signs, and provide an opportunity for park staff to comment on the process and draft list of vital signs. Park-based meetings were chosen over one meeting at a central location because they allowed more staff to participate and provided greater opportunity for the Network coordinator to review and discuss the program with two superintendents who only recently (December 2003) became members of the BOD.

Table 3-1 *National Ecological Monitoring Framework, including vital signs for which the SWAN is working independently or jointly with a Network park, federal, state, or private partner to develop and implement monitoring protocols.*

Ecological Monitoring Framework								
Level 1	**Level 2**	**Level 3**	**SWAN Vital Sign**	**ALAG**	**ANIA**	**KATM**	**KEFJ**	**LACL**
Air and Climate	Air Quality	Visibility and Particulate Matter	Visibility and Particulate Matter	-	●	-	-	●
	Weather and Climate	Weather and Climate	**Weather and Climate**	-	-	╬	╬	╬
Geology and Soils	Geomorphology	Glacial Features and Processes	**Glacier Extent**	-	-	╬	╬	╬
		Coastal/Oceanographic Features and Processes	**Geomorphic Coastal Change**	-	-	╬	╬	╬
	Subsurface Geologic Processes	Volcanic and Seismic Activity	Volcanic and Earthquake Activity	●	●	●	●	●
Water	Hydrology	Surface Water Dynamics	**Surface Hydrology**	╬	╬	╬	╬	╬
	Water Quality	Water Chemistry	**Marine Water Chemistry**	-	-	╬	╬	╬
			Freshwater Chemistry	╬	╬	╬	╬	╬
Biological Integrity	Invasive Species	Invasive/Exotic Plants and Animals	Invasive/Exotic Species	●	●	●	●	●
	Infestations and Disease	Insect Pests	Insect Outbreaks	-	-	●	●	●
	Focal Species or Communities	Marine Communities	**Kelp and Eelgrass**	-	-	╬	╬	╬
		Marine Invertebrates	**Marine Intertidal Invertebrates**	-	-	╬	╬	╬
		Fishes	**Resident Lake Fish**	╬	╬	╬	╬	╬
			Salmon	●	●	●	●	●
		Birds	**Black Oystercatcher**	-	-	╬	╬	-
			Bald Eagle	╬	╬	╬	╬	╬
			Seabirds	-	-	╬	╬	╬
		Mammals	**River Otter (coastal)**	-	-	╬	╬	╬
			Brown Bear	╬	╬	╬	-	╬
			Wolf	╬	╬	╬	╬	╬
			Wolverine	╬	╬	╬	╬	╬
			Moose	╬	╬	╬	-	╬
			Caribou	●	●	●	-	●
			Sea Otter	-	-	╬	╬	╬
			Harbor Seal	-	-	●	●	●
		Vegetation Complex	**Vegetation Composition and Structure**	╬	╬	╬	╬	╬
			Sensitive Vegetation Communities	╬	╬	╬	╬	╬

(continued on next page)

Table 3-1 (continued)

Ecological Monitoring Framework								
Level 1	**Level 2**	**Level 3**	**SWAN Vital Sign**	**ALAG**	**ANIA**	**KATM**	**KEFJ**	**LACL**
Human use	Consumptive Use	Consumptive Use	Resource Harvest for Subsistence and Sport	●	●	●	-	●
	Visitor and Recreation Use	Visitor Use	Visitor Use	●	●	●	●	●
Landscapes (Ecosystem Pattern and Processes)	Landscape Dynamics	Land Cover and Use	**Land Cover/Land Use**	╬	╬	╬	╬	╬
			Landscape Processes	╬	╬	╬	╬	╬

╬ Vital signs that the SWAN is working independently or jointly with a Network park, federal, state, or private partner to develop and implement monitoring protocols using funding from the vital signs or water quality monitoring programs (category 1, also noted with bold text and shading)

● Vital signs that are monitored independently of SWAN by a Network park, another NPS program, or another federal, state, or private agency. (category 2, information is obtained and used by SWAN)

- Vital sign will not be monitored in that park.

Note: Landscape Processes includes snow cover, lake and coastal ice, and suspended sediments.

Board members expressed satisfaction with the Network's vital sign selection process and outcome. Questions centered on the challenges and costs of monitoring in large remote parks, inclusion of vital signs that are currently being monitored by partnering agencies, the relationship between concurrently funded pilot projects and the list of vital signs, and the direction that the planning process would take. Park staff acknowledged that the list of vital signs represents an optimum program, not all of which may be achieved with Network funding, and that additions or deletions may occur during the coming years as new information becomes available. Board members approved the list of vital signs and signed the Phase II Report.

Chapter 4
Sampling Design

A sampling design used for monitoring vital signs dictates where, when, and how often to sample. Stevens and Urquhart (2000) distinguished a sampling design from a response design, which describes how to best record information from sample locations. Although the focus of this chapter is on sampling design, we also will discuss the response design component because it is integral to development of a monitoring plan.

There are four key characteristics of a sampling design for monitoring: the ability to make valid inferences beyond areas actually sampled when applicable, representativeness of the sample across both space and time, minimum quality of data (precision and bias) necessary to achieve an objective, and feasibility (logistics, cost effectiveness). Because proper monitoring of natural resources is usually very expensive and time-consuming, sampling designs should provide reliable information in a cost-efficient manner. Monitoring in national parks in southwest Alaska is particularly daunting because these parks mainly consist of large, remote wilderness areas that are difficult to access except perhaps via floatplane, ski plane, helicopter, or boat, which is context-specific and dependent on weather conditions. Consequently, practical considerations, such as accessibility and cost, will limit design alternatives that can be realistically implemented in these parks. A design also should be flexible enough to allow continued sampling within a restricted range of high-priority areas or sites if funding drops to levels too low to support the full program.

In this chapter, we discuss basic concepts and terminology of sampling design and describe specific designs relevant to SWAN parks for monitoring status, trend, or both. Although our primary focus will be on monitoring trends, we also will be monitoring both status and trend for certain vital signs (e.g., Volcanic and Earthquake Activity; see Table 7-1 in Chapter 7). Topics covered in this chapter are not mutually exclusive in that reasonable vital signs and their metrics are required for specifying achievable monitoring objectives, which in turn influence the type of sampling designs, sample sizes, and analytical techniques used.

4.1 Basic Concepts and Terminology

In this section we introduce terminology and provide the conceptual framework for our proposed sampling designs for monitoring vital signs in SWAN parks discussed later in this chapter. We begin by defining *status* as a measure of a current attribute, condition, or state, and *trend* as a measure of net change, which includes contributions from immigration or emigration as well as those occurring within the area of interest (i.e., individual change; McDonald 2003). Status applies to specific points in time, whereas trend pertains to measurements across multiple time periods. Whenever possible, we use terminology that is consistent with the statistical survey literature and Phase III reports from other I&M networks.

An important step when developing a sampling design is defining the collection of animals, plants, natural resources, or environmental attributes of interest within a specified area. This quantity is referred to as the *target population*. Note that this is a statistical population; it may or may not refer to a biological population. A target population consists of *elements*, which are the items or attributes that are measured, such as individual animals or plants (Scheaffer et al. 1990). We attempt to quantify our target population through use of a *sampling frame* (“frame”), which consists of *sampling units*. Sampling units are nonoverlapping collections of elements, although some may not contain any elements. Common examples of sampling units (“units”) in area sampling include plots, quadrats, and transects. Moreover, an element and a sampling unit sometimes may be one and the same quantity, such as a list of licensed hunters in telephone surveys. A *sample* is a subset of units chosen to record a response through counts, observation, or other form of measurement (Cochran 1977).

There are two types of sampling frames. A *list frame* contains a specific description of potential sampling units, such as a list of existing lakes, with their locations and characteristics, in a national park. An *area frame* defines the geographic boundary of the area of interest (Haines and Pollock 1998), such as all terrestrial habitats within the boundary of a national park.

A carefully constructed frame is important to ensure strong inference and defensible results. Nonetheless, factors beyond our control often compromise the integrity of a frame so that only a reduced portion of it can potentially be sampled. For instance, certain areas within a frame may be unsuitable habitats for the species or vital sign in question (e.g., glaciers); too expensive to sample from the ground because of low accessibility or remoteness; or too dangerous to sample from the ground because of extreme topography, environmental conditions, or presence/abundance of dangerous animals. The *sampled population* is the portion of the target population that is available to be sampled and hence the portion to which statistical inferences can be made (Cochran 1977; Figure 4-1). Ideally, we would like the sampled and target populations to be the same, but this often is not the case due to the aforementioned and other reasons.

An imperfect frame is one source of error that may adversely affect our ability to achieve our monitoring objectives. In general, there are two types of error common to surveys: bias and precision. *Bias* refers to a persistent error that is not due to random chance (Cochran 1977). Specifically, it is the difference between the average of estimates from all possible samples from a sampling frame and the true value of the parameter of interest (e.g., vital sign metric). This definition points to the distinction between bias and representativeness. A design may be based on an unbiased estimator of say, abundance, but a given sample may produce an abundance estimate far from the true abundance and hence is not representative. This situation is due to a large spread in estimates among samples, which is characteristic of a spatially unbalanced sample from a clustered spatial distribution of elements (e.g., plants or animals). The degree of spread in estimates from repeated samples is referred to as *precision* (Cochran 1977). Designs that produce spatially balanced samples are preferred because samples tend to be more representative and produce more precise estimators than more spatially restricted samples during a given sampling period.

Physical scientists frequently use *measurement precision* to refer to uncertainty in an instrument's ability to exactly record a physical quantity, such as chlorophyll level in a water quality sample. This type of

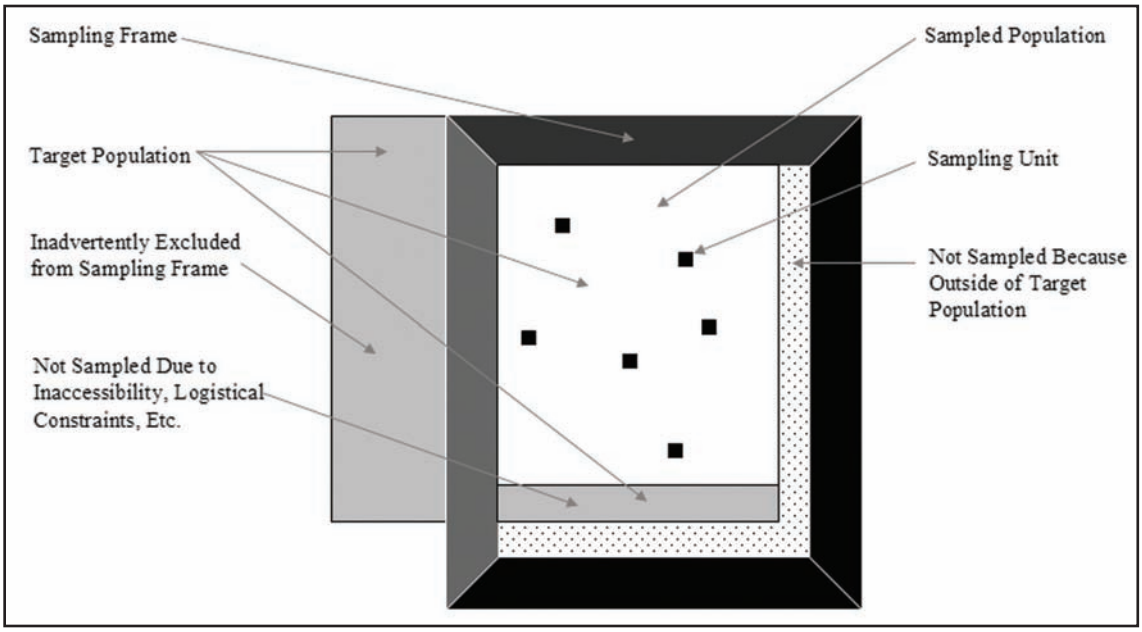


Figure 4-1 *Conceptual representation of terms used to characterize the area and population of interest to be sampled. The combined gray/taupe and white areas denote the target population, the white area alone represents the sampled population, and the stippled white area is outside of the target population. (Original figure was adapted from A.R. Olsen [unpublished presentation] and Lohr [1999]; reproduced with permission from R. Bennetts, GRYN Phase III Report.)*

precision applies to the recording scatter around a single sample, whereas estimator precision discussed in the previous paragraph refers to scatter or spread in estimates from repeated samples. This chapter will focus on estimator precision.

As in the Central Alaska Network, sampling designs proposed for SWAN parks may sometimes rotate sampling efforts through different collections of units over time. We define a *panel* of sampling units to be those that are sampled together during the same sampling period (McDonald 2003). This definition does not preclude a sampling unit from being a member of different panels. However, the typical situation for SWAN will be for sampling units to be members of only one panel. For example, it may be feasible to sample only a third of selected ground plots during a given year so a different third is sampled each year over a 3-yr period, which would be a rotating panel design consisting of three panels.

There are two basic components of a sampling design for monitoring natural resources: membership and revisit designs. A *membership design* dictates how sampling units are chosen to become members of a panel, which includes how to spatially allocate sampling effort (McDonald 2003). Sample selection methods used in membership designs can be placed in one of two categories: nonrandom and random sampling. Nonrandom sampling is a choice of units based on convenience, perceived representativeness, haphazard contact, or other subjective criteria. A feature shared by all nonrandom samples is that statistical inference is limited to sites actually sampled. Attempting to expand beyond these sites will nearly always result in selection bias, usually of an unknown magnitude. This bias could potentially be mitigated if the relationship between vital sign metrics in nonrandomly sampled units and unsampled units is reasonably approximated by a model (e.g., known habitat or environmental associations). In addition, bias will likely be reduced if a large proportion of the frame is (nonrandomly) sampled, especially if sample locations are spatially balanced. However, neither of these scenarios can be assumed without validation, which is one reason why nonrandom sampling approaches have been criticized in the literature (e.g., see Anderson 2001, Ellingson and Lukacs 2003).

Random or probability sampling employs some form of randomized procedure to select units. Because of this, each potential sample has a known probability of selection and results can be statistically inferred to the larger sampled population. Common examples of probability sampling schemes include simple random, systematic, and stratified sampling (or some combination thereof; Cochran 1977). The generalized random-tessellation stratified (GRTS; Stevens and Olsen 2004) design is a recently proposed probability sampling method that produces a spatially balanced sample and allows units to be easily added to existing samples while maintaining their spatial balance. A GRTS design also can incorporate stratification and units with unequal probabilities of selection (e.g., size). Trent McDonald of WEST, Inc., has developed a freeware program called S-Draw (http://www.west-inc.com/programs/S-Draw1b.zip) that draws a GRTS sample of discrete units from one- or two-dimensional space.

A *revisit design* determines when and how often selected units are sampled (or visited) among sampling occasions and hence how to temporally allocate sampling effort (McDonald 2003). For example, members of one panel may be sampled during every sampling occasion and members of another panel may be sampled every third sampling occasion. Sampling frequency will be dictated both by level of temporal variation in the vital sign metric and by logistical/funding constraints.

An important consideration when choosing a revisit design is its ability to retain a representative sample across time. A sample that is initially representative may lose this quality if there are changes or shifts in population numbers or other attributes during later time periods that are no longer captured by the original sampled units. These shifts across time could be induced by natural changes (e.g., habitat succession), anthropogenic actions, or a combination of both. If large shifts are not expected to occur or if the membership design is spatially balanced enough to adequately capture any shifts, the best revisit design to detect trend is to repeatedly sample the same plots across time, all else being equal. However, repeated visits to the same units could potentially have a negative impact on the response, such as trampling in vegetation monitoring plots, which would introduce bias. The optimum design to estimate status is to choose a new

sample of units each time, which would account for any shifts and avoid potentially deleterious effects of repeated sampling on the response, but would be inefficient for detecting a trend because it would incorporate an additional among-unit variance component. If temporal representativeness is uncertain, a mixture of panels containing repeated samples and new samples (split panel) would be a compromise that balances status and trend. We will initially rely on spatially balanced samples as a means to avoid potential problems of retaining representative samples across time, but may adopt split-panel designs if deemed necessary in the future.

A *response design* directs how to record the response (vital sign metric) within each sampled unit, which includes choosing a method of measurement and an optimum shape and size of units (Stevens and Urquhart 2000). In area sampling, a complete count or measurement of elements within a sampling unit often is not possible, especially when elements are mobile organisms. Even sessile organisms such as plants may be overlooked if sampled during a time when their floristic or other features used for identification are not present or if the organisms are present but below ground, such as those species that exhibit dormancy. Note that a probability sample of units may still result in a biased estimator of trend if bias is associated with the response design.

The probability of detecting an individual or species within a sampling unit, given it is present, is called probability of detection or detectability. There are two processes that lead to incomplete detectability: perception and availability (Marsh and Sinclair 1989, Pollock et al. 2004). Perception bias arises from missing elements that are available for detection, i.e., nonzero probability of detection. In our previous plant example, individuals or species left unrecorded due to their lack of features typically used for identification produce perception bias. Methods such as capture-recapture (Pollock 2000) and distance sampling (Buckland et al. 2001) have been developed to account for this component of individual detectability (see also Williams et al. 2002); Nichols et al. (1998) offered an approach to estimate this component of species detectability in community metrics such as species richness.

Availability bias is produced when elements are present but are unavailable for detection, i.e., zero probability of detection. In the plant example, individuals or species missed because they are dormant underground result in availability bias. Conducting surveys from the same platform or employing the same method also may induce availability bias. For example, repeated aerial surveys of bald eagle nests may miss more nests than a combination of aerial and ground surveys, i.e., nests undetectable from the air, such as those obscured by dense vegetation, may be detectable from the ground and vice versa. There has been recent activity (e.g., Pollock et al. 2004) in developing methods to account for availability bias; SWAN staff will track future developments in this area and adapt their response designs whenever applicable and feasible.

Failing to properly account for either individual or species detectability leads to biased estimators of trend. The magnitude of this bias relative to the specified level of change and to the variability of the estimator will determine whether the level of bias should be a concern. However, either estimates or a realistic range of estimates of detectability bias and variability are required to confirm this relationship (see next section). Bias also may be ignored if the observed change is proportional to the true change, but this is far from guaranteed because of various factors affecting this relationship, even if standardized methods are used (Thompson 2002). If detection bias has a large influence on the trend estimator, one cannot distinguish a true change in a population or community from a false trend generated by temporal changes in detection rates of individuals or species. Bias of this sort can have a deleterious effect on natural resource decisions (Moore and Kendall 2004), and hence relevant SWAN response designs will incorporate methods that properly account for incomplete detectability whenever possible.

SWAN membership, revisit, and response designs often will be applied within a multistage sampling context, e.g., a count or measurement (stage 3) within randomly selected subunits (stage 2) within randomly selected units (stage 1; Skalski 1994). Each stage may have variance and/or bias components as discussed above. Variance components can be divided into temporal, spatial, and sampling variation

(Thompson et al. 1998). Temporal and spatial variation arise from natural processes (e.g., environmental, demographic, etc.), whereas sampling variation arises from the sampling process. Models can be used to separate and remove (or greatly reduce) sampling variation from overall variation when estimating trend, which will be discussed in Chapter 7.

4.2 Minimum Sample Size Required for Detecting a Trend

The minimum number of units sampled across space and time is dictated by survey cost, both in accessing units and in recording the responses within them, and by the maximum allowable amount of bias and variance in the trend estimator to achieve the monitoring objective. A large change will require fewer units and less robust data to detect than a small change. The topic of this section is computing initial estimates of how many sampled units are enough. It is better to gather data of sufficient quality on fewer vital signs than insufficient data on many of them. The estimator of the vital sign metric should be precise enough to detect a trend within existing constraints; if it does not, another metric should be considered instead.

