National Park Service - Southwest Alaska Network
Inventory & Monitoring Program

Phase II Report
Vital Signs Monitoring Plan
Southwest Alaska Network

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September 30, 2004

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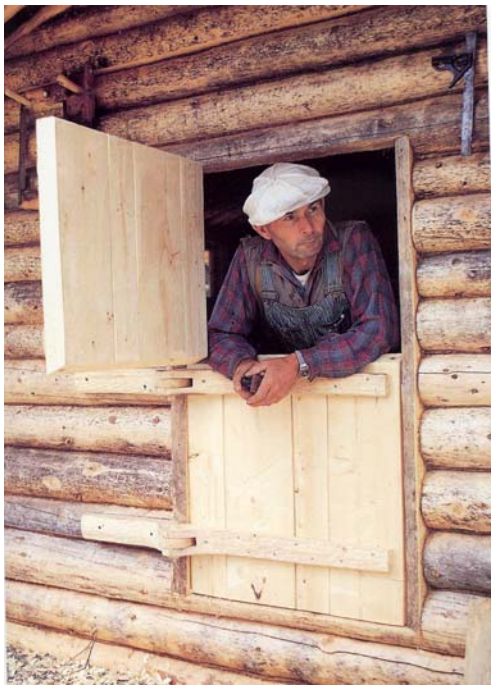
In Memory
Richard Proenneke 1917-2003



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 in 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 his 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 natural resources monitoring program. This report summarizes three years of progress in designing that program. Completion of a final monitoring plan for the network is anticipated to take five years and involve three-phases. Phase's I and II, described in chapters 1-3 of this report, involved defining goals and preliminary objectives; evaluating and synthesizing existing data; developing conceptual ecosystem models; identifying and ranking a draft list of vital signs. Phase III will address the final chapters and involve sampling design, protocols, and data management. Subsequent revisions to this monitoring plan will incorporate new information under chapter headings on pages ii-iii. Some of the material presented is preliminary and may be revised as additional background information is compiled or new concepts emerge.

In chapter 1 we define the purpose and scope of the monitoring program and use examples to describe how managers can use information gained from long-term monitoring to protect park resources. Next, we highlight natural resources and ecosystems of network parks that are of national and global significance and describe the process that the network followed to compile and summarize existing data and understanding of these resources. We define network objectives and questions for monitoring marine, freshwater, and terrestrial ecosystems and describe how they are nested within the national goals for Vital Signs Monitoring. Finally, we review some general principles of landscape ecology, such as space, time and scale concepts, and explain why they are the foundation of a holistic approach to long-term monitoring in large national parks.

In chapter 2 we use conceptual models to explain our understanding of how drivers of change and ecological interactions affect landscape patterns, ecological processes, and selected natural resource components of network parks. Our objectives in presenting the models are to: a) provide a conceptual characterization of geophysical setting; b) explain and illustrate how climate/landform, landscape-scale disturbance, biotic interactions, and human activities interactively affect the network landscape; and c) depict key linkages and functional relationships among marine, aquatic, and terrestrial ecosystems.

In chapter 3 we present the networks draft vital signs and describe the process by which they were selected and prioritized. We also describe how they relate to the conceptual ecosystem models and the networks goals and objectives for monitoring. 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 website. 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 appendixes and other information is available on the Southwest Alaska Network website.

EXECUTIVE SUMMARY

- 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.

- National parks have been grouped into 32 vital signs networks linked by geographic similarities, common natural resources, and resource protection challenges. The network approach facilitates collaboration, information sharing, and economies of scale in natural resource monitoring. The approach also will provide parks with a "minimum infrastructure" to initiate natural resource monitoring.

- The Southwest Alaska Network (SWAN) includes five units of the National Park Service (NPS):
  1. Alagnak Wild River,
  2. Aniakchak National Monument and Preserve,
  3. Katmai National Park and Preserve,
  4. Kenai Fjords National Park, and
  5. Lake Clark National Park and Preserve.

  Collectively these units comprise 9.4 million acres, 11.6 percent of the land managed by the NPS, and 2 percent of the Alaska landmass. Network parks encompass climatic conditions, geologic features, near pristine ecosystems, natural biodiversity, freshwater, and marine resources equaled few places in North America.

- Initial planning efforts in the SWAN began in early 2002 with the staffing of a network coordinator and data manager and the formation of a board of directors and technical committee. During March through May 2002, the technical committee developed a strategy for breaking the three Phase I steps into manageable pieces that could be addressed sequentially. A key element of the strategy involved a series of mini-scoping workshops to develop preliminary objectives for monitoring and review and to discuss the current state of knowledge concerning park ecosystems and resource protection issues.