Statistical power analysis (Gerrodette 1987) is the typical approach to estimating sampling sizes for monitoring population trends. However, canned programs for computing sample sizes via power analysis (e.g., TRENDS; Gerrodette 1993) lack the capability for properly fitting complex membership and revisit designs. Consequently, we will be using either commercial software (e.g., SAS Institute, Inc. 2004) or freeware (R; http://www.r-project.org/) statistical programs to run simulations to estimate sample sizes required under various design scenarios. This information then can be incorporated into cost functions to assess whether the initial sample size suggested by simulation results will be adequate to achieve monitoring objectives within funding constraints.

The basic components of our simulations will be spatial and temporal scale specified in the monitoring objective; spatial variability (degree of clustering of elements); a realistic range of temporal variability; a realistic range of detection probabilities for within-unit counts (bias); a range of levels of change; membership design; revisit design; and trend analysis model(s) (Chapter 7). Elzinga et al. (2001:192) reviewed existing literature to provide estimates of variability from selected plant and animal populations monitored for at least 5 yr. These values provide initial estimates for certain taxa, but we cannot assume that the range of previously generated estimates may be representative of future variability (e.g., larger future deviations due to climate change). Thus, determining sample sizes will be an iterative process through refining estimates as more data are gathered over time. This iterative approach also applies to setting minimum levels of change that will best meet park or network monitoring objectives.

4.3 Overview of SWAN Sampling Designs

Our general approach to developing sampling designs is outlined in Figure 4-2. Note that there is no single overall design that we can use for all vital signs and metrics because of the different sampling contexts, such as spatial scale and configuration, and because we sometimes will be acquiring monitoring data from existing programs conducted by other agencies that employ various sampling designs. Nonetheless, whenever possible we will use a common probabilistic design that incorporates collocation and/or covisitation of units for recording data for different vital signs (e.g., Marine Nearshore, Freshwater Flow Systems).

There is the sampling design we would like to implement and the one we can implement due to logistical, personnel, and funding constraints. A monitoring program with unlimited resources could probably obtain high resolution data for all vital signs on a parkwide scale. This is not realistic for many monitoring programs, particularly those conducted in very large, remote parks in Alaska. Therefore, even though our target populations are in all suitable areas within park boundaries, the actual areas of inference (sampled populations) may be much smaller, especially for vital signs requiring ground- or water-based sampling. It is better to gather sufficient data on a smaller area of inference than inadequate data on a larger scale of inference. When necessary, we will incorporate accessibility and prioritization components into our designs, where prioritization criteria will be heavily influenced by park staff. High-priority, easily accessible units

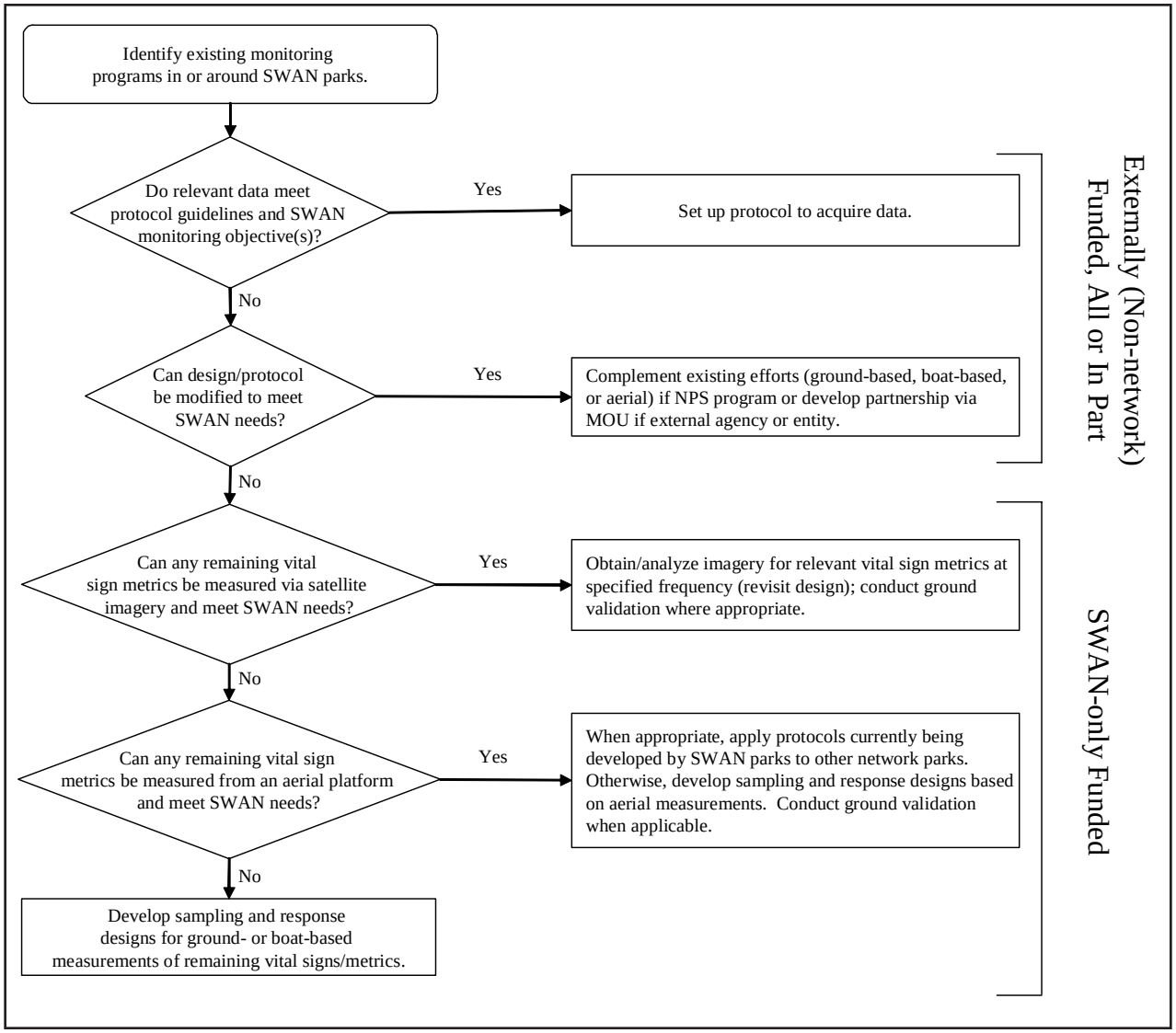


Figure 4-2 *Steps involved in developing sampling and response designs for monitoring SWAN vital signs. Ground-based designs will be developed only for those vital sign metrics for which remote sensing or aerial measurement is either not feasible or provides data at an inadequate spatial resolution to meet SWAN monitoring objectives.*

or sites will be sampled more frequently than others. This will ensure that at minimum these high priority areas will be monitored even during years of low funding. Note that access is not necessarily equated with distance; a more remote unit may be less costly to sample because it is accessible via floatplane, whereas a less remote one may be more costly because it can be accessed only via helicopter.

We will use a combination of random and nonrandom sampling designs for those vital signs whose protocols are developed by SWAN alone (e.g., last two steps in Figure 4-2). The random sampling design will primarily be GRTS and systematic sample with a random start, often with a level or levels of stratification based on environmental attributes (e.g., slope) to increase precision of our trend estimators. Stratification criteria should change little or remain unchanged during the course of the monitoring program (Overton and Stehman 1996). The nonrandom samples will be sites where changes are predicted to most likely occur, presumably represent the range of conditions within a park, or a combination of these two. Randomly chosen sites will always supplement nonrandom units to broaden the scale of inference and to assess whether changes observed at nonrandom sites are occurring elsewhere.

Proposed sampling designs used for monitoring vital signs are summarized below by project, with additional details in Table 4-1. Complete measurement at the parkwide scale (e.g., satellite imagery) will

Table 4-1 *Existing and proposed sampling/response designs for monitoring SWAN vital signs (FIA=Forest Inventory and Analysis; RAWS= Remote Automated Weather Stations; TBA = to be announced; see section 4.3.4 for explanation of lake tier system). Sampling frequencies are subject to change depending on observed variability and funding/logistical constraints.*

		Sampling Design Component		
Project	**SWAN Vital Sign**	**Membership**	**Revisit**	**Response Design**
Weather and Climate	Visibility and Particulate Matter*	Nonrandom (Expert Judgment)	Continuous Measurement	Ground-based IMPROVE
	Weather and Climate	Nonrandom (Expert Judgment)	Continuous Measurement	Ground-based RAWS Stations
Landscape Dynamics and Terrestrial Vegetation	Glacier Extent	Complete Survey Nonrandom (Expert Judgment)	Every 12–15 Years Every 12–15 Years	Landsat Imagery Ground Validation
	Volcanic and Earthquake Activity*	Complete Survey	Continuous Measurement	Ground-Based Sensors
	Invasive/Exotic Species*	Opportunistic	TBA	Ground Surveys
	Insect Outbreaks*	Nonrandom (Expert Judgment)	Annual	Aerial Photography
	Sensitive Vegetation Communities	Nonrandom (Expert Judgment, Accessibility)	Every 3–5 Years For First 10 Years; Every 7–10 Years Thereafter	Ground Measurement Within Subplots Along Random Transects
	Vegetation Composition and Structure	Complete Survey Restricted Random (Accessible Areas) GRTS Sample Within Core Areas	Every 10 Years Every 10 Years Annually for First 5 Years and Rotating Panel (3 Years) Thereafter	Satellite Imagery, Aerial Photography Ground Validation Ground Measurement of Vegetation Plots (Supplemented by FIA Plots)
	Land Cover/Land Use	Complete Survey Restricted Random (Accessible Areas)	Every 10 Years Every 10 Years	Satellite Imagery, Aerial Photography Ground Validation
	Landscape Processes	Complete Survey Restricted Random (Accessible Areas)	Seasonal/Annual TBA	Satellite Imagery Ground Validation

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Table 4-1 (continued)

		Sampling Design Component		
Project	**SWAN Vital Sign**	**Membership**	**Revisit**	**Response Design**
Marine Nearshore	Geomorphic Coastal Change	Survey Entire Coastline Nonrandom (Expert Judgment)	Every 10–12 Years Every 10–12 Years	Aerial Videography Ground Validation, Beach Profiles
	Marine Water Chemistry	Survey Entire Coastline Stratified GRTS	Annual Annual	Satellite Imagery Ground Measurement: HOBO Data Loggers
	Kelp and Eelgrass	Survey Entire Coastline TBA	Every 10–12 Years Annual	Aerial Video Imagery (Coarse Scale) Aerial Video Imaging (Site Specific)
	Marine Intertidal Invertebrates	Stratified GRTS	Annual	Ground Measurement: Plots Along Transects
	Black Oystercatcher	TBA	Annual	Ground Measurement: Nest/Nesting Territory Survey
	Seabirds	Stratified Random	Annual	Boat Surveys Along Random Transects
	River Otter (Coastal)	TBA	TBA	Boat-Based Latrine Surveys
	Sea Otter	Stratified Systematic Sample	Annual	Aerial Transect Survey
	Harbor Seal*	Survey Entire Coastline Complete Survey of Specific Areas (KEFJ)	Every 5 Years Seasonal	Aerial Photosurvey of Haul Outs, Sightability Model Aerial Survey
Lakes, Rivers, and Fish	Surface Hydrology	Survey All Tier 1 Water Bodies Stratified GRTS (Tier 2 and 3)	Annual (Lake Level), 2–5 Years (Discharge) Every 2–10 Years	Stream and Lake Measurement Same as Above
	Freshwater Chemistry	Survey All Tier 1 Water Bodies Stratified GRTS (Tier 2 and 3)	Seasonal, Annual Some Annual, Most Every 2–10	Boat-based, Shoreline, Stream Measurements (HOBO Data Loggers) Same as Above

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Table 4-1 (continued)

		Sampling Design Component		
Project	**SWAN Vital Sign**	**Membership**	**Revisit**	**Response Design**
Lakes, Rivers, and Fish *(cont.)*	Resident Lake Fish	Survey All Tier 1 Water Bodies Stratified GRTS (Tier 2 and 3)	Every 3–5 Years Every 5–10 Years	Gill Nets and Beach Seines Same as Above
	Salmon*	Nonrandom (Expert Judgment)	Annual	Tower, Weir, and Sonar Counts; Aerial Stream Surveys
Terrestrial Animals	Bald Eagle	Stratified Random (ALAG, ANIA, KATM) Targeted and Complete Surveys (LACL)	Every 3 Years Annual	Aerial Survey Aerial Survey
	Brown Bear	Stratified Random	Every 5–10 Years	Aerial Survey, Double-Count Line Transect With Covariates
	Wolf	Stratified Random (SUPE)	Every 3–5 Years	Aerial Survey, Tracks (Network Sampling)
	Wolverine	Stratified Random (SUPE)	Every 3–5 Years	Aerial Survey, Tracks (Network Sampling)
	Moose	Stratified Random	Every 3–5 Years	Aerial Survey, Sightability Model
	Caribou*	Nonrandom, Extensive Coverage	Annual	Aerial Photosurvey
Human Activities	Resource Harvest for Subsistence and Sport*	Nonrandom	Annual	Harvest and Subsistence Reporting
	Visitor Use*	TBA	TBA	TBA

* Vital signs that are monitored independently of SWAN by a Network park, another NPS program, or another federal, state, or private agency (information is obtained and used by SWAN).

not require a membership design. Further details are provided in Chapter 5, Appendix III, and the full protocol (if available; see SWAN listings at http://science.nature.nps.gov/im/monitor/protocoldb.cfm). Designs developed by SWAN or in cooperation with partners will require frequent sampling during the first 3-5 yr of the program to evaluate and refine protocols (e.g., better estimate frequency of sampling).

4.3.1 Weather and Climate

Aerosol data will be obtained from existing stations in southwest Alaska within the Interagency Monitoring of Protected Visual Environments (IMPROVE) network. Temperature, relative humidity, precipitation, and related data will be collected from strategically placed Remote Automated Weather Stations (RAWS) within SWAN parks. Site placement will be based on guidelines used by the Western Regional Climate Center (Redmond et al. 2005), knowledge of park staff , distribution of existing weather stations (Appendices I-7, I-8, I-9, I-10, and I-11), and models from the Program for Integrated Earth System Modeling and north Gulf of Alaska wind events.

4.3.2 Landscape Dynamics and Terrestrial Vegetation

Data collected in existing programs by other agencies will be obtained and used by SWAN to monitor status and/or trend in Volcanic and Earthquake Activity, Invasive/Exotic Species, and Insect and Disease Outbreaks. Satellite imagery will be used at the parkwide scale to monitor vital sign metrics for Glacier Extent, Vegetation Composition and Structure (in part), Land Cover/Land Use (with aerial photography), and Landscape Processes. Sampling frequencies vary by vital sign (Table 4-1).

Ground-based sampling for Sensitive Vegetation Communities and Vegetation Composition and Structure will be a combination of nonrandom and random sampling. Systematic samples of transects with random starts will be established within sites deemed representative of sensitive vegetation communities in a given park. Subplots within transects will be sampled every 3-5 yr for the first 10 yr to obtain estimates of variance and every 7-10 yr thereafter.

Ground-based sampling of Vegetation Composition and Structure will occur in 2-3 core areas, deemed representative of common late-successional plant communities, within the relevant parks. In addition, due to logistical and funding constraints, these core areas will be < 25º slope and/or < 3 km from established access points. A certain portion of ground plots will be collocated with weather stations when possible, whereas locations of the remaining ones will be chosen using either a systematic sample (nested grid) with a random start or GRTS sample. Data will be collected annually for the first 5 yr and then in a rotating panel (a third of the plots) every 3 yr thereafter. Data from Forest Inventory and Analysis (FIA) plots will be used to supplement SWAN-collected data.

4.3.3 Marine Nearshore

In partnership with the U.S. Geological Survey-Biological Resources Division (USGS-BRD) Alaska Science Center (ASC), U.S. Fish and Wildlife Service, National Marine Fisheries Service (NMFS), and State of Alaska, SWAN will assist in developing protocols for monitoring vital signs associated with the marine nearshore (except Geomorphic Coastal Change and Harbor Seal) as part of the Gulf Ecosystem Monitoring (GEM) initiative being developed by the Exxon Valdez Oil Spill Trustee Council. The sampling designs are under development, but will include stratified random sampling (Seabirds), stratified systematic (Sea Otter), and stratified GRTS (Marine Intertidal Invertebrates, Marine Water Chemistry), where stratification criteria will be based on physical features expected to remain relatively static during the course of the monitoring program. A certain portion of ground-based plots will be nonrandomly selected from nearshore areas where impacts are expected to be greatest (e.g., coastal towns). Most of these metrics will be sampled annually (Table 4-1). Geomorphic coastal change will be monitored at a coarse scale every 10-12 yr over the entire coastline and on a site-specific scale via beach profiles at the same frequency. Site selection will be judgment-based for ground measurements. SWAN will acquire

abundance data of harbor seals at haul-outs every 5 yr from the existing NMFS program, supplemented by survey data collected by the Alaska Sea Life Center in KEFJ.

4.3.4 Lakes, Rivers, and Fish

Sampling within lakes and streams in SWAN parks will be based on a combination of targeted and random selection procedures. Invited experts and SWAN park staff employed a three-tier categorization to prioritize sampling of SWAN lakes or streams to ensure that key flow systems will be monitored annually (except resident lake fish). Categorization criteria included access, level of use/management issues, and ecological and spatial coverage. Tier 1 (high priority) lakes and streams are easily accessible, so they receive the heaviest use/impact and are of the greatest management concern. Naknek and Brooks Lakes, both anadromous, are Tier 1 lakes representative of the Naknek flow system in KATM. Tier 1 lakes in the Lake Clark flow system in LACL include Lake Clark (anadromous) and Kontrashibuna Lake (nonanadromous). Resurrection River/Exit Creek is the Tier 1 river system in KEFJ (Figure 4-3).

Tier 2 (medium priority) lakes and rivers are less accessible than their Tier 1 counterparts, and a randomly chosen subset will be sampled less frequently (e.g., 2-5 yr). These lakes and rivers are important for expanding the spatial inference beyond Tier 1 lakes and rivers, e.g., to ensure trends observed at Tier 1 sites are present in other flow systems in the parks. Tier 3 (low priority) lakes and rivers further expand the scale of inference, but will be sampled less frequently (e.g., 10 yr), if at all, because of funding constraints. However, data for certain vital sign metrics may be collected annually at Tier 2 and 3 locations where volunteer and/or park staff are seasonally present and data collection does not require advanced training or equipment. Tier 2 and 3 lakes and rivers, by SWAN park, are (Figure 4-3):

Tier 2
ANIA: Aniakchak River drainage, including Surprise Lake
KATM: JoJo Lake, Grosvenor Lake, Murray Lake, Hallo Lake system
LACL: Kijik Lake, Lachbuna Lake, Crescent River system
KEFJ: Delusion Lake, Nuka River
Tier 3
KATM (includes ALAG): Kukaklek Lake, Battle Lake, Dakavak Lake
LACL: Twin Lakes, Telaquana Lake

Surface Hydrology and Freshwater Chemistry data, in part, will be collected at the main outlet streams for the Tier 1 lakes, whereas related data will be gathered at the deepest point of each lake. In addition, a GRTS design will be used to select feeder streams in these sampled lakes for collecting stream discharge and water chemistry data. Discharge data from existing stream-gaging stations will be used to help determine sampling frequencies (Appendix I-12). Tier 2 and/or Tier 3 lakes or rivers will be stratified by lake size, water type (clear, glacial, brown), and accessibility prior to selecting a GRTS sample from the Tier 2 or 3 list. Sampling within randomly selected Tier 2 or 3 water bodies will follow the same sampling protocols as those used in Tier 1 lakes and rivers.

We will use beach seines and multimesh gill nets (Appelberg 2000) to sample resident fish species in selected lakes every 3-5 yr, where lake selection will additionally be restricted to those with a boat available for sampling. Each lake first will be stratified by shoreline slope and then these strata will be stratified further by distance to nearest tributary. A GRTS sample will be chosen from each stratum to identify net locations. We will use catch data in robust design, mark-recapture models (Pollock 1982) to estimate both occupancy (MacKenzie et al. 2003) of key species and relative species richness (Cam et al. 2000) of resident fish communities within selected SWAN lakes across time, where relative species richness is the ratio of resident fish species present in a given lake to the maximum number present in the relevant flow system.

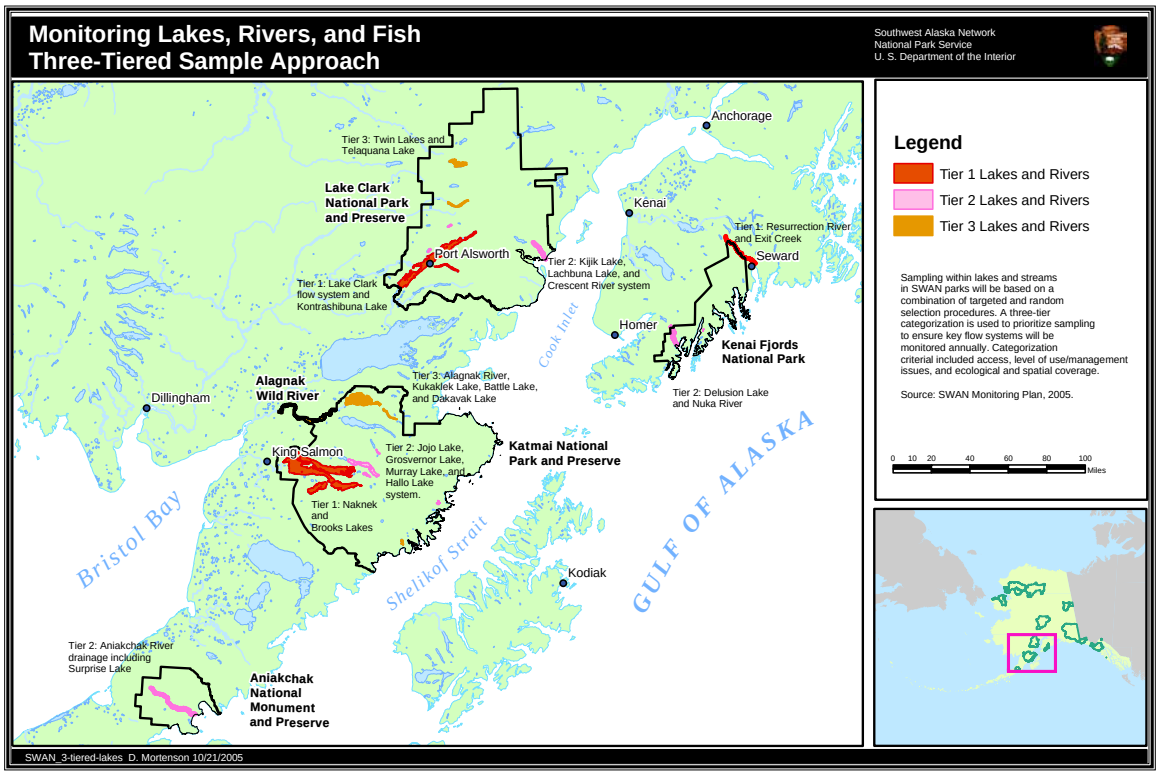

Figure 4-3 *List and locations of proposed Tier 1, 2, and 3 lakes and rivers for monitoring aquatic resources in SWAN parks.*

SWAN will obtain data on salmon spawner abundance, distribution, run timing, and freshwater residence time from the existing monitoring program conducted by the Alaska Department of Fish and Game (ADF&G), supplemented by tower counts (at least through 2007) on the Newhalen River by the USGS-BRD ASC in cooperation with NPS. ADF&G currently uses a combination of counting towers, a sonar station, a weir, and aerial surveys to monitor abundance and/or distribution of spawning sockeye salmon in selected streams and lakes within SWAN parks. Sites were selected based on expert judgment.

4.3.5 Terrestrial Animals

Stratified random sampling will be used to select areas in which to perform aerial surveys of bald eagles, brown bears, moose, wolves, and wolverines. Stratification criteria will include physical features related to perceived densities of the target species, typically focusing on those features that change little during the monitoring program (e.g., kilometers of coastline in bald eagle surveys) or considering more static correlates for criteria based on vegetation cover for existing survey protocols (moose). However, the sample unit probability estimator (Becker et al. 1998), which will be used to survey wolves and wolverines, is a stratified network (or snowball) sampling design and hence does not necessarily have fixed stratum boundaries across time. Aerial surveys of brown bears, moose, wolves, and wolverines will incorporate sightability corrections to their counts and will be performed every 3-10 yr (Table 4-1).

SWAN will obtain monitoring data on caribou from existing surveys of the Northern Alaska Peninsula and/or Mulchatna Herds cooperatively conducted by ADF&G, Alaska Department of Natural Resources (ADNR), U.S. Bureau of Land Management, U.S. Fish and Wildlife Service (USFWS), and NPS. Current efforts employ photosurvey and radiotracking techniques to estimate abundance, sex-age composition, and distribution of these herds over an extensive area in lieu of subsampled areas only.

4.3.6 Human Activities

SWAN will obtain annual data on Resource Harvest for Subsistence and Sport from ADF&G and the Federal Subsistence Board. The sampling design for monitoring Visitor Use is currently under development.

Chapter 5
Sampling Protocols

Sampling protocols for monitoring vital signs are study plans detailing how "data are to be collected, managed, analyzed, and reported, and are a key component of quality assurance for natural resource monitoring programs" (Oakley et al. 2003:1000). Protocols consist of three main sections: 1) narrative; 2) standard operating procedures; and 3) supplementary materials (Oakley et al. 2003). The protocol narrative describes why a particular vital sign and metric(s) were selected; specifies objectives and details of the proposed sampling design to meet those objectives; identifies field methods that will be used to gather data; explains how these data will be managed, analyzed, and reported; discusses personnel requirements and training procedures; and describes operational requirements such as scheduling, equipment, and budget. Standard operating procedures provide detailed instructions on how to accomplish every topic mentioned in the narrative. Supplementary information includes relevant sources of data such as sample databases and digital images (Oakley et al. 2003).

SWAN staff met with cooperators from SWAN parks, NPS Alaska Regional Office (NPS-ARO), and USGS-BRD during January 2005 to discuss an implementation schedule for sampling protocols for the next 5 yr. Three full protocols are scheduled for implementation and testing during the first year (2006): Glacier Extent, Landscape Processes, and Resident Lake Fish. Table 5-1 displays the 5-yr (2006–2010) schedule of development and testing of protocols monitored only by SWAN or monitored in partnership with SWAN parks or other agencies. See Section 8.4 in Chapter 8 of this report for further details on partnerships with other agencies.

A protocol development summary (PDS) briefly describes key elements of sampling protocols that will be implemented within 3–5 yr of initial draft release of the Phase III Report (see http://science.nature.nps.gov/im/monitor/ for the basic guidelines). A summary of the justification and measurable objectives for all PDSs is provided in Table 5-2; the PDSs are in Appendix III.

Table 5-1 *Schedule for developing and testing protocols for vital signs monitored only by SWAN or in partnership with SWAN parks or with other federal and state agencies.* Develop Draft *refers to the period during which input on the proposed protocol is solicited from park staff, agency partners, and other subject area experts,* Implement and Test *is the period when protocols are field tested, and* Peer Review & Finalize *is the time when protocols undergo formal peer review and are modified accordingly as a prelude to final acceptance.*

SWAN Project	Vital Sign and Protocol	Protocol Development Status				
		2006	2007	2008	2009	2010
Weather and Climate	Weather and Climate		*Develop Draft*	Implement & Test	**Peer Review & Finalize**	
Landscape Dynamics and Terrestrial Vegetation	Glacier Extent	Implement & Test	**Peer Review & Finalize**			
	Sensitive Vegetation Communities		*Develop Draft*	Implement & Test	**Peer Review & Finalize**	
	Vegetation Composition and Structure	*Develop Draft*	Implement & Test	**Peer Review & Finalize**		
	Land Cover/Land Use		*Develop Draft*	Implement & Test	**Peer Review & Finalize**	
	Landscape Processes	Implement & Test	**Peer Review & Finalize**			
Marine Nearshore	Geomorphic Coastal Change	*Develop Draft*	Implement & Test	**Peer Review & Finalize**		
	Marine Water Chemistry	*Develop Draft*	Implement & Test	**Peer Review & Finalize**		
	Kelp and Eelgrass	*Develop Draft*	Implement & Test	**Peer Review & Finalize**		
	Marine Intertidal Invertebrates	*Develop Draft*	Implement & Test	**Peer Review & Finalize**		
	Black Oystercatcher	*Develop Draft*	Implement & Test	**Peer Review & Finalize**		
	Seabirds	*Develop Draft*	Implement & Test	**Peer Review & Finalize**		
	River Otter (Coastal)	*Develop Draft*	Implement & Test	**Peer Review & Finalize**		
	Sea Otter	*Develop Draft*	Implement & Test	**Peer Review & Finalize**		
Lakes, Rivers, and Fish	Surface Hydrology		*Develop Draft*	Implement & Test	**Peer Review & Finalize**	
	Freshwater Chemistry	*Develop Draft*	Implement & Test	**Peer Review & Finalize**		

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Table 5-1 *(continued)*

SWAN Project	Vital Sign and Protocol	Protocol Development Status				
		2006	2007	2008	2009	2010
Lakes, Rivers, and Fish cont.	Resident Lake Fish	Implement & Test	**Peer Review & Finalize**			
	Salmon	*Develop Draft*	Implement & Test	**Peer Review & Finalize**		
Terrestrial Animals	Bald Eagle			*Develop Draft*	Implement & Test	**Peer Review & Finalize**
	Brown Bear		*Develop Draft*	Implement & Test	**Peer Review & Finalize**	
	Wolf			*Develop Draft*	Implement & Test	**Peer Review & Finalize**
	Wolverine			*Develop Draft*	Implement & Test	**Peer Review & Finalize**
	Moose			*Develop Draft*	Implement & Test	**Peer Review & Finalize**
Human Activities	Visitor Use		*Develop Draft*	Implement & Test	**Peer Review & Finalize**	

Table 5-2 *Justifications and measurable objectives for sampling protocols used to monitor vital signs within SWAN parks.*

SWAN Project	Vital Sign and Protocol	SWAN Park	Justification	Measurable Objective
Weather and Climate	Visibility and Particulate Matter	ANIA, LACL	Airborne pollutants and increased particulate loads have potential to affect climatic conditions and ecological processes.	-- Develop a protocol to acquire aerosol data and summary reports from the Interagency Monitoring of Protected Visual Environments (IMPROVE) sites in southwest Alaska.
	Weather and Climate	KATM, KEFJ, LACL	Climate is a basic driver of all ecological systems. Global climate models predict climate change and variability will be most severe at high latitudes, and there are many indications that environmental conditions are already changing in Alaska.	-- Record and archive hourly weather parameters, including temperature, precipitation, wind speed/direction, solar radiation, relative humidity, and snow depth at weather stations located in representative areas within SWAN parks. -- Produce monthly and annual summaries of climatic parameters and identify extremes of climatic conditions for common parameters (precipitation and air temperature), and other parameters for which sufficient data are available (e.g., wind speed and direction, solar radiation).
Landscape Dynamics and Terrestrial Vegetation	Glacier Extent	KATM, KEFJ, LACL	Glaciers are highly sensitive, natural, large-scale, representative indicators of the energy balance of both mountains and lowlands within SWAN, but they have been in widespread retreat and thinning in SWAN parks since the Little Ice Age (1900).	-- Document whether the surface area of glacier ice cover is growing or shrinking, the rate of any change, and where the greatest change is occurring.
	Volcanic and Earthquake Activity	All	Earthquake occurrence is common in the SWAN parks and region. The location and magnitude of seismic events could be significant in terms of human health and safety and landscape change (mass movement).	-- Record the occurrence and magnitude of seismic events (earthquakes) in the SWAN parks and region. -- Record the occurrence and magnitude of volcanic events (eruptions and/or ash deposition events) in the SWAN parks and region.
	Invasive/Exotic Species	All	The level of invasive exotic species infestation is currently very low in SWAN parks, but the combined effects of environmental warming and human activities in previously remote areas will likely increase the rate of exotics introduction and facilitate their establishment in park ecosystems.	-- Monitor number of nonnative, vascular plant species in or near SWAN parks. -- Monitor amount of acreage infested by nonnative vascular plant species in or near SWAN parks. -- Estimate long-term rate of change in acreage infested by nonnative vascular plant species in or near SWAN parks.

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Table 5-2 (continued)

SWAN Project	Vital Sign and Protocol	SWAN Park	Justification	Measurable Objective
Landscape Dynamics and Terrestrial Vegetation *(cont'd)*	Insect Outbreaks	All	Disturbance is an important force regulating landscape pattern and process in SWAN parks. High-latitude forests have experienced widespread mortality and/or loss of canopy cover due to insect and disease outbreaks in the past. Resultant changes in stand structure and composition have the potential to substantially affect primary productivity, fuel loads and fire regimes, wildlife habitat and foraging patterns, biogeochemical cycling, and water quality.	-- Detect the establishment of new native and nonnative insects and pathogens in SWAN parks, as identified by ADNR/USFS inventories. -- Use ADNR/USFS inventory data to monitor extent and rate of expansion of insect and disease outbreaks in SWAN parks over 1-, 5-, and 10-year intervals. -- Identify areas in SWAN that have experienced the greatest insect-related mortality (e.g., post-stratify by elevation class and/or landform).
	Sensitive Vegetation Communities	All	High-latitude plant communities are expected to be sensitive to increased climatic variation and physical disturbance, and hence they may serve as early indicators of environmental change on the landscape.	--Estimate long-term changes in species richness, cover and diversity in focal ecosystems in KATM, KEFJ, and LACL. --Where applicable, estimate long-term changes in the density of seedlings, saplings, and mature trees and/or shrubs at these sites.
	Vegetation Composition and Structure	All	Vegetation is integral to ecosystem function, energy transfer, and element cycling, and has the potential to both affect and respond to environmental drivers. Vegetation composition and structure are shaped by many factors, including climate, disturbance, and biotic interactions, and thus are excellent integrators of these forces on the landscape.	-- Map long-term, landscape-scale changes in the distribution and extent of major land cover classes in SWAN using satellite imagery and/or aerial photographs. -- Quantify long-term changes in the extent of land cover classes in SWAN. -- Quantify long-term changes in the distribution of land cover classes in SWAN. -- Estimate long-term changes in species richness, cover and diversity in focal ecosystems in KATM, KEFJ, and LACL. -- Where applicable, estimate long-term changes in the density of seedlings, saplings, and mature trees and/or shrubs at these sites.

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Table 5-2 (continued)

SWAN Project	Vital Sign and Protocol	SWAN Park	Justification	Measurable Objective
Landscape Dynamics and Terrestrial Vegetation *(cont'd)*	Land Cover/Land Use	All	Human-induced changes in biological diversity and modification of ecosystem processes are two of the more pronounced ecological trends of the last century. Model simulations and empirical data indicate that a combination of land use change and climatic variation could have profound impacts on subarctic vegetation, both through vegetation loss and changes in species composition.	-- Map long-term, landscape-scale changes in vegetation to identify areas where vegetation loss is occurring due to human activities in and adjacent to SWAN. -- Document changes in land-use patterns in and adjacent to SWAN parks.
	Landscape Processes	All	Climate and terrain, and the interactions between them, are the major landscape drivers in SWAN parks. Important landscape processes include freeze-up and break-up of large freshwater and marine water bodies, pattern and timing of snow cover, pattern and timing of surface sediment in large lakes, timing of vegetation green up and senescence, and relative biomass.	-- Track long-term trends in lake freeze-up and ice break-up dates in large lakes in SWAN parks. -- Estimate long-term trends in duration of snow cover in SWAN parks. -- Estimate long-term trends in spatial extent of August sediment plumes for Lake Clark, Naknek Lake, and Resurrection Bay offshore of Bear Glacier. -- Estimate long-term trends in the normalized difference vegetation index (NDVI) during growing seasons in SWAN parks.
Marine Nearshore	Geomorphic Coastal Change	KATM, KEFJ, LACL	Shoreline change is a prime geo-indicator of coastal environmental resource threats within parks. The physical configuration of the SWAN coastal shoreline is dynamic and constantly changing due to coastal erosion and accretion from natural events. Changes in the position of the shoreline affect the composition, relative abundance, and distribution of coastal habitats.	-- Document changes in the width of the dry beach, position of the mean water line, the high water line, and the base of the beach. -- Document how the position of top and toe of the bluffs is changing. -- Document how the position of foreshore and backshore vegetation is changing. -- Document how the sediment type and grain size is changing between the high water line and the base of the beach.

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Table 5-2 (continued)

SWAN Project	Vital Sign and Protocol	SWAN Park	Justification	Measurable Objective
Marine Nearshore *(cont'd)*	Marine Water Chemistry	KATM, KEFJ, LACL	Water chemistry is critical to intertidal fauna and flora and is likely to be an important determinant of both short- and long-term fluctuations in the intertidal biotic community.	-- Acquire regional synoptic nearshore oceanographic data collected by the Alaska Ocean Observing System and incorporate into regional (SWAN) data sets. -- Document daily, seasonal, and annual variability and gradients in temperature and salinity at randomly selected shallow water (< 20 m) nearshore sampling sites.
	Kelp and Eelgrass	KATM, KEFJ, LACL	Kelp and eelgrass are "living habitats" that serve as a nutrient filter and provide understory and ground cover for planktivorous fish, clams, and urchins, and a physical substrate for invertebrates, crustose corals, and algae. Kelp plants are the major primary producers in the marine nearshore.	-- Estimate long-term trends in abundance and distribution of kelp and seagrass along marine coastlines of KATM, KEFJ, and LACL.
	Marine Intertidal Invertebrates	KATM, KEFJ, LACL	Marine intertidal invertebrates provide a critical prey resource 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.	-- Monitor long-term trends in invertebrate species richness in randomly sampled sites along marine coastlines. -- Document how the size distribution of limpets and mussels is changing annually in randomly sampled sites along marine coastlines of KATM, KEFJ, and LACL. -- Estimate long-term trends in abundance of littleneck clams in randomly sampled sites along marine coastlines of KATM, KEFJ, and LACL. -- Document how the size distributions and growth rates of littleneck clams are changing annually in randomly sampled sites along marine coastlines of KATM, KEFJ, and LACL. -- Monitor status and trends in the concentration of metals, organochlorides, PCBs, and mercury in mussel tissues in randomly sampled sites along marine coastlines of KATM, KEFJ, and LACL.

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Table 5-2 (continued)

SWAN Project	Vital Sign and Protocol	SWAN Park	Justification	Measurable Objective
Marine Nearshore *(cont'd)*	Black Oystercatcher	KATM, KEFJ	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.	-- Estimate long-term trends in relative density of black oystercatchers along marine coastlines of KATM and KEFJ.
	Seabirds	KATM, KEFJ, LACL	Seabirds are predators near the top of marine nearshore food webs. Their abundance and population trends reflect the dynamics of the processes that maintain the integrity of the marine nearshore environment.	-- Estimate long-term trends in the seasonal abundance of seabirds along marine coastlines of KATM, KEFJ, and LACL.
	River Otter (Coastal)	KATM, KEFJ, LACL	Where river otter occur in coastal environments they are a keystone species for the land-margin ecosystem and a "sentinel species" for monitoring levels of environmental contamination.	-- Estimate long-term trends in river otter abundance along marine coastlines of KATM, KEFJ, and LACL.
	Sea Otter	KATM, KEFJ, LACL	Sea otters dramatically change the structure and complexity of their nearshore ecological community. The relationship between sea otters and kelp is a prime example of the top-down cascade type of food chain in which the highest trophic level can determine the populations of the lower trophic levels.	-- Estimate long-term trends in sea otter abundance in randomly sampled areas along marine coastlines of KATM, KEFJ, and LACL. -- Estimate and compare age-specific survival rates of sea otters among regions within the Gulf of Alaska.
	Harbor Seal	ANIA, KATM, KEFJ, LACL	Harbor seals perform a dynamic role in the marine nearshore environment by transferring nutrients and energy though their predatory activities and by influencing the physical complexity of their environment. Thus, they may serve as indicators of status and change of the marine nearshore environment.	-- Devise and implement a protocol for obtaining past, present, and future survey data of harbor seals for marine coastlines of ANIA, KATM, KEFJ, and LACL from the Polar Ecosystems Program at NMFS-NMML. -- Estimate long-term trends in abundance and occupancy of harbor seals at haul-outs sampled via aerial photosurvey along marine coastlines of ANIA, KATM, KEFJ, and LACL.

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Table 5-2 (continued)

SWAN Project	Vital Sign and Protocol	SWAN Park	Justification	Measurable Objective
Lakes, Rivers, and Fish	Surface Hydrology	All	Climate warming is decreasing glacial coverage in SWAN and increasing evaporation from water and land surfaces. These changes in surface hydrology also influence water chemistry and availability of aquatic habitats to fish and wildlife populations, affect the timing and amount of stream flows, and alter the areas in which boats and floatplanes can be used by park managers and visitors.	-- Monitor maximum and minimum annual daily flow, maximum and minimum annual 3-day or 7-day duration flow, and total annual water yield in selected SWAN river systems. -- Monitor annual trends in the timing and magnitude (average, maximum, minimum) of lake levels in selected SWAN flow systems.
	Freshwater Chemistry	All	Water quality, especially dissolved oxygen, pH, and temperature, is not only important for maintenance of biological life, but can control or alter biogeochemical cycling as well as the toxicity of some elements. Because water quality in SWAN parks is relatively pristine, focus will be on documenting natural variability within park systems, future changes from existing conditions, and changes due to far-field effects such as climate change.	-- Document annual and inter-annual variability in maximum, minimum, and average temperature, pH, dissolved oxygen, specific conductance, and turbidity in selected SWAN flow systems. -- Quantify midsummer lake profiles of temperature, specific conductance, pH, dissolved oxygen, and turbidity on an annual basis for high-priority lake systems, and less frequently for other SWAN lakes. -- Estimate nutrient and chlorophyll concentrations on an annual basis in high-priority lake systems, and less frequently for other SWAN lakes. -- Monitor dissolved major ion, trace elements and alkalinity on an annual basis for high-priority lake systems, and less frequently for other SWAN lakes.

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Table 5-2 (continued)

SWAN Project	Vital Sign and Protocol	SWAN Park	Justification	Measurable Objective
Lakes, Rivers, and Fish *(cont'd)*	Resident Lake Fish	All	Resident lake fishes occupy a variety of trophic levels and hence reflect changes that occur in the food chain. They also provide an indicator of environmental contaminants in aquatic systems.	-- Estimate occupancy of important recreational, subsistence, and other endemic species of resident fish every 3–5 years within high priority lakes and every 5–10 years within lower priority lakes in KATM and LACL. -- Estimate long-term trends in relative species richness of resident fish communities in high-priority lake systems within SWAN parks. -- Annually monitor influx of nonendemic fish species every 3–5 years within high priority lakes and every 5–10 years within lower priority lakes in KATM and LACL. -- Collect and archive tissue samples of resident fish for later biocontaminant analysis every 5 years from within high priority lakes and every 10–15 years within lower priority lakes in KATM and LACL.
	Salmon	All	Pacific salmon play a critical role in maintaining productivity of many freshwater and adjacent terrestrial systems, and provide a crucial food resource to brown bears, an excellent recreational opportunity to anglers, and an important subsistence and cultural resource to native Alaskans.	-- Devise and implement a protocol for obtaining past, present, and future data from ADF&G on spawner abundance and distribution, timing of spawning runs, and freshwater residence time of sockeye salmon from sampled systems in SWAN parks. -- Estimate long-term trends in spawner abundance, growth rates and distribution, timing of spawning runs, and freshwater residence time and body condition of sockeye salmon in SWAN parks.
Terrestrial Animals	Bald Eagle	All	Bald eagles are keystone predators on avian (e.g., seabirds) and fish (e.g., salmon) populations and hence serve an important ecological role in freshwater and marine coastal systems.	-- Estimate long-term trends in nest occupancy and productivity from a random sample of bald eagles nesting along interior rivers/lakes and marine coastlines of SWAN parks.

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Table 5-2 (continued)

SWAN Project	Vital Sign and Protocol	SWAN Park	Justification	Measurable Objective
Terrestrial Animals *(cont'd)*	Brown Bear	ALAG, ANIA, KATM, LACL	Brown bears are an integral part of SWAN parks and are specifically mentioned in the enabling legislation of ANIA, KATM, and LACL. They serve important ecological roles as top predators influencing population dynamics of other species and as means of nutrient transfer from spawning salmon to the terrestrial system.	-- Estimate long-term trends in abundance and area of occupancy of brown bears from a random sample of relevant elevations and terrains in ALAG, ANIA, KATM and LACL.
	Wolf	All	Wolves significantly influence population dynamics of their ungulate prey species and indirectly affect structure, composition, and parkwide patterns of vegetation communities through their influence on ungulate abundance and distribution.	-- Estimate long-term trends in abundance and distribution of wolves from randomly sampled areas in SWAN parks.
	Wolverine	All	Wolverines serve an important ecological role as scavengers and predators, are a significant economic resource to fur trappers, and are effective indicators of the cumulative effects of changes in human harvest and other activities, habitat, and prey populations.	-- Estimate long-term trends in abundance and distribution of wolverines from randomly sampled areas in SWAN parks.
	Moose	ALAG, ANIA, KATM, LACL	Moose have the potential to influence structure and function of terrestrial systems both through browsing effects on vegetational communities and their role as a prey species. They are an important subsistence and cultural resource to local native Alaskans and provide significant recreational opportunities for resident hunters.	-- Estimate long-term trends in abundance, sex composition (bulls:100 cows), age composition (calves:100 cows), and distribution of moose from a random sample of areas in ALAG, ANIA, KATM, and LACL.

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Table 5-2 (continued)

SWAN Project	Vital Sign and Protocol	SWAN Park	Justification	Measurable Objective
Terrestrial Animals *(cont'd)*	Caribou	ALAG, ANIA, KATM, LACL	Caribou have the potential to influence structure and function of terrestrial systems both through grazing effects on vegetational communities and their role as a prey species. Caribou also are an important subsistence and cultural resource to local native Alaskans and provide significant recreational opportunities for resident hunters.	-- Devise and implement a protocol for obtaining past, present, and future survey data of Northern Alaska Peninsula and/or Mulchatna caribou herds in ALAG, ANIA, KATM, and LACL from the multiagency team performing aerial photosurveys and radiotelemetry flights. -- Estimate long-term trends in abundance, calf:cow ratios, extent of occurrence, and area of occupancy of Northern Alaska Peninsula and/or Mulchatna caribou herds in ALAG, ANIA, KATM, and LACL.
Human Activities	Resource Harvest for Subsistence and Sport	ALAG, ANIA, KATM, LACL	The Alaska National Interest Lands Claim Settlement Act of 1980 established the legality of subsistence hunting, fishing, and gathering on 41,458,000 acres of new parklands, including lands within ALAG, ANIA, KATM, and LACL. Subsistence harvest regulations and bag limits are often more liberal than sport harvest and have the potential for depressing wildlife populations in local areas, such as around human population centers or access routes.	-- Track annual harvest of resident and anadromous fish species within ALAG, KATM and LACL. -- Track number and locations of brown bear, black bear, caribou, Dall sheep, and moose harvested annually within Game Management Units and Uniform Coding Units that include portions of ALAG, ANIA, KATM (Preserve), and LACL. -- Track annual harvest levels within and adjacent to ALAG, ANIA, KATM, and LACL for beaver, lynx, river otter, wolf, and wolverine.
	Visitor Use	All	Human presence can have unexpected and significant effects on ecosystems and ecosystem processes. Humans can serve as a vector for exotic species and, through habitat change, decreased competitive ability of resident species. Heavy use can fragment the landscape for sensitive wildlife, modify wildlife behavior through conditioning, and lead to overfishing or overharvest in focal areas.	-- Track annual numbers of recreational visitors in SWAN parks. -- Document timing of visits, activities, and destinations of visitors in SWAN parks. -- Monitor long-term trends in points of visitor origin and entry into SWAN parks.

Chapter 6
Data Management and Archiving

The Data Management Plan (DMP; Mortenson 2006) and Vital Signs Monitoring Plan, although separate documents, were prepared simultaneously and are conceptually linked. This chapter presents an overview of the DMP and outlines the steps that SWAN will follow in managing and disseminating data that are acquired from long-term ecological monitoring. Information is the common currency among the activities and staff involved in the stewardship of natural resources for the NPS. This chapter summarizes the SWAN data management strategy, which is more fully presented in the SWAN DMP. The DMP is a guide for current and future project leaders and Network staff to ensure the continuity and documentation of data management methods and procedures over time. The DMP, in turn, refers to other guidance documents and standard operating procedures that convey the specific standards and steps for achieving the data management goals.

The DMP focuses on the processes used to:

1. Acquire, store, manage, and archive data
2. Ensure data quality
3. Document, analyze, summarize, and disseminate data
4. Ensure the long-term access to and utility of data.

6.1 Data Management Goals

The goal of the NPS Inventory & Monitoring (I&M) Program is to provide scientifically and statistically sound data to support management decisions for the protection of park resources. The goal of data management is to ensure the quality, interpretability, security, longevity, and availability of our natural resource data. The goal of the DMP is to outline the procedures and work practices that support effective data management.

The DMP objectives are to ensure that:

- **Data managed by the Network are of high quality**, including designing standardized data entry, importation, and handling procedures that effectively screen for inappropriate data and minimize transcription and translation errors;
- **Network data can be easily interpreted**, by considering the users' needs as the primary factor driving the design of summary reports and analyses; establishing rigorous data documentation standards; integrating common data tables and fields in NPS or regional standards; and making summary information available in formats tailored to the variety of audiences interested in I&M program results;
- **Data are secure for the long term**, including instituting standard procedures for versioning, data storage, and archiving; and natural history archiving, curation, and records management are provided to NPS curators;
- **Network data are readily available**, by implementing standard procedures for distributing data, while protecting sensitive data and by designing a standardized filing system for organizing I&M information.

6.2 Type of Information Managed by SWAN

The term "data" is frequently used in a way that also encompasses other products generated alongside the tabular and spatial data that are the primary targets of our data management efforts. These products fall into general categories listed in Table 6-1.

Table 6-1 *General categories of data products.*

Category	Description	Examples
1) Data		
•***Raw Data***	Data obtained from the environment and that has not been subjected to any quality assurance or control beyond those applied during field work.	• field data sheets • specimens • remotely sensed data • data gathered electronically on field computers • GPS rover files • photographic imagery
•***Validated and Verified Data***	Data that have been verified according to the standard operating procedure under which the data were gathered (typically the protocol for a given monitoring component) and are deemed ready for reporting and/or analysis.	• Relational databases • Tabular data files • Laboratory results • GIS layers • Maps • Processed or analyzed remote sensing data
•***Analyzed Data***	Data that have been subjected to analytical routines after field collection and verification. This includes statistical operations conducted on the data for the purposes of arriving at a measure of the given ecological parameter or a compilation of analyzed data from different sources or time periods to derive new information.	• Summarized reports, data and maps from statistical or query operations • GIS/maps derived or repeated from remote sensing data. • Multimedia products, such as videos or slideshows
2) Documentation	Documentation provides the information required to understand the context of the data.	• Data collection protocols • Data processing/analysis protocols • Record of protocol changes • Data dictionary • FGDC metadata • Database design documents • QA/QC reports • Catalogs
3) Reports	Reports provide a means of presenting and publishing the methods and the results of analysis in the context of which it was intended.	• Annual progress reports • Final reports • Trend analysis reports • Publications • Final data posted on websites
4) Administrative Records	Administrative records supplement the context of a project and should be considered part of the projects deliverables.	• Contracts and agreements • Study and work plans • Research permit • Critical administrative correspondence

6.3 Priorities of Natural Resource Data

The priorities for Network data management efforts are:

- Produce and curate high-quality, well-documented data originating with the I&M Program
- Assist with data management for current projects, legacy data, and data originating outside the I&M Program that complement program objectives
- Help ensure good data management practices for park-based natural resource projects that are just beginning to be developed and implemented.

6.4 Data Stewardship Roles and Responsibilities

Every individual involved in the I&M Program is required to understand and perform data stewardship responsibilities in the production, analysis, management, and end use of the data as described in the DMP and the specific monitoring protocols. Specific roles and responsibilities for vital signs monitoring are written in each monitoring protocol. Senior staff (described in Chapter 8) share the responsibility in ensuring that data management procedures are followed (see Figure 6-1).

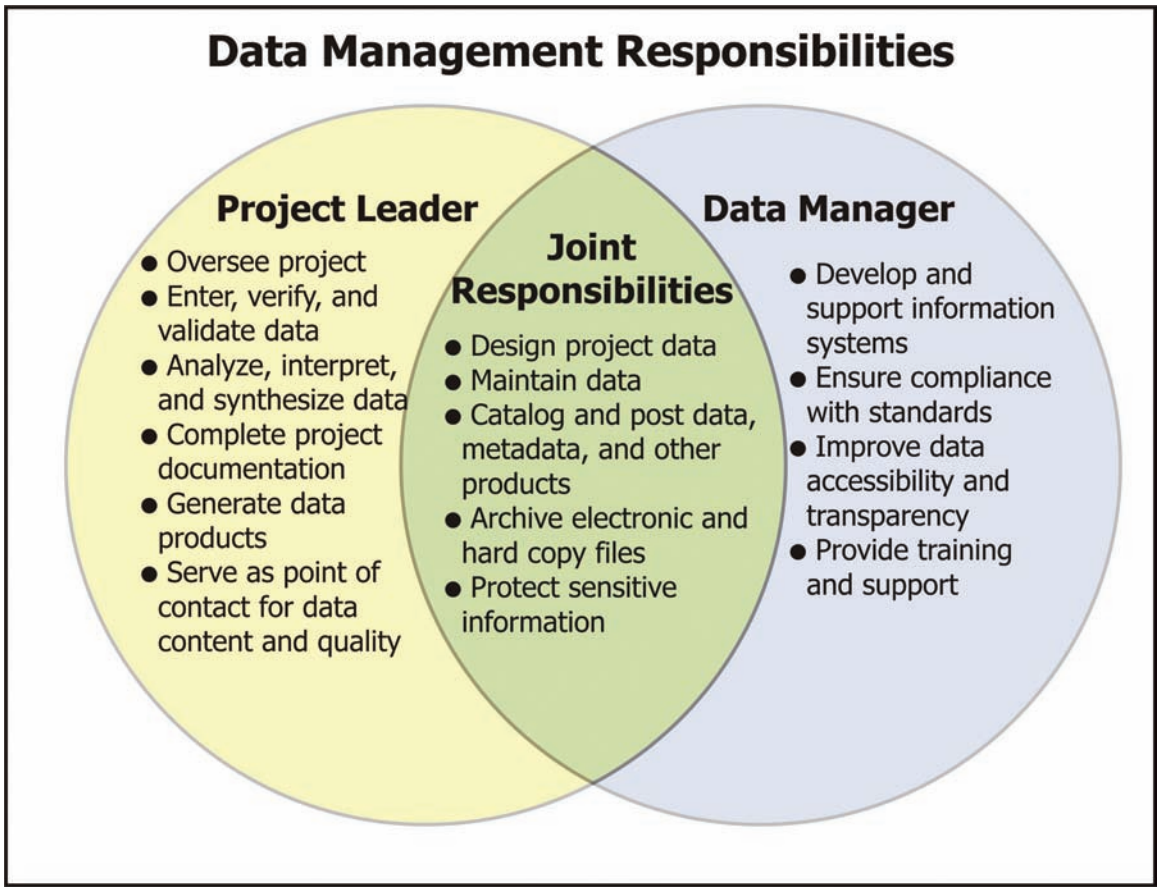

Figure 6-1 *Core project data stewardship duties of project leaders and data managers.*

6.5 Information Work Flow

Understanding the life cycle of data throughout a project will help to manage the staffing resources necessary to complete and support quality data. For data management to be effective, it must occur throughout the project life cycle.

A project is divided here into the following stages (see Figure 6-2):

1. Project initiation
2. Planning and approval
3. Design and testing
4. Implementation
5. Product delivery
6. Product integration
7. Closure and evaluation

SWAN uses a project tracking database to document and support the progress of information collected for vital signs monitoring. Most notably, this database tracks the status, changes, archiving and distribution of deliverables.

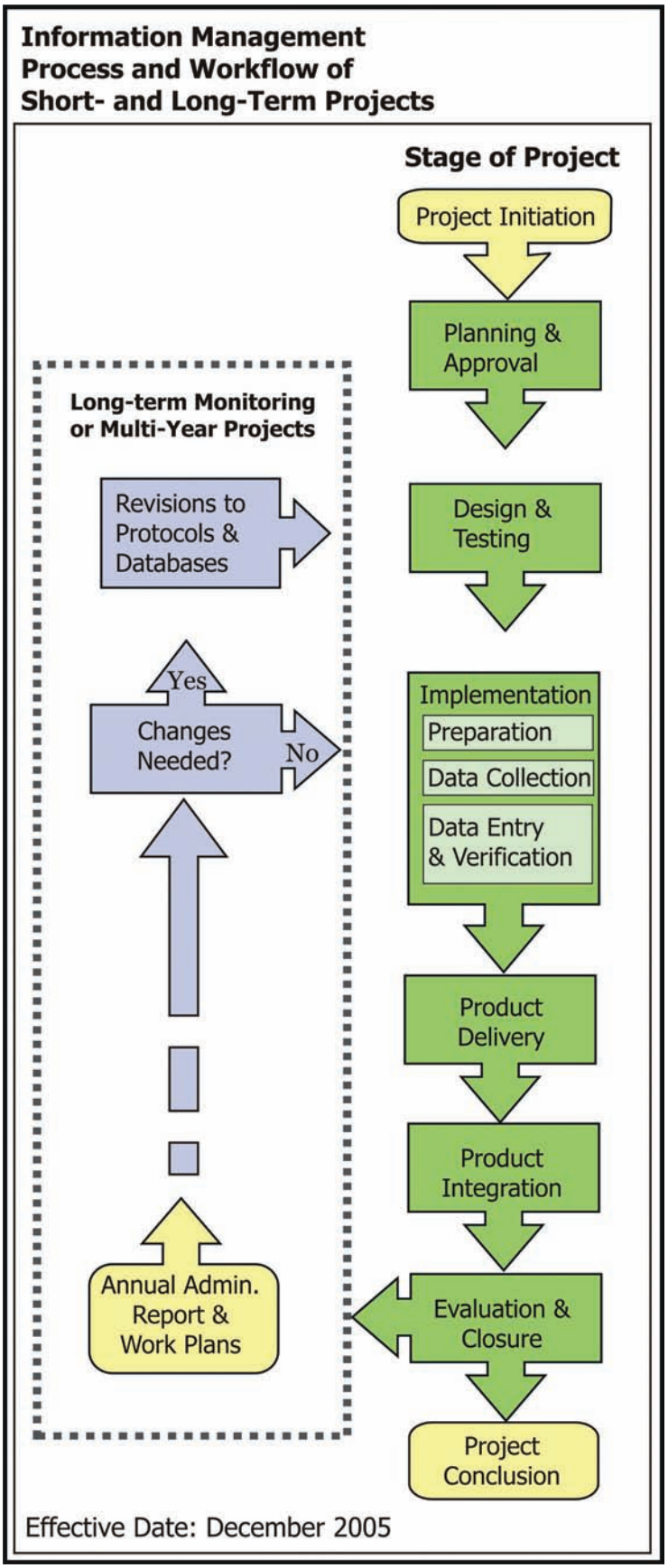

Figure 6-2 *Workflow overview.*

6.6 Information Technology (IT) Infrastructure for Data Management

Infrastructure refers to the network of computers and servers that our information systems are built upon. SWAN relies heavily on the national, regional, and park IT personnel and resources to maintain its computer infrastructure. This includes, but is not limited to: computers, servers, and other related hardware; software installation and support; e-mail administration; security updates; virus protection; telecommunications; computer networking; and backups of servers.

The infrastructure needs to support these required functions:

- Provide a central repository for master data sets
- Provide controlled subsets of data for local computing
- Provide a means for uploading and downloading data for both the NPS and the public
- Support desktop and internet applications
- Provide security, stability, and backups.

SWAN will also utilize infrastructure and information systems from partners who share monitoring objectives or provide source information. Anticipated partners are listed in Chapter 8 (Section 8.4).

6.7 Database Design Strategies

The project leader and the data manager will work together to develop conceptual data models to:

- Understand conceptually the data life cycle flow of the data collection process, e.g., where is the starting point of the data collection (for example, a visit to a site) and what happens next.
- Determine the data relationships as the implementation progresses, e.g., one site visited many times with many collections.
- Determine how the information will be presented.

Understanding the relationships between the data components collected is key to the success of a database and its utility. If the relationships are misunderstood, the database may become tedious in data entry and cumbersome at data output.

The SWAN DMP specifies the standards by which data will be handled. Data management elements or principles common to more than one vital sign will be managed in a conventional manner to allow for greater comparison of data across the Network, as well as to ensure further general data integrity.

6.8 Acquiring and Processing Data

The types of data handled by the I&M Program fall into three general categories:

- Program data—produced by projects that are either initiated (funded) by the I&M Program or involve the I&M Program in another manner (e.g., natural resource inventories and vital signs monitoring projects)
- Nonprogram legacy/existing data—produced by NPS entities without the involvement of the I&M Program (e.g., park or regional projects)
- Nonprogram external data—produced by agencies or institutions other than the NPS (e.g., weather and water quality data).

Most data acquired by the Network will be collected as field data (inventories and monitoring studies) or discovered through data mining initiatives (legacy/existing data). Methods of field data collection, such as paper filed data forms, field computers, automated data loggers, and GPS units will be specified in individual monitoring protocols and study plans. Field crew members will closely follow the established standard operating procedures (SOPs) in the project protocol. Data acquired by non-program sources, such as data downloaded from other agencies, will also be specified in individual monitoring protocols.

6.9 Ensuring Data Quality

The effort to detect trends and patterns in ecosystem processes requires data of documented quality that minimize error and bias. High quality data and information are vital to the credibility and success of the I&M Program, and everyone plays a part in ensuring that products conform to data quality standards.

Although many quality assurance/quality control (QA/QC) procedures depend upon the individual vital signs being monitored, some general concepts apply to all. Specific procedures to ensure data quality must be included in the protocols for each vital sign. Examples of QA/QC practices include:

- Field crew training
- Standardized field data sheets with descriptive data dictionaries
- Use of handheld computers and data loggers
- Equipment maintenance and calibration
- Procedures for handling data in the field
- Database features to minimize transcription errors, including imports from data loggers, range limit, pick lists, etc.
- Verification and validation, including automated error-checking database routines

QA methods should be in place at the inception of any project and continue through all project stages to final archiving of the data set. It is critical that each member of the team work to ensure data quality.

The final step in project QA is the preparation of summary documentation that assesses the overall data quality. A statement of data quality will be composed by the project leader and incorporated into formal metadata. Metadata for each data set will also provide information on the specific QA procedures applied and the results of the review.

6.10 Data Documentation

Documenting data sets, data sources, and methodology by which the data were acquired establishes the basis for interpreting and appropriately using data. At a minimum, all data managed by the Network will require the following elements of documentation:

- Project documentation
- Formal metadata compliant with Federal Geographic Data Committee (FGDC) standards
- Data dictionaries and entity relationship diagrams for all tabular databases.

Data documentation will be available and searchable in conjunction with related data and reports via the SWAN Web site as well as with the NPS Natural Resource and GIS Programs metadata and data store (NR-GIS Metadata and Data Store).

6.11 Summarizing and Analyzing Data

Providing meaningful results from data summary and analysis is a cornerstone of the I&M Program and characterizes the Network's data management mission to provide useful information for managers and scientists. Each monitoring protocol establishes requirements for on-demand and scheduled data analysis and reporting. Based on these requirements, the associated databases for the protocols include functions to summarize and report directly from the database as well as output formats for import to other analysis software programs. In addition to tabular and charted summaries, the Network provides maps of natural resource data and geographic information system (GIS) analysis products to communicate spatial locations, relationships, and geospatial model results. See Chapter 7 for a more detailed description of the Network's analysis and reporting schedule and procedures.

6.12 Data Dissemination

The SWAN data dissemination strategy aims to ensure that:

- Data are easily discoverable and obtainable.
- Only data subjected to complete QC are released, unless necessary in response to a Freedom of Information Act (FOIA) request.
- Distributed data are accompanied by appropriate documentation.
- Sensitive data are identified and protected from unauthorized access and inappropriate use.

Access to SWAN data products will be facilitated via a variety of means that allow users to browse, search, and acquire Network data and supporting documents. These means include, but are not limited to:

- SWAN public Web site, under "Information Discovery" (http://www.nature.nps.gov/im/units/swan/)
- NR-GIS Metadata and Data Store. Distribution instructions for each data set will be provided in the respective metadata. The NR-GIS Metadata and Data Store is available at http://science.nature.nps.gov/nrdata/, and is also accessible by the National Spatial Data Infrastructure, Geospatial One Stop Web site (http://gos2.geodata.gov).
- Alaska Geographic Data Committee Web site
- Service-wide databases, such as NPSTORET, NPSpecies, and NatureBIB
- Regional, Network, or park data servers protected with read-only access
- External repositories such as the Alaska Resource Library and Information Service, U.S. Geological Survey, University of Alaska, Alaska Department of Fish and Game, Western Regional Climatic Center, Exxon Valdez Oil Spill Trustee Council, and many others
- FTP sites, CDs, or DVDs, as appropriate.

6.13 Ownership, FOIA, and Sensitive Data

SWAN products are considered property of the NPS. However, FOIA establishes access by any person to federal agency records that are not protected from disclosure by exemption or by special law enforcement record exclusions. The NPS is directed to protect information about the nature and location of sensitive park resources under one Executive Order and four resource confidentiality laws:

- Executive Order No. 13007: Indian Sacred Sites
- National Parks Omnibus Management Act (NPOMA; 16 U.S.C. 5937)
- National Historic Preservation Act (16 U.S.C. 470w-3)
- Federal Cave Resources Protection Act (16 U.S.C. 4304)
- Archaeological Resources Protection Act (16 U.S.C. 470hh)

When any of these regulations are applicable, public access to data can be restricted. If disclosure could result in harm to natural resources, the records may be classified as "protected" or "sensitive" and information may be withheld regarding the following resources recognized as sensitive by the NPS:

- Endangered, threatened, rare, or commercially valuable National Park System resources
- Mineral or paleontological sites
- Objects of cultural patrimony
- Significant caves

The Network will comply with all FOIA restrictions regarding the release of data and information, as instructed in NPS Director's Order 66 and accompanying Reference Manuals 66A and 66B (currently in development). Managing natural resource information that is sensitive or protected requires the following steps:

- Identification of potentially sensitive resources
- Compilation of all records relating to those resources
- Determination of which data must not be released in a public forum
- Management and archiving of those records to avoid their unintentional release

Classification of sensitive data will be the responsibility of Network staff, park superintendents, and project leaders. Network staff will classify sensitive data on a case-by-case, project-by-project basis and will work closely with project leaders to ensure that potentially sensitive park resources are identified, that information about these resources is tracked throughout the project, and that potentially sensitive information is removed from documents and products that will be released outside the Network.

6.14 Data Maintenance, Storage, and Archiving

SWAN data maintenance, storage, and archiving procedures aim to ensure that data and related documents (digital and analog) are:

- Kept up to date with regards to content and format such that the data are easily accessed and their heritage and quality are easily learned.
- Physically secure against environmental hazards, catastrophe, and human malice.

Primary data maintenance will be performed on the central Alaska Regional Office server or Network server and will follow the regional office's backup procedures. Data and information content of SWAN files stored on this server will be kept current. Accompanying documentation files will reflect any updates. These information files will be properly cataloged and maintained on the SWAN Web site. Latest versions of primary data will be available in conventional formats reflecting common data usages in the resource management community.

Project data will be electronically archived as stand-alone products and will include:

- Project documentation
- Data in raw, verified, and analyzed conditions
- Respective metadata
- Supporting files, such as photographs, maps, etc.
- All associated reports

Final deliverables from project data will be integrated with ongoing libraries and databases.

6.15 Natural History Archiving, Curation, and Records Management

In most instances, administrative documents, natural history specimens, photographs, audio tapes and other materials are essential companions to the digital data. Direction for managing many of these materials (as well as digital materials) is provided in NPS Director's Order 19: Records Management (2001) and its appendix, NPS Records Disposition Schedule (NPS-19 Appendix B, revised 5-2003). NPS-19 states that all records of natural and cultural resources and their management are considered mission-critical records, that is, necessary for fulfillment of the NPS mission, and must be permanently archived.

The SWAN DMP includes a project checklist to guide project leaders in complying with archival directives. Physical items considered project products, such as reports, maps, photographs, or notebooks, will be cataloged and filed in the Network's central office and accessioned through the NPS Rediscovery curatorial database. A copy of the accessioned material will be archived according to NPS Standards and follow the procedures outlined in the SWAN DMP. Physical specimens, such as plants, animals, or tree core samples, will be accessioned and housed at the appropriate and accepted archival institution.

6.16 Water Quality Data

Water quality data are managed according to guidelines from the NPS Water Resources Division. This includes using the NPSTORET desktop database application to help manage data entry, documentation, and transfer. The Network oversees the use of NPSTORET according to the Network's integrated and regulatory water quality monitoring protocols and ensures that the content is transferred at least annually to the NPS Water Resources Division for upload to the STORET database.

Chapter 7
Data Analysis and Reporting

This chapter explains how data discussed in the previous three chapters will be analyzed and the results reported to park staff, resource managers, and policymakers. We have divided data analysis into three components: (i) descriptive analysis; (ii) trend analysis; and (iii) linking analyses to decisionmaking. Reporting describes the mode and frequency of delivery for providing this information to the relevant audience.

7.1 Data Analysis

The method of data analysis is intimately linked to spatial and temporal aspects of the sampling design that produced the data. Spatial inferences are clearly dictated by the sampling unit size and mode of selection, but additional decisions are required during the analytic stage regarding minimum resolution of inference. Combining sampled units into a single, parkwide (average) estimate of trend may obscure area-specific trends within a park. For instance, there may be a strong positive trend in a vital sign metric in the northern half of a park, but a strong negative trend in the southern half, which may essentially cancel one another when combined into a single estimate. A more effective approach may be to estimate trends within sampling units or ecologically relevant collections of sampling units and summarize these results as percent of those with positive, negative, stable, or unknown trends (e.g., see Rieman et al. 2001). Proper specification of temporal units also is important in data analysis because procedures for modeling trend have minimum sample size (number of temporal observations) requirements for their use. Analyses will be limited to descriptive approaches until a requisite number of observations are available to reliably estimate trend.

7.1.1 Descriptive Analysis

Various descriptive statistics (e.g., means and standard deviations) and graphs will be generated frequently to provide information on status of a given vital sign. The frequency of analysis will depend on the vital sign and metric (Table 7-1). Graphical methods may include, but are not limited to, bar charts, scatter plots, and maps for viewing data on spatial distributions.

7.1.2 Trend Analysis

Observations recorded from the same area or individual over time are called repeated measures data. Within a population monitoring context, these data often have two components of total variance: 1) process variance, which includes spatial and temporal variances; and 2) sampling variance, which arises from measuring only a portion of the population or quantity of interest (Thompson et al. 1998). A key to increasing the ability to detect a trend of a specified size is to remove the sampling variance from the total variance so that only the temporal variance remains. Moreover, because repeated measures data are not independent, the correlation or covariance structure of the observations must be properly modeled to avoid bias. Consequently, we will use empirical Bayes models (also known as random effects or hierarchical linear/nonlinear models; Ver Hoef 1996, Clark 2005) to estimate trends. These models allow specification of different covariance structures, removal of the estimated sampling variance component, and incorporation of additional variables thought to influence trends in the response variable (e.g., abundance). When appropriate, we will build a candidate set of trend models that includes variables thought to most influence a given vital sign metric, use information-theoretic approaches to choose the best-fitting covariance structure and model, and, if necessary, model average over the candidate models (see Burnham and Anderson 2002). Ver Hoef (1996) and Ver Hoef and Frost (2003) used empirical Bayes models to estimate trends in abundance of harbor seals (*Phoca vitulina*), whereas Link et al. (2002) employed Markov Chain Monte Carlo methods with empirical Bayes models to fit bird population data.

Table 7-1 Summary of analytical techniques and responsibilities for analyzing data collected for SWAN vital signs. Lead contacts (program managers) work in collaboration with the SWAN biometrician on data analysis and interpretation. Trend analyses will be based on empirical Bayes models.

SWAN Project	Vital Sign and Protocol	Analysis	SWAN Lead Contact
Weather and Climate	Visibility and Particulate Matter	Annually summarize atmospheric/particulate data received from IMPROVE sites. Estimate trends in existing atmospheric/particulate data and every 5 years thereafter.	Physical Scientist
	Weather and Climate	Annually summarize data from weather stations. Estimate trends after 5 years of weather data are collected and every 5 years thereafter.	Physical Scientist
Landscape Dynamics and Terrestrial Vegetation	Glacier Extent	Document decadal change in glacier extent from satellite imagery.	Physical Scientist
	Volcanic and Earthquake Activity	Document important episodes of activity as they occur.	Physical Scientist
	Invasive/Exotic Species	Annually document and map occurrences of invasive species.	Botanist
	Insect Outbreaks	Annually document and map occurrences of new native and nonnative insect outbreaks. Estimate rates of expansion over 1-, 5-, and 10-year intervals.	Botanist
	Sensitive Vegetation Communities	Prepare summary statistics on species richness, species diversity, relative cover, and density of trees/shrubs every 3–5 years for first 10 years, and every 7–10 years thereafter.	Botanist
	Vegetation Composition and Structure	Prepare summary statistics on landscape-level vegetation change using satellite images taken at 5–10 year intervals. Summarize data on species richness, species diversity, relative cover, and density of trees/shrubs every 3–5 years for the first 10 years, and every 7–10 years thereafter.	Botanist
	Land Cover/Land Use	Map land cover change using satellite imagery every 5–10 years. Prepare summary statistics of changes in cover.	Botanist & Landscape Ecologist

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Table 7-1 (continued)

SWAN Project	Vital Sign and Protocol	Analysis	SWAN Lead Contact
Landscape Dynamics and Terrestrial Vegetation *(cont'd)*	Landscape Processes	Annually document dates of onset, dates of break-up, duration, and extent of ice cover on lakes; timing, extent, and location of snow cover; timing and extent of sediment plumes in large lakes and rivers; and onset, duration, and relative biomass of vegetation productivity. Estimate trends in these data every 10 years.	Landscape Ecologist
Marine Nearshore	Geomorphic Coastal Change	Summarize coastal shoreline change decadally. Estimate trends in shoreline position and substrate type every 10–12 years.	Coastal Ecologist
	Marine Water Chemistry	Summarize water chemistry data as available. Estimate trends every 5 years.	Coastal Ecologist
	Kelp and Eelgrass	Annually summarize data on abundance, distribution, and composition. Estimate trends after 10 years of data and every 5 years thereafter.	Coastal Ecologist
	Marine Intertidal Invertebrates	Annually summarize data on species richness, size distribution of limpets, abundances of littleneck clams, and contaminant levels in mussels. Estimate trends after 10 years of data and every 5 years thereafter.	Coastal Ecologist
	Black Oystercatcher	Annually summarize relative density of nests. Estimate trends after 10 years of data and every 5 years thereafter.	Coastal Ecologist
	Seabirds	Annually summarize abundance. Estimate trends after 10 years of data and every 5 years thereafter.	Coastal Ecologist
	River Otter (Coastal)	Annually summarize abundance and distribution data. Estimate trends after 10 years of data and every 5 years thereafter.	Coastal Ecologist
	Sea Otter	Annually summarize abundance and age-specific survival. Estimate trends after 10 years of data and every 5 years thereafter.	Coastal Ecologist

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Table 7-1 (continued)

SWAN Project	Vital Sign and Protocol	Analysis	SWAN Lead Contact
Marine Nearshore *(cont'd)*	Harbor Seal	Summarize abundance and distribution of haul-outs every 5 years. Estimate trends of existing data and every 5 years thereafter.	Coastal Ecologist
Lakes, Rivers, and Fish	Surface Hydrology	Annually summarize data on magnitude and timing of peak river discharge and lake-level change. Estimates trends every 5 years.	Aquatic Ecologist
	Freshwater Chemistry	Summarize water chemistry data as available. Estimate trends every 5 years.	Aquatic Ecologist
	Resident Lake Fish	Summarize data on species richness, species occurrence, and biocontaminant levels every 3–5 years. Estimate trends after 10 years and every 5 years thereafter.	Aquatic Ecologist
	Salmon	Annually summarize data on spawner abundance, distribution, timing of spawning, and freshwater residence times. Estimate trends from existing data and every 5 years thereafter.	Aquatic Ecologist
Terrestrial Animals	Bald Eagle	Summarize data on nest occupancy and distribution every 1-5 years. Estimate trends every 5 years.	Wildlife Biologist/ Biometrician
	Brown Bear	Summarize data on abundance and distribution every 5-10 years. Estimate trends after 20 years of data and every 10 years thereafter.	Wildlife Biologist/ Biometrician
	Wolf	Summarize data on abundance and distribution every 3–5 years. Estimate trends after 10 years of data and every 10 years thereafter.	Wildlife Biologist/ Biometrician
	Wolverine	Summarize data on abundance and distribution every 3–5 years. Estimate trends after 10 years of data and every 10 years thereafter.	Wildlife Biologist/ Biometrician

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Table 7-1 (continued)

SWAN Project	Vital Sign and Protocol	Analysis	SWAN Lead Contact
Terrestrial Animals *(cont'd)*	Moose	Summarize data on abundance, distribution, and sex-age composition every 3–5 years. Estimate trends after 10 years of data and every 10 years thereafter.	Wildlife Biologist/ Biometrician
	Caribou	Annually summarize data on abundance, distribution, and productivity. Estimate trends from existing data and every 5 years thereafter.	Wildlife Biologist/ Biometrician
Human Activities	Resource Harvest for Subsistence and Sport	Annually summarize harvest and subsistence data. Estimate trends from existing data and every 3–5 years thereafter.	Wildlife Biologist/ Biometrician
	Visitor Use	Annually summarize data on visitor use. Estimate trends from existing data and every 3–5 years thereafter.	Wildlife Biologist/ Biometrician

Due to the inherent variability of ecological and environmental systems, obtaining a precise estimator of trend often requires many observations. Based on a linear regression model, Urquhart et al. (1998) recommended a minimum of 10–15 sample years to detect even a moderate trend in U.S. Environmental Protection Agency water quality data. Therefore, even if trend analyses are conducted at frequent intervals, the ability to detect a trend will be low early in the process of data collection.

7.1.3 Linking Analyses to Decisionmaking

Lee and Bradshaw (1998) contended that the primary role of monitoring is to inform decisionmaking. They suggested that monitoring functioned best when it: (i) provided accurate estimates of trend of the environmental attribute(s) or natural resource(s) of interest; (ii) ensured that management decisions are implemented correctly; and (iii) provided insight into natural systems. They recommended use of Bayesian belief networks (BBNs) to link these goals within a single probabilistic framework. A BBN is a graphical model using geometric shapes (variables) and arrows (direction of causal influence) to depict the causal relationship among variables and to an outcome (e.g., population trend; Marcot et al. 2001). This model can use both empirical data and expert judgment in a probabilistic manner (see Appendix IV for further details; see also Marcot et al. 2001, Rieman et al. 2001). BBNs offer a transparent and quantitative framework to link monitoring data to decisions regarding the current "state of the park" for different vital signs.

Figure 7-1 shows an example BBN plus decision node for population trend of sockeye salmon (*Oncorhynchus nerka*) escapement in the Lake Clark watershed (see Table 7-2 for details). An important step is to build a population dynamics model to simulate adult recruitment. Simulation model outputs and existing data can help parameterize the network. The parametrized network then can be used to identify the most likely trend category (increasing, stable, or decreasing), with associated level of uncertainty, as well as to evaluate different harvest strategies. The network can be easily updated over time as more trend data are collected.

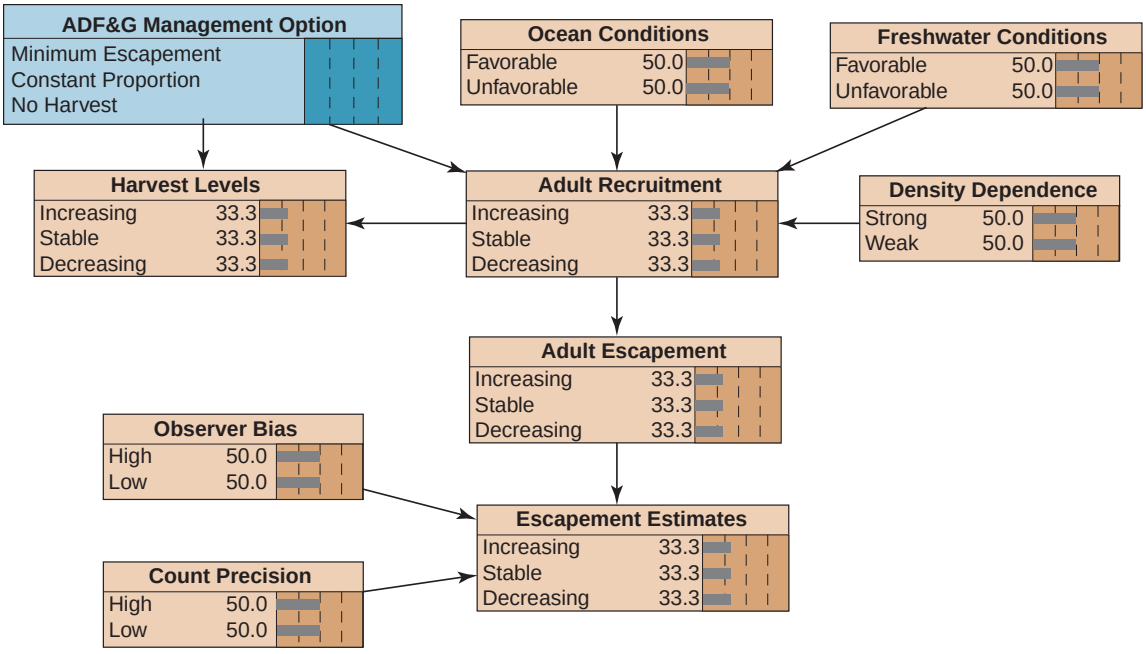

Figure 7-1 *An example belief network plus decision node (ADF&G Management Option) to illustrate information used to estimate the most likely trend (with measure of uncertainty) in sockeye salmon escapement in the Lake Clark watershed (example network provided by D. C. Lee).*

7.2 Reporting

As described in Section 1.2, the broad-based, scientifically sound information obtained through vital signs monitoring has multiple applications for management decisionmaking, research, education, and promoting public understanding of park resources. How information is communicated, archived, and made available largely determines a monitoring program's efficacy, reputation for reliability, and image among critics, peers, and advocates (Davis 2005).

> *"State of the art science," no matter how much it is admired by academics, should often be dispensed with in favor of science that can be understood and believed by the people who will use it.*
> *(N. Thompson Hobbs)*

The primary audience for the results of vital signs monitoring is park management: superintendents, park resource chiefs, and other managers who require natural resource data to make and defend management decisions. However, other key audiences for monitoring results include park planners, interpreters, researchers and other scientific collaborators, the general public, and Congress and the Office of Management and Budget. To be most effective, monitoring data must be analyzed, interpreted, and provided at regular intervals to each of these audiences in a format they can use, which means that the same information needs to be packaged and distributed in several different formats. Monitoring reports will undergo peer review by locally involved specialists (other SWAN scientists), and external peer review by scientists from other federal, state, or private agencies.

The content and amount of detail included in the various products of the monitoring program will differ depending on the intended audience for each report (Figure 7-2). At the Network level, park managers and natural resource staff and collaborators need to have available the detailed, complex scientific data relevant to the park's issues and resources. At the national level, however, a different scale of analysis and reporting is needed to be most effective. To report on the status and trends in the condition of natural resources in the National Park System, the NPS is developing a Natural Resource Scorecard that will involve the integration and evaluation by experts of detailed scientific data for each park and resource category. For effective communication, the overall assessment of resource status and trends (the "highly aggregated indices" zone at the top of the information pyramid shown in Figure 7-2) will be presented

Table 7-2 *Description of nodes within the example belief network (D. C. Lee, personal communication) portrayed in Figure 7-1.*

Node Label	Node Description
Harvest Policy	Decision node. ADF&G has regulatory authority over commercial fishing harvest of sockeye salmon in Bristol Bay and currently follows a minimum escapement harvest policy. Belief network can evaluate relative impacts of different harvest policies on sockeye salmon escapement.
Harvest Levels	Commercial fishing harvest of returning adult sockeye salmon could potentially have an adverse impact on run sizes during years of low runs. ADF&G maintains annual commercial catch statistics of returning adult sockeye salmon in Bristol Bay.
Ocean Conditions	Survival of sockeye salmon during ocean residence as related to the Pacific Decadal Oscillation (Mantua et al. 1997) and other factors. Use range of estimates from other studies (e.g., Beamish et al. 2004).
Freshwater Conditions	Effect of spawning/rearing freshwater conditions on egg-to-smolt survival, pre-spawning survival, and spawning success. Use data collected for Lake Clark from SWAN I&M program's proposed water quality monitoring protocol.
Density Dependence	Level of constraint imposed on population numbers by habitat capacity, i.e., increased escapement leads to fewer recruits and vice versa.
Adult Recruitment	Trend in number of adults surviving to adulthood prior to spawning.
Adult Escapement	Actual trend in number of adult sockeye salmon returning to spawn that avoid capture by commercial, recreational, and subsistence fishing.
Escapement Estimates	Estimated trend in number of adult sockeye salmon returning to spawn that avoid capture by commercial, recreational, and subsistence fishing. Trend estimated from tower counts along the Newhalen River.
Observer Bias	Systematic error in tower counts of adult salmon returning to spawn on the Newhalen River. Key variables influencing counting conditions (e.g., cloud cover, wind velocity, turbidity) are recorded daily for tower counts on the Newhalen River. Also, use published estimates of bias for similar species in other studies (e.g., O'Connell 2003).
Count Precision	Degree of spread in repeated tower counts of adult salmon returning to spawn on the Newhalen River.

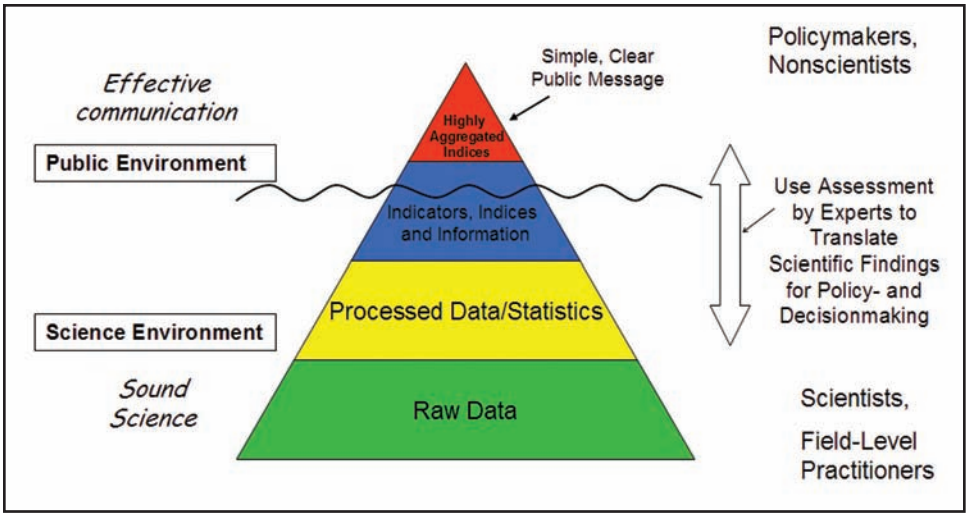

Figure 7-2 *The information pyramid. The amount of detail and scale of analysis of scientific data will differ depending on the intended audience for the various reports and presentations. National-level reporting to the American public and to Congress will involve assessments by experts using simple graphical messages, but the results will be supported by often complex data that are available at the park and Network level. (Taken from presentation by S. Fancy, NPS, 2/2005).*

using a simple, clear public message, but the results will be supported by the large amount of detailed, complex scientific data and information depicted as the lower levels of the information pyramid.

We propose to meet the challenges of information reporting by communicating frequently and providing our results and products in a variety of formats (Table 7-3). Frequent communication will occur through scheduled annual reporting and informal meetings with park managers. Information will be reported in numerous formats using language that simultaneously fits within both scientists' and nonscientists' frames of reference, such that progress and findings are technically accurate and understandable. Collaborative learning will occur in forums such as the investigators report to the technical committee and informal park meetings that are designed to provide immediate access to new information and develop a shared understanding of ecological change and how it relates to resource management issues. We anticipate that reporting procedures will evolve with the monitoring program and adapt to changing communication technology.

7.2.1 Newsletters

Newsletters will provide contemporary information, including network news, alerts, recent discoveries, or changes in staff, among other information. Newsletters will be two to four pages and published annually or semiannually. They will be published online and circulated to the parks in hard copy so they are easily accessible. Newsletters will be archived on the network web page to provide an easily accessed record of network activity.

7.2.2 Annual Park-Specific Status Report

Park vital sign status reports will annually summarize information from the vital signs program. These reports will be park specific and provide clear linkage to how the vital signs data addresses specific network goals. Reporting will coincide with park managers' needs to integrate the information into park reporting requirements. For example, if parks are reporting on GPRA goals in November–December, then SWAN will provide summaries of vital signs that address GPRA goals in September–October.

7.2.3 Scientific Posters and Peer-Reviewed Literature

Monitoring project leaders and cooperators will develop and present posters at meetings, workshops, and conferences. SWAN will provide copies of these posters to parks for them to display. The distillation of network projects into posters or other easily interpreted formats will be included as products in cooperative agreements. Peer-reviewed literature will be a primary means of communicating information to other scientists as well as park biologists and managers.

7.2.4 Personal Contact

Personal relationships with park managers through face-to face-interactions will be an important element of reporting. These meetings will facilitate strong relationships with park staff and integrate monitoring results into park resource management. These meetings may occur during park seasonal training periods to present the I&M program to incoming seasonal staff of all divisions; through park-specific presentations or "SWAN Road shows" where network staff present park specific information to each park; and through biennial symposiums where scientists present their research results to network park staff and the public.

7.2.5 Tracking How I&M Information is Used

As an element of reporting, SWAN will track how network staff are used to assist with park management issues and how vital signs monitoring data are used in park planning and resource protection. This process will be used to measure the effectiveness of the long-term monitoring program in meeting objectives and improving science-based park management.

7.3 Interpretation and Outreach

The goal of the SWAN education and interpretation program is to strengthen the understanding and appreciation of science in our national parks. This goal capitalizes on the ability of SWAN to link education, research, stewardship, and resource management, into meaningful messages about the status and trends of park resources. Most interpretation and outreach will be accomplished though park-based interpreters, Ocean Alaska Science and Learning Center-Seward (OASLC), and Islands and Ocean Visitor Center-Homer. An education coordinator based at the OASLC will oversee the program and work with project leaders to identify potential products.

Information will be disseminated to the public by:

- Web sites and posters
- Participating in public workshops, conferences, and meetings
- Articles in journals/newsletters of local organizations
- Local educational and outreach programs
- News releases to local media
- Public lecture series

Table 7-3 *Summary of various reporting outlets for information produced from the SWAN vital signs monitoring program.*

Type of Report	Purpose of Report	Primary Audience	Frequency	Person(s) Responsible
Annual Administrative Report and Work Plan	Program account for funds and FTEs expended; summary of accomplishments, highlights, and plans for upcoming year of the monitoring program	Board of Directors, Technical Committee, Regional and Washington Office Staff	Annual	Network Coordinator and Staff
Annual Technical Reports for a Protocol or Project	Present comprehensive data results, including data tables, discussions of results, and charts, and the Status and Trends of a resource. Document changes in monitoring protocols. Inform park and Network staff.	Park Resource Managers, Network Staff, External Scientists	Annual	Network Coordinator and Staff
Annual Report on “State of the SWAN Parks” (Report and Web-based information)	Summarize for managers and interested members of the public some of the major, current findings of the monitoring program. This annual report is intended to be a standing report that SWAN staff adds to, edits or changes once each year.	Superintendents, Park Resource Managers, Network Staff, External Scientists, Public	Annual	Network Coordinator and Staff
Investigators Report to the Technical Committee	Project investigators update park and Network staff on progress, highlights, preliminary findings, and future plans. Provides an opportunity for investigators to share information and plans.	Superintendents, Park Resource Managers, Network Staff, Cooperators	Biennial	Network Coordinator and Staff
Scientific Posters and Peer Reviewed Literature	Convey significant findings to professional audiences.	Park Staff, Agency, External Scientists, Public	Infrequent	Network Staff and Cooperators
DVD's and Glossy Brochures	Information and educational products that are integrated into park interpretive programs	Superintendents, Park Staff, Visitors, General Public	Infrequent	Network Outreach Staff
Informal Park Meetings	In-park "open house" meeting where Network staff provide an update and answer questions.	Park Staff From All Divisions	Annual	Network Staff and Host Park I&M Leader

Chapter 8

Administration and Implementation of the Monitoring Program

In this chapter, we describe the composition of the Board of Directors (BOD) and Technical Committee (TC); the decisionmaking process of the Network; the staffing plan; how Network monitoring operations will be integrated with other park operations; anticipated state and federal partnerships; and the periodic review process for the program.

8.1 SWAN Board of Directors and Technical Committee, and Their Roles in Developing and Implementing the Monitoring Program

Membership and operation of the SWAN Board of Directors is guided by a charter (http://www.nature.nps.gov/im/units/swan/Libraries/Reports/ProgramDocuments/SWAN_2002_Charter.pdf). The BOD for SWAN includes the superintendent from each park, the Alaska Region I&M coordinator, the Alaska Region science advisor, and the Network coordinator (Table 8-1). One of the superintendents serves as the chair for the BOD, and this position rotates among the superintendents every 2–3 yr. The three superintendents and regional I&M coordinator are the voting members of the BOD, and the other members serve as advisors to the superintendents.

Table 8-1 *Composition of the SWAN Board of Directors, 2006.*

Title	Current Member	Voting	Advisor
Superintendent, KATM	Ralph Moore	x	
Superintendent, KEFJ	Jeff Mow	x	
Superintendent, LACL	Joel Hard, Chair	x	
Regional I&M Coordinator	Sara Wesser	x	
Regional Science Advisor	Robert Winfree		x
Network Coordinator	Alan Bennett		x

The BOD ensures that the monitoring program is built upon a collaborative vision for the Network and considers the mandates, needs, interests, and goals of all park units. The BOD works to maintain the integrity of Vital Signs Monitoring and Water Resources funds and staff and assures that monitoring resources are not diverted or reassigned to other programs. Additionally, the BOD ensures that park staff selected to participate in SWAN are fully committed to vital signs monitoring and establishes personnel appraisal systems that reward Network cooperation. Finally, the BOD responds to what we have learned through long-term monitoring and acts on recommendations from the TC to institute new management actions or modify existing management actions where necessary to protect or restore park ecosystems.

The SWAN TC consists of the chiefs of resource management from KATM, KEFJ, and LACL, the Network coordinator (chair), the Network data manager, the regional ecologist, and the USGS-BRD liaison to NPS for long-term monitoring (Table 8-2). All members of the TC except the USGS-BRD representative are “voting” members. As with the BOD, membership and operation of the TC is guided by a charter (http://www.nature.nps.gov/im/units/swan/Libraries/Reports/ProgramDocuments/SWAN_2002_TC-Charter.pdf).

Table 8-2 Composition of the SWAN Technical Committee, 2005.

Title	Name	Park
SWAN Coordinator, Chair	Alan Bennett	SWAN
SWAN Data Manager	Dorothy Mortenson	SWAN
Chief Natural Resources	Shelley Hall	KEFJ
Chief Natural Resources	Troy Hamon	KATM
Chief Natural Resources	Colleen Matt	LACL
Regional Ecologist	Page Spencer	ARO
Biologist, USGS	Karen Oakley	USGS

The TC is a working group, decisionmaking, and technical oversight body. Key roles are to provide guidance and support needed to sustain on-the-ground monitoring efforts and to assist the Network Coordinator in the preparation of the Annual Administrative Report and Work Plan. The TC may make frequent use of work groups to evaluate options and provide alternatives and may often rely on work group reports as a basis for action. All work groups will be chaired by a member of the TC and work group members will be approved by the TC.

8.2 Staffing Plan

SWAN parks are characterized by relatively small natural resources staffs (3–4 people per park). In some parks there is good representation by fisheries and wildlife biologists but low representation in the disciplines of physical science, marine science, and vegetation ecology. A challenge for SWAN is to secure the range of technical specialists needed to implement the monitoring program without overcommitting the Network budget to staff salaries. We plan to meet this challenge by strategic sharing of positions with the Network parks, Alaska Regional Office (ARO), and outside agency partners (Table 8-3).

SWAN is currently centrally based in Anchorage at the NPS-ARO and administratively supported by LACL, also headquartered in Anchorage with field stations in Homer and Port Alsworth. Headquarter and field station locations for other network parks units are described in Chapter 1. In 2005, the Technical Committee and Board of Directors endorsed the concept of centrally basing the network in Homer. Advantages cited for this location include the opportunity to collocate with park staff, partnership opportunities with other agencies and NGOs, logistical proximity to parks, and education and outreach potential. Homer is a public "gateway" to SWAN parks and provides a unique opportunity for place-based scientists to become information brokers and act as bridge between science and community-based stewardship of national parks. Elements of the SWAN staffing plan are the inclusion of network staff who assume multiple roles, and a reliance on substantial involvement by park-based staff in organizing and conducting field monitoring. This design is based upon the need to:

- Minimize staff costs and conserve funding needed for field operations;
- Capitalize on efficiency and safety associated with local knowledge of park staff;
- Ensure programmatic integration of monitoring with other park operations, such as resource protection and interpretation; and
- Fully utilize the breadth of both Network and park staff expertise.

Staff organization of SWAN is built around four program areas: **data collection (monitoring), design and analysis, data management**, and **reporting**. The core of the staffing plan is an interdisciplinary team of six project leaders who are centrally based in Anchorage (Figure 8-1). We believe that the most effective approach to understanding complex ecosystems and how they are changing is to use an interdisciplinary team that pools knowledge and expertise and works together. For example, marine ecologists need to talk to atmospheric scientists and wildlife biologists need to talk with landscape ecologists. Project leaders provide oversight, direct on-the-ground monitoring, and provide a critical link between data collection, synthesis, interpretation, and reporting. In many cases, project leaders may rely on existing park staff

Table 8-3 *Roles of Network and park staff in FY 2006–2009 (* New position not existing in FY 2005).*

POSITION GRADE & STATUS	PRIMARY DUTIES	DUTY STATION	TOTAL PAY PERIODS TO NETWORK/YR
Network Coordinator GS-12 Permanent	Coordinates and administers all aspects of the monitoring program. Cochairs the Technical Committee to formulate direction and administration of the program. Supervises project leaders and data manager, serves as advisor to the Board of Directors in making programmatic decisions and maintaining accountability of program. Also serves as a project leader for monitoring or research.	Anchorage or Homer	Included under project leader salaries
Assistant Network Coordinator GS-12 Permanent	Works under direction of the lead coordinator to administer all phases of the monitoring program. Responsible for details of day-to-day monitoring projects and integration of results across disciplines. Primary contact with park staffs. Serves as a project lead in field of expertise.	Anchorage or Homer	Included under project leader salaries
Data Manager GS-11 Permanent	Is the primary person responsible for all aspects of data management for the Network. This includes establishing the flow of data from collection to reporting and archiving. Designs the architecture for World Wide Web dissemination of program information. Works with Principal Investigators to design appropriate databases for data collection and for integration of data.	Anchorage or Homer	26
*Assistant Data Manager/GIS GS-7/9 Permanent	Serves as the assistant to the Data Manager. Undertakes detailed database and GIS design work and programming as needed. Handles technical aspects related to delivery/communication of monitoring program information via the World Wide Web. Works with Principal Investigators to ensure that data are entered and analyzed appropriately.	Anchorage or Homer	26
Biometrician/ Wildlife Biologist GS-12 Permanent	Responsible for all aspects of sampling design and data analysis associated with monitoring and research, development, and application of models, and serves as project leader for terrestrial wildlife monitoring and research. May also serve as Network Coordinator, member, and cochair of the Technical Committee.	Anchorage or Homer	26
*Marine Nearshore Ecologist GS-12 Permanent	Project leader for marine nearshore vital signs monitoring and research; liaison to the Gulf of Alaska Ecosystem Monitoring Program and Alaska Ocean Observing System. May also serve as Network Coordinator, member, and cochair of the Technical Committee.	Anchorage or Homer	26
*Landscape Ecologist GS-12 Permanent	Serves as a project leader for monitoring land cover change and landscape processes using remote sensing analyses. Maintains and updates inventory of remote sensing-related information and database. Interprets and integrates results of other vital signs in context of ecosystem processes. May also serve as Network Coordinator, member, and cochair of the Technical Committee.	Anchorage or Homer	26
Botanist GS-11 Term (current) Proposed *GS-11/12 Permanent	Serves as project leader for vegetation monitoring in the Network. Is responsible for design, implementation, and reporting of vegetation monitoring. Oversees synthesis of vegetation and climate-related data. May also serve as Network Coordinator, member, and cochair of the Technical Committee.	Anchorage or Homer	26

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Table 8-3 (continued)

POSITION GRADE & STATUS	PRIMARY DUTIES	DUTY STATION	TOTAL PAY PERIODS TO NETWORK/YR
Freshwater Ecologist GS-11 Term (current) Proposed *GS-11/12 Permanent	Serves as project leader for freshwater monitoring in the Network. Responsible for developing and directing operational monitoring for water chemistry, surface hydrology, and resident lake fish. May also serve as Network Coordinator, member, and cochair of the Technical Committee.	Anchorage or Homer	26
*Biological Technicians (2 positions) GS-7 Term	Supervised by a project leader and serve as the park-based contact regarding any logistics and permitting for monitoring work in a given park. Expedite all biological monitoring fieldwork in their parks, assist with data collection, entry, summary, analysis, and reporting.	Park Field Offices	26 26
*Physical Science Technician GS-7 Term	Supervised by a project leader and serves as the park-based contact regarding any logistics and permitting for monitoring work in a given park. Is responsible for implementing climate and other monitoring protocols, including collection, collation, and summarization of data.	Park Field Offices	26
Clerical Assistant GS-7 Term (part-time)	Provides assistance to the Network by helping to complete and file paperwork (travel, supervision), assisting in preparing annual reports, entering budget information on financial systems, formatting correspondence, and arranging logistics for meetings. Also enters project information on tracking database to maintain program accountability.	Anchorage or Homer	13
Alaska Regional Office Staff Working on Network Vital Signs Monitoring but Paid from ARO Funds			
Physical Scientist GS-12 Permanent	Serves as project leader for climatic and glacier monitoring in the Network. Provides general oversight for all physical resource monitoring and is responsible for designing, conducting, and reporting of monitoring data on glaciers and climate/weather data.	Anchorage	2–4
Kenai Fjords Staff Working on Network Vital Signs Monitoring but Paid from Park-Based Funds			
Ecologist GS-11 Permanent	Is park lead for marine, terrestrial, and aquatic vital signs monitoring. In conjunction with SWAN project leader(s) is responsible for scheduling and organizing field sampling, collecting and summarizing data. May assist in other monitoring and may work in other parks.	Seward	3–6
Education/ Outreach Specialist GS-11 Permanent	Directs education and outreach program for the Network. Coordinates interpretation and education programs that transfer information about Network resources to park-based interpreters and the public at large, through outreach to schools, Web site development, and other means.	Seward	3–6
Katmai Staff Working on Network Vital Signs Monitoring but Paid from Park-Based Funds			
Wildlife Biologist (mammals and birds) GS-11 Permanent	Is park lead for brown bear, wolf, wolverine, moose, and caribou monitoring. In conjunction with SWAN project leader(s) is responsible for scheduling and organizing field sampling, collecting and summarizing data. May assist in other monitoring and may work in other parks.	King Salmon	2–4

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Table 8-3 (continued)

POSITION GRADE & STATUS	PRIMARY DUTIES	DUTY STATION	TOTAL PAY PERIODS TO NETWORK/YR
Fisheries Biologist) GS-11 Permanent	Is park lead for water quality, surface hydrology, salmon, and resident lake fish monitoring. In conjunction with SWAN project leader(s) is responsible for scheduling and organizing field sampling, collecting and summarizing data. May assist in other monitoring and may work in other parks.	King Salmon	3–6
Coastal Biologist GS-11 Permanent	Serves as park leader for marine nearshore monitoring and works with SWAN/Gulf Ecosystem Monitoring partners. In conjunction with SWAN projects leader(s) is responsible for scheduling and organizing field sampling, collecting and summarizing data. May assist in other monitoring and may work in other parks.	King Salmon	2–4
Lake Clark Staff Working on Network Vital Signs Monitoring but Paid from Park-Based Funds			
Fisheries Biologist) GS-11 Permanent	Is park lead for water quality, surface hydrology, salmon, and resident lake fish monitoring. In conjunction with SWAN projects leader(s) is responsible for scheduling and organizing field sampling, collecting and summarizing data. May assist in other monitoring and may work in other parks.	Port Alsworth	3–6
Wildlife Biologist (mammals and birds) GS-11 Permanent	Is park lead for brown bear, wolf, wolverine, moose, and caribou monitoring. In conjunction with SWAN projects leader(s) is responsible for scheduling and organizing field sampling, collecting and summarizing data. May assist in other monitoring and may work in other parks.	Port Alsworth	2–4
Biological Technician GS-7 Permanent	Supports park vital signs monitoring, including field sampling and summarization of data. May assist in other monitoring and may work in other parks.	Port Alsworth	2–4

or other partners to conduct field sampling. Analysis and data management will be directed by senior, centrally based Network staff. Information and outreach will be directed by park or Network-based staff who are shared among the programs. Field sampling will be conducted by teams consisting of park-based Network technicians, park staff, and project leaders. Creating monitoring teams from centrally based network scientists and park-based biologists and managers plays a crucial role in integrating science and management and institutionalizing the monitoring program within park operations.

The make-up and roles of project leaders and other Network staff have been given careful attention and aligns with the breath of physical and biological vital signs that will be monitored (Table 8-3). It is critical that we have top-quality active scientists leading SWAN, but we do not want to compromise the very research experience and knowledge that make them well-suited for a leadership role. In recognition of this, coordination of SWAN will be based upon a dual leadership approach whereby two project leaders will serve as senior and assistant Network coordinators. By splitting responsibilities between two individuals, each individual will be a contributor to program administration without sacrificing the role as practitioners in monitoring and research. Network coordinators have a crucial role of being *translators*; i.e., senior scientists who stand up when a meeting is descending into a hopeless quagmire and pull everyone back to the broad, important questions that really matter, using words that everyone can understand.

Under a dual leadership approach, the senior and assistant coordinators will have both shared and independent responsibilities. For example, both coordinators will serve as cochairs on the TC and staff to the BOD. The senior coordinator will supervise all project leaders (including the assistant coordinator) and represent SWAN as point-of-contact for the regional and national I&M programs. Specific shared and

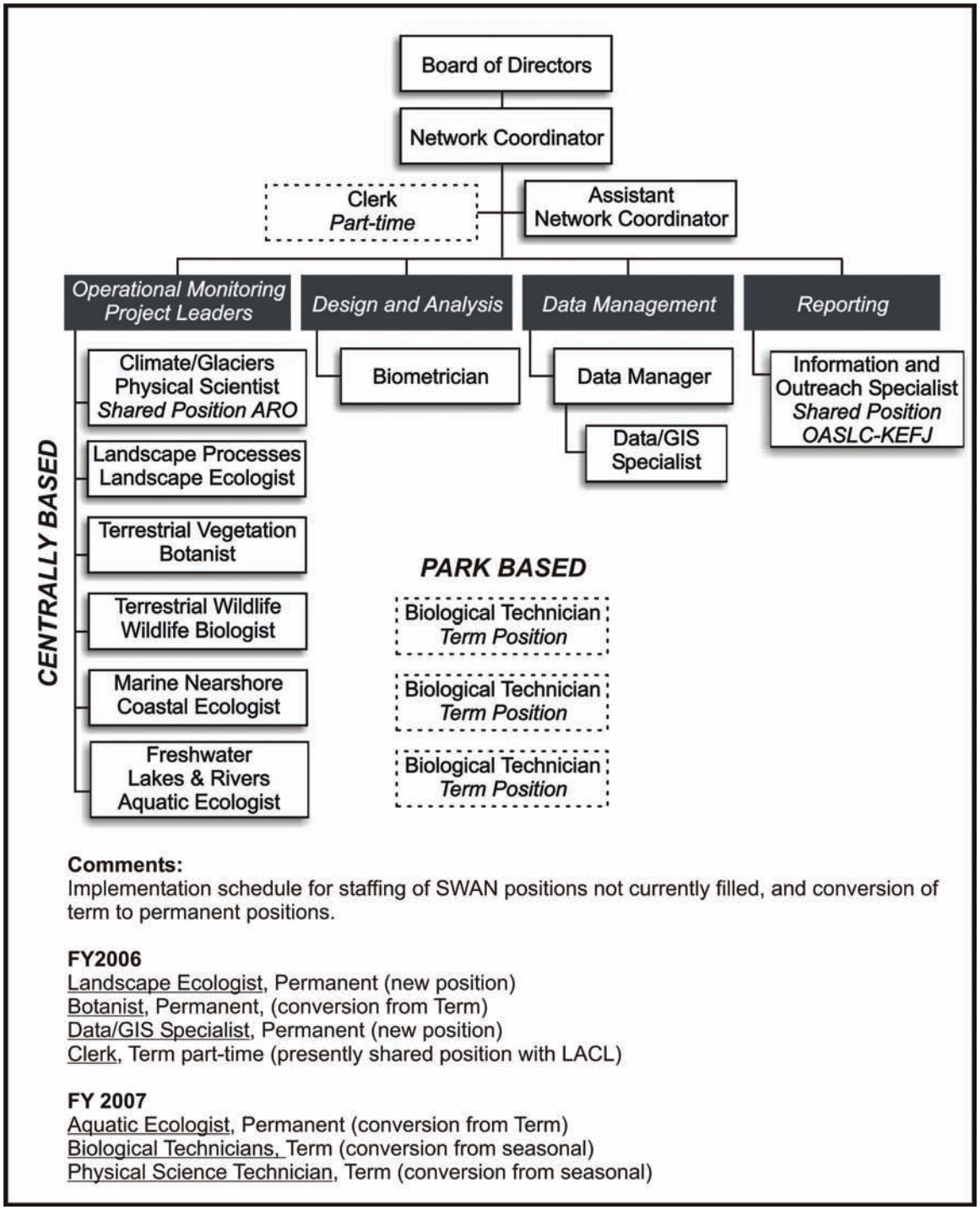

Figure 8-1 *Staff organization chart for SWAN once monitoring is implemented in 2007. Positions in dashed boxes are Term or Part-time, whereas positions in solid boxes are permanent.*

independent roles will be negotiated among the Network coordinators and approved by the BOD. A dual leadership approach will minimize program disruption that can occur with staff turnover.

8.3 Integration of Program with Park Operations

The "network concept" is based on the principle of park and network staff joining together to plan, coordinate activities, share resources, leverage additional resources, and implement operational monitoring (S. Fancy). Programmatic integration of monitoring with park operations such as protection, interpretation, maintenance, and stewardship is crucial. In SWAN, integration will be built around four principles—**lead**,

inform, **listen**, and **involve**.

- Network vital signs monitoring staff must professionally **lead** the program in order to inspire confidence and build strong internal support and respect. This is extremely important during initial years of the program and will be achieved by (i) hiring qualified professionals who possess background and understanding of long-term monitoring and the needs of the National Park System; and (ii) involving park staff in the recruitment and orientation of Network personnel.
- Senior Network staff will regularly **inform** all park staff of *who we are and what we do*. To promote recognition, Network staff will (i) attend and participate in spring all-employees/seasonal orientation meetings; (ii) participate in semiannual park program managers' meetings; (iii) work though the Ocean Alaska Science and Learning Center (OASLC) to widely distribute information and education products to park interpreters and staff.
- Vital Signs Monitoring staff must **listen** to park staff concerns, such as insight into human-related impacts affecting park resources, natural events, and recommendations concerning how monitoring is conducted. Senior Network staff will conduct periodic informal park visits to (i) keep in touch with the realities of field personnel and life as an NPS employee in rural Alaska; and (ii) solicit feedback on current and developing issues involving park monitoring, management, and research.
- Finally, a goal of this program is to **involve** park biologists, interpreters, rangers, pilots, maintenance, and other staff in the collection of monitoring data, as educators, or in a support capacity for carrying out most monitoring operations. Involvement will also be achieved by basing at least one Network staff member in each park year-round to serve as the onsite expeditor for field monitoring. Decisions on both annual and day-to-day program operations are reached jointly by the onsite expeditor and senior Network staff.

8.4 Anticipated Partnerships

Parternerships have been pivotal in planning of SWAN's monitoring program and will continue to be so during implementation (Table 8-4). Example partnerships addressing multiple vital signs include the following:

- Gulf of Alaska Ecosystem Monitoring Program (GEM) of the *Exxon Valdez* Oil Spill Trustee Council. The GEM is a core monitoring program conducted by a consortium of resource agencies and research entities with the goals of detecting environmental change over time and expanding understanding of the Gulf of Alaska ecosystems. Nearshore coastal monitoring in SWAN will be fully integrated with the GEM program.
- Cook Inlet Region Citizens Advisory Council (CIRCAC) was created by the Oil Pollution Act of 1990 and has a federal mandate to monitor for environmental impacts of oil-related activities in Cook Inlet, including coastal areas of Lake Clark and Katmai National Parks. SWAN may partner with CIRCAC for monitoring of bioacculated contaminants in coastal waters.
- The Kachemak Bay Estuarine Research Reserve (KBERR) is managed by NOAA and the ADNR. A primary objective of KBERR is to understand changes in the bay and surrounding waters by linking monitoring with process-oriented experiments. SWAN will partner with KBERR on fixed stations sensors to measure seawater temperature, pH, salinity, and dissolved oxygen in transects crossing Cook Inlet and Shelikof Strait.
- The Alaska Maritime, Kenai, Kodiak, Becharof, and Alaska Peninsula National Wildlife Refuges are managed by the USFWS and consist of offshore islands and interior lands that directly adjoin SWAN parks. Long-term data are collected annually by these refuges for selected species and ecosystems under the trust of the USFWS. SWAN will partner with these refuges in monitoring of birds, fish, mammals, and air quality.
- The ADF&G is responsible for the protection and management of fish, game, and aquatic plant resources in Alaska consistent with the sustained yield principle. SWAN will partner with several ADF&G divisions in monitoring large mammals, salmon, and marine resources.

- The ADNR is responsible for protecting water quality, fish and wildlife habitat, and other forest values through appropriate forest practices and administration of the Forest Resources and Practices Act. ADNR provides assistance to various federal resource program partners (including SWAN) for forest insect research, periodic ground surveys, and annual aerial monitoring.
- The USFS partners with ADNR to produce the Annual Forest Health Protection Reports that will be used by SWAN staff to monitor forest insect and disease outbreaks. In addition, SWAN staff are currently engaged in discussions regarding the establishment of a Memorandum of Understanding (MOU) with the USFS, Pacific Northwest Experiment Station, for cooperation in forest inventory and monitoring activities on NPS lands.
- USGS-BRD Alaska Science Center is responsible for research on trust lands and waters, including those of the NPS. ACS has been involved with the SWAN biological inventories and monitoring design since 2001.
- The Western Regional Climate Center (WRCC) is administered by NOAA and serves as a focal point for coordination of applied climate activities in Alaska. SWAN will partner with WRCC to archive and deliver climate data via the World Wide Web and to develop analysis tools for climate data.
- The Alaska Volcano Observatory (AVO) is a joint program of USGS, the Geophysical Institute of the University of Alaska Fairbanks, and the State of Alaska Division of Geological and Geophysical Surveys. Its volcano monitoring program consists of networks of continuously recording seismometers installed at active volcanoes in SWAN.
- The West Coast/Alaska Tsunami Warning Center (WCATWC) in Palmer, Alaska, operates recording stations throughout southwestern Alaska and provides data on earthquake events.
- The Alaska SeaLife Center (ASC) is a nonprofit marine science facility dedicated to understanding and maintaining the integrity of the marine ecosystem of Alaska through research, rehabilitation, and public education.

8.5 Program Reviews

Periodic reviews of the Network's monitoring program and protocols are critical to ensure that objectives of the Vital Signs Monitoring Program are being met, or if course corrections are needed, that they are accomplished quickly to save unnecessary expenditures of resources and time. The Annual Administrative Report and Work Plan will provide the TC and BOD with an opportunity to review ongoing and planned projects. A second level of review will be afforded by a biennial SWAN Science Symposium/Investigators Report to the TC. This will be a 2-day meeting at which all Network staff, park staff, and cooperators conducting monitoring or research will give technical presentations and discuss the results of their work. During the second day of the meeting the TC will discuss the presentations and evaluate progress and results. Finally, the program will be reviewed formally, at least once every 5 yr (Table 8-5). A formal report will be generated from this periodic review, with specific suggestions for improvements to the monitoring program.

Table 8-4 *Anticipated partnerships in the monitoring of SWAN vital signs. (See text for abbreviation spell-outs.)*

Project	Vital Sign	Monitoring Conducted Solely by SWAN	Monitoring Conducted by SWAN and Partner(s)	Monitoring Conducted Only by Partner(s) Cooperator(s)
Weather and Climate	Weather and Climate		SWAN WRCC-DRI	
Landscape Dynamics and Terrestrial Vegetation	Glacier Extent	SWAN		
	Landscape Processes	SWAN		
	Land Cover and Land Use	SWAN		
	Vegetation Composition and Structure		SWAN USFS	
	Sensitive Vegetation Communities	SWAN		
	Volcanic & Earthquake Activity			AVO WCATWC
	Insect Outbreaks			ADNR
Marine Nearshore	Geomorphic Coastal Change		SWAN GEM KBERR CIRCAC USGS-BRD	
	Kelp & Eelgrass			
	Intertidal Invertebrates			
	Seabirds			
	Black Oystercatcher			
	Sea Otter			
	Water Chemistry			
	Harbor Seal			NMFS ASC
Lakes, Rivers and Fish	Surface Hydrology	SWAN		
	Water Chemistry	SWAN		
	Resident Lake Fish	SWAN		
	Salmon		SWAN ADF&G	
Terrestrial Animals	Brown Bear		SWAN ADF&G	
	Wolf & Wolverine		SWAN ADF&G	
	Moose		SWAN ADF&G	
	Caribou			ADF&G
	River Otter (coastal)		SWAN GEM	
	Bald Eagle		SWAN USFWS	
Human Activities	Resource Harvest			USFWS
	Visitor Use		SWAN	
	Invasive/Exotic Species		SWAN ARO	
	Air Quality			USFWS

Table 8-5 *Process and schedule for reviews of the SWAN monitoring program.*

REVIEW	TIMING	PARTICIPANTS	INTENT OF REVIEW
Annual Administrative Report and Work Plan	Annual	Technical Committee Board of Directors Regional Office Washington Office	Provide yearly accountability for program. Report on accomplishments and explain goals and projects for next fiscal year.
Science Symposium/Investigators Report to the Technical Committee	Biannual	Network Staff Technical Committee Board of Directors Regional Office	Provide technical details on results and status of all monitoring projects. Provides a forum for all project leaders, cooperators, partners, and park staff working in SWAN to discuss progress and new potential directions.
5-year Program Review	Once Every 5 Years (First Review, 2011)	Network Staff Technical Committee Board of Directors Washington Office Outside Invited Experts	Provide synthesis of data collected by program, evaluate the utility to park management, evaluate administration and operations of program, make recommendations for improvement of all aspects of program.

Chapter 9
Schedule

This chapter identifies the target completion dates for protocols still to be developed, identifies tasks that need to be completed in support of those protocols, and summarizes the frequency of sampling for protocols that will be implemented in 2007. Our approach to the implementation of monitoring in SWAN is to **start slowly, focus on a small number of projects, and be prepared to make adjustments.** During the early years of the program, it is important not to overburden Network and park staff with overzealous plans to take on too much to quickly and discover that your program has overshot its capabilities.

Integrated ecosystem monitoring can be viewed as hierarchical and occurring at multiple levels (tiers) based on scale of resolution and rates of change (Figure 9-1). Temporally and spatially continuous monitoring (Tier 1) is usually conducted by satellite remote sensing or aerial photography and is directed at broad landscape-scale patterns of change. Frequent multipoint ground-based monitoring using probabilistic sampling designs (Tier 2) are used to document status or change in a resource or to provide ground verification of remotely sensed parameters in Tier 1. Finally, the most frequent monitoring and intensive sampling (Tier 3) occurs at a limited number of smaller intensively monitored areas for the purpose of determining cause and effect relationships, the status of a harvested resource, or to understand how processes interrelate.

Implementation of vital signs monitoring will be phased in over 5 yr beginning in 2006 (Table 5-1). Most Tier 1 vital signs monitoring will be implemented first because these protocols provide important context for ground-based monitoring that will follow and they are likely to be the least expensive to conduct. Protocols for monitoring glacial ice extent and landscape processes (snow-cover date and snow-free date, extent and duration of ice cover, timing and degree of lake turbidity) were developed in 2005 and will be tested in 2006. Simultaneously, we will develop and test protocols for monitoring water quality and resident lake fish.

Throughout the 5-yr implementation phase, draft protocols will be written, field-tested for 1–2 yr, submitted for peer review, and finalized. Some key questions that need to be answered during protocol testing include: Are there problems with methods or equipment? Do procedures require too much time or staff? Are standard operating procedures (SOPs) for data collection and management too complex? How can the protocols be made more efficient? We anticipate that in many cases pilot monitoring, including tests of data management SOPs, will reveal the need for changes in protocol design.

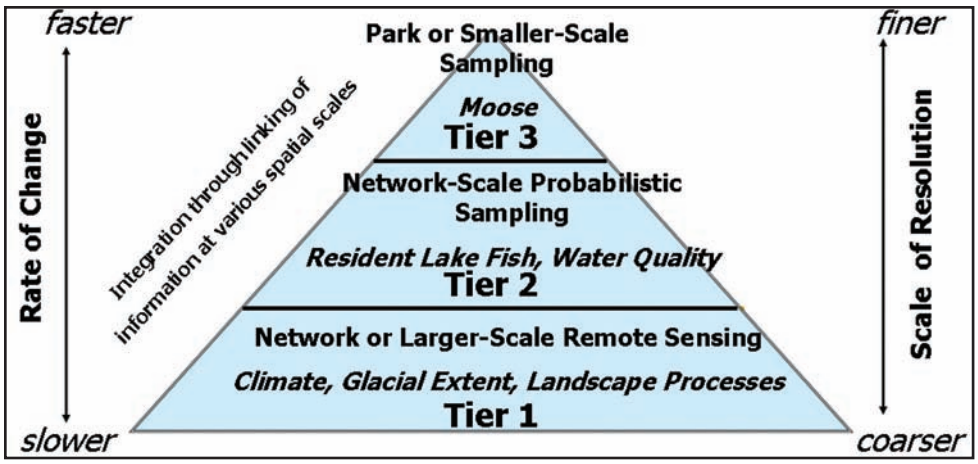

Figure 9-1 *Temporal and spatial considerations as they relate to implementation of SWAN vital signs monitoring. Protocols for vital signs monitored by remote sensing (Tier 1) will be developed and implemented during the first years of the program.*

Expected implementation dates for final protocols and key tasks associated with the development of protocols are summarized in Table 9-1. In many cases these tasks reflect the fact that SWAN is working with a range of Network partners to collectively develop monitoring protocols. The success of our program may hinge upon our ability to work efficiently and effectively with other programs that complement SWAN.

Table 9-1 *Summary of tasks to be completed for protocol development or for acquiring existing data, SWAN Vital Signs Monitoring Program.*

Protocol Finalization Date	Vital Sign (Protocol Category)	Issues to be Addressed During Protocol Development and Testing
2008	**Geomorphic Coastal Change**	Conduct a cost and methods comparison for the use of global positioning system ground surveys, aerial LIDAR, videography, and aerial photo analysis. Identify other shoreline change monitoring programs that may be able to cost-share with the Network.
	Marine Nearshore-Kelp & Eelgrass	Aerial surveys for canopy coverage need to be evaluated to develop a SWAN/GEM protocol that will allow data on kelp and eelgrass to be incorporated into a Gulf of Alaska database.
	Marine Nearshore-Marine Intertidal Invertebrates	Recent intertidal invertebrate inventories (2004–05) have helped characterize the benthic community in Network parks and will be used to develop a SWAN/GEM sampling approach.
	Marine Nearshore-Seabirds	The interagency Alaska Predator Ecosystem Experiment developed a long-term monitoring strategy for seabirds in the Exxon Valdez spill area. This strategy will be adapted to a SWAN/GEM protocol.
	Marine Nearshore-Black Oystercatcher	Techniques for monitoring black oystercatchers are well established and have been applied at KEFJ. This information will be used to develop a SWAN/GEM protocol that will allow data on oystercatchers to be incorporated into a Gulf of Alaska database.
	Marine Nearshore-Sea Otter	Aerial strip transect survey methods for sea otter are well established. The SWAN nearshore needs to be delineated into density strata based on distance to shore and bathymetry.
	Marine Nearshore-River Otter	Ongoing research is attempting to establish whether population levels and trends of river otters can be monitored among various coastal shoreline habitats by recording the use of latrine sites and scat deposition rates.
	Marine Nearshore-Water Chemistry	Several programs are conducting hydrographic observations offshore of SWAN parks from both hydrographic transects and moorings. Work will focus on developing a process to acquire and use this existing data. An SOP needs to be developed for measuring seasonal intertidal water temperature.
	Freshwater Chemistry	Select a subset of larger lakes for more intensive routine sampling. Determine sampling interval based on natural variability of parameters in relation to climate, season, and discharge data.
	Salmon	Techniques for monitoring adult salmon are well established by ADF&G and cooperatively in use by SWAN parks. Work will focus on database development.
	Air Quality	A data management protocol is needed to acquire and utilize data from the IMPROVE stations on/near the coasts of ANIA and LACL.
2009	**Weather and Climate**	Weather station configuration and design will be finalized based on testing of a prototype station on the Harding Ice Field. Conduct field reconnaissance of potential sites identified by climatic modeling.

(continued on next page)

Table 9-1 (continued)

Protocol Finalization Date	Vital Sign (Protocol Category)	Issues to be Addressed During Protocol Development and Testing
2009	**Vegetation Composition and Structure**	Traditional techniques for determining vegetation community analysis generally involve plot-based fieldwork. SWAN will investigate how to use a combination of IKONOS satellite-type data and plot-based fieldwork to detect changes in subtle natural systems.
	Sensitive Vegetation Communities	Standard techniques for plot-based sampling are well established, involving permanent markers and repeated visits. Determine how to array plot sampling (temporal and spatial) to detect change in community composition in small-scale communities that are sensitive to environmental change.
	Land Cover and Land Use	Techniques for multispectral classifications are well established and used for vegetation mapping and detection of drastic land use changes. Most previous change detection work with satellite data involves drastic changes such as fires, logging, and agriculture. It is necessary to determine how to use Landsat satellite-type data to repeatably map and describe land cover classes and such changes as herbaceous to woody or forested types, large-scale disturbances such as insect outbreaks or deglaciation, and human-caused changes on neighboring lands.
	Volcanic & Earthquake Activity	The Alaska Volcano Observatory and West Coast/Alaska Tsunami Warning Center operate recording stations throughout southwestern Alaska and provide continuous data on volcanic and earthquake activity. Work will focus on developing a process to acquire and used this existing data.
	Insect Outbreaks	The ADNR conducts aerial surveys each summer jointly with the USFS to assess forest condition statewide. Work will focus on developing a process to acquire and use existing data.
	Harbor Seal	Techniques for monitoring harbor seals are well established by NMFS and in practice in the northern Gulf of Alaska. Work will focus on developing a process to acquire and use existing data.
	Surface Hydrology	Design and testing is needed to develop relationships between water levels of core lakes sampled for water chemistry and discharge of outlet streams. It is also necessary to evaluate manually collected records of water level versus use of an analogue or digital data recorder.
	Brown Bear	Line-transect double-count aerial survey techniques are used in the interior of SWAN parks to obtain brown and black bear density estimates. Work is needed to assess the application of this technique at concentration sites such as coastal salt marshes. Develop a process to acquire defense of life and property bear killing data from the Bear-Human Information Management System maintained by the NPS-ARO.
	Visitor Use	Research will be implemented in 2006 to determine how best to count remote and dispersed visitors in SWAN. Focus will be on backcountry areas and involve all users. A final component of this project will include development and testing of a protocol.

(continued on next page)

Table 9-1 (continued)

Protocol Finalization Date	Vital Sign (Protocol Category)	Issues to be Addressed During Protocol Development and Testing
2009	**Invasive/Exotic Species**	Network staff will work with the Exotic Plant Management Team from the ARO as they develop a monitoring program for exotic plants and animals in the parks to ensure compatibility of objectives, data collection, and analyses.
2010	**Wolf and Wolverine**	Techniques for monitoring wolves and wolverines using sample unit probability estimation are well established by the ADF&G but need to be tested in areas with unstable late-winter snow conditions such as LACL and KATM.
	Moose	Techniques for monitoring moose are well established by ADF&G and cooperatively in use by SWAN parks. Work will focus on developing a sightability model for KATM and development of a database.
	Caribou	Techniques for annual monitoring of caribou are well established by ADF&G and cooperatively in use by ANIA, KATM, and LACL. Work will focus on developing a process to acquire and use existing data.
	Bald Eagle	Techniques for monitoring bald eagles are well established by USFWS and in use by some SWAN parks. Work will focus on supplementing existing survey strata with randomly chosen quadrats and selecting a stratified random sample of quadrats to be surveyed at 1–3 year frequencies.
	Resource Harvest	Harvest records are collected by the State of Alaska and USFWS through community profile surveys. Work will focus on developing a process to acquire and use existing data.

The timing and frequency of monitoring is guided by the spatial and temporal patterns of variance in the parameters being measured and by the information desired. The limited resources of SWAN and the large spatial expanse of the parks prohibit routine measurements at high frequencies (i.e., daily or hourly) or close spatial intervals. Measurements will be made at intervals of time and space that allow the detection of large-scale changes in physical processes and smaller scale biotic responses among adjacent years and in adjacent locations. For example, frequency of monitoring for projects implemented in 2007 will range from once per decade or longer for glacial extent to weekly for selected landscape processes (Table 9-2).

Table 9-2 *Frequency and timing of sampling for vital signs to be monitored by SWAN in 2007.*

Vital Sign and Metrics	Sample Interval	January	February	March	April	May	June	July	August	September	October	November	December
Glacier Extent													
Areal Extent	Decadal												
Terminus Photography	Decadal												
Landscape Processes													
Ice-Cover Date and Ice-Free Date	Weekly												
Extent and Duration of Snow Cover	Weekly												
Timing and Degree of Lake Turbidity	Weekly												
Seasonal Productivity, Leaf-On	Weekly												
Resident Lake Fish													
Species Richness and Species Turnover	Every 3–5 years												

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Chapter 11
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Glossary

Adaptive management is a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. Its most effective form—"active" adaptive management—employs management programs that are designed to experimentally compare selected policies or practices, by implementing management actions explicitly designed to generate information useful for evaluating alternative hypotheses about the system being managed. (http://science.nature.nps.gov/im//monitor/glossary.htm)

ANILCA is the Alaska National Interest Lands Conservation Act or Public Law 96-487 - Dec. 2, 1980, which provided for the designation and conservation of certain public lands in Alaska, including the designation of units of the National Park Service, National Wild and Scenic Rivers, and National Wilderness Preservation Systems (http://www.r7.fws.gov/asm/anilca/toc.html).

Anthropogenic effects are caused by or attributed to humans. As used here, they are human-influenced factors that cause stress in natural systems.

Attributes are any living or nonliving feature or process of the environment that can be measured or estimated and that provide insights into the state of the ecosystem. The term **indicator** is reserved for a subset of attributes that is particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon 2003). See Indicators, (http://science.nature.nps.gov/im//monitor/glossary.htm)

Biotic integrity is the ability to maintain and support "a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region." (Karr and Dudley 1981).

Community is a group of interacting populations in time and space. Sometimes, a particular subgrouping may be specified, such as the fish community in a lake or the soil arthropod community in a forest. (http://www.epa.gov/emap/html/pubs/docs/resdocs/mglossary.html)

Drivers are major external driving forces on ecosystems, such as climate change, regional land-use change, or air pollution, that have large-scale influences on natural systems. Drivers can be natural forces or anthropogenic. These may be related to global or regional changes in climate, nutrient inputs, or human pressures.

Ecological integrity is a concept that expresses the degree to which the physical, chemical, and biological components (including composition, structure, and process) of an ecosystem and their relationships are present, functioning, and capable of self-renewal. Ecological integrity implies the presence of appropriate species, populations, and communities, and the occurrence of ecological processes at appropriate rates and scales, as well as the environmental conditions that support these taxa and processes. (http://science.nature.nps.gov/im//monitor/glossary.htm)

Ecoregion is an area over which the climate is sufficiently uniform to permit development of similar ecosystems on sites having similar properties. Ecoregions contain many landscapes with different spatial patterns of ecosystems.

Ecosystem is defined as, "a spatially explicit unit of the Earth that includes all of the organisms, along with all components of the abiotic environment within its boundaries" (Likens 1992). (http://science.nature.nps.gov/im//monitor/glossary.htm)

Ecosystem management is the process of land-use decisionmaking and land-management practice that considers the full suite of organisms and processes that characterize and comprise the ecosystem. It is based on the best understanding currently available as to how the ecosystem works. Ecosystem management includes a primary goal of sustainability of ecosystem structure and function, recognition that ecosystems are spatially and temporally dynamic, and acceptance of the dictum that ecosystem function depends on ecosystem structure and diversity. Coordination of land-use decisions is implied by the whole-system focus of ecosystem management. (http://science.nature.nps.gov/im//monitor/glossary.htm)

Focal resources are park resources that, by virtue of their special protection, public appeal, or other management significance, have paramount importance for monitoring regardless of current threats or whether they would be monitored as an indication of ecosystem integrity. Focal resources might include ecological processes, such as deposition rates of nitrates and sulfates in certain parks, or they may be a species that is harvested, endemic, alien, or has protected status. (http://science.nature.nps.gov/im//monitor/glossary.htm)

Function is the role that any process, species, population, or physical attribute plays in the interrelation between living and nonliving components of an ecosystem.

Indicators are a subset of monitoring attributes that are particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon 2003). Indicators are a selected subset of the physical, chemical, and biological elements and processes of natural systems that are selected to represent the overall health or condition of the system. (http://science.nature.nps.gov/im//monitor/glossary.htm)

Inventory is an extensive point-in-time effort to determine location or condition of a resource, including the presence, class, distribution, and status of plants, animals, and abiotic components such as water, soils, landforms, and climate.

Landscape is a spatially structured mosaic of different types of ecosystems interconnected by flows of materials (e.g., water, sediments), energy, and organisms (Miller et al. 2003).

Monitoring is the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective (Elzinga et al. 1998). Detection of a change or trend may trigger a management action, or it may generate a new line of inquiry. Monitoring is often done by sampling the same sites over time, and these sites may be a subset of the sites sampled for the initial inventory. (http://science.nature.nps.gov/im//monitor/glossary.htm)

Research has the objective of understanding ecological processes and, in some cases, determining the cause of changes observed by monitoring.

Stressors are physical, chemical, or biological perturbations to a system that are either (i) foreign to that system or (ii) natural to the system but applied at an excessive [or deficient] level (Barrett et al. 1976:192). Stressors cause significant changes in the ecological components, patterns, and processes in natural systems. Examples include water withdrawal, pesticide use, timber harvesting, traffic emissions, stream acidification, trampling, poaching, land-use change, and air pollution. (http://science.nature.nps.gov/im//monitor/glossary.htm)

Structure refers to the components of an ecosystem, including plants, animals, and the nonliving environment.

Trend as used by the NPS I&M program, refers to directional change measured in resources by monitoring their condition over time. Trends can be measured by examining individual change (change experienced by individual sample units) or by examining net change (change in mean response of all sample units). (http://science.nature.nps.gov/im//monitor/glossary.htm)

Vital signs, as used by the National Park Service, are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The elements and processes that are monitored are a subset of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. Vital signs may occur at any level of organization, including landscape, community, population, or genetic level, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes). (http://science.nature.nps.gov/im//monitor/glossary.htm)

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