- Preparation for workshops involved "data mining" and literature synthesis, construction of conceptual ecosystem models, compilation of park resource protection issues, and identification of existing park monitoring efforts. Before and during workshops, participants reviewed and identified partnership opportunities and the monitoring efforts conducted by other federal and state agencies. Workshop summaries were compiled and circulated for technical review.

- This network of relatively untouched wilderness parks is a unique resource and offers unparalleled opportunities to learn about ecological systems minimally affected by humans. In recognition of this, the monitoring framework will emphasize:

a) establishing reference conditions representing the current status of park, monument, and preserve ecosystems; and b) detecting and understanding changes through time.

- The network's conceptual foundation acknowledges that monitoring must address the interplay of multiple forces, which occur at a variety of spatial and temporal scales and that climate/landform, natural disturbance, biotic interactions, and human activities, are the most important drivers in determining ecosystem structure and function.

- The SWAN program is envisioned to be: a) ecologically based and issues oriented, with emphasis on assessing long-term and cumulative effects rather than short-term and isolated effects; and b) interdisciplinary, incorporating biology, hydrology, geomorphology, and landscape ecology and at multiple scales (e.g., coarser-grained network scale, and finer-grained park scale).

- 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.

- Climate influences on SWAN ecosystems are strongly tied to conditions in the North Pacific, especially location and strength of the Aleutian Low winter storm system, and the shift in storm track direction that occurs in summer. Various broader scale influences affect how these annual patterns play out in longer time scales. Climate drives the timing and amount of water entering SWAN ecosystems and is a determinant of fundamental properties of the ecosystems.

- 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, and landslides) create and maintain a shifting mosaic of landscape patterns.

- Important biological interactions in the Southwest Alaska Network involve the transport of nutrients by mobile species, herbivore-predator interactions that maintain a heterogeneous distribution of resources, "ecosystem engineers" such as beavers and marine clams 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, detritus, salmon, and bears. 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 when they are not present in 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, or over-harvesting.

- Candidate vital signs were chosen during a series of scoping workshops held between August 2002 and April 2003. The initial combined list that emerged from the scoping workshops contained 61 vital signs. This list was reduced to 38 after duplicate entries were removed, similar indicators were merged under a single vital sign, or weakly supported vital signs removed.

- Technical committee members reviewed each vital sign in the context of why it was selected, how it relates to conceptual ecosystem models, and how it contributes to the networks 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 draft list of vital signs in March 2004.

CHAPTER 1. INTRODUCTION AND BACKGROUND

A. The Importance of Long-term Monitoring

In 1992, the National Academy of Sciences (1992) reviewed the natural resource management program of the National Park Service (NPS) and concluded, “If this agency is to meet the scientific and resource management challenges of the twenty-first century, a fundamental metamorphosis must occur.” Indeed, that metamorphosis materialized when the National Park Service 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 National Park Service is to protect or maintain natural ecosystem structure and function in national parklands. Alaska national park units are among the last remaining wilderness areas of the world—large enough to allow ecological processes and wildlife populations to fluctuate and biological diversity to evolve and adapt naturally. These large national 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).

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, requiring a landscape approach (see section E, part 1) and integrated long-term monitoring to understand and protect the park's natural resources.

> *“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)*

In this plan, we define integrated monitoring as “systematic, consistent, and simultaneous measurements of physical, chemical, biological, and human-effects variables through time and at specified locations.” 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:

- First, ecological monitoring can provide important understanding and insights into long-term ecological phenomena and the functioning of complex ecosystems across park and network boundaries.

- Second, ecological monitoring is necessary to evaluate objectively whether 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).

- Third, ecological monitoring is necessary in order 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 provides significant data.

- Fourth, information that flows from ecological monitoring elevates the stature of park ecosystems, organisms, and ecological processes to stakeholders, park visitors, and the public.

B. NPS Policies and Mandates That Link Monitoring and Management of Parks: Who is interested in the information provided by monitoring and why?

The enabling legislation establishing the National Park Service 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). National Park Service 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 in order to fulfill the NPS mission of conserving parks unimpaired (figure 1-1). The laws and management policies that follow provide the mandate for inventorying and monitoring in national parks.

National park managers are directed by federal law and National Park Service policies and guidance to know the status and trends in the condition of natural resources under their stewardship in order to fulfill the NPS mission to conserve parks unimpaired (see Summary of Laws, Policies, and Guidance). The mission of the National Park Service (National Park Service 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 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 National Park Service'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 Appropriations 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:

- 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.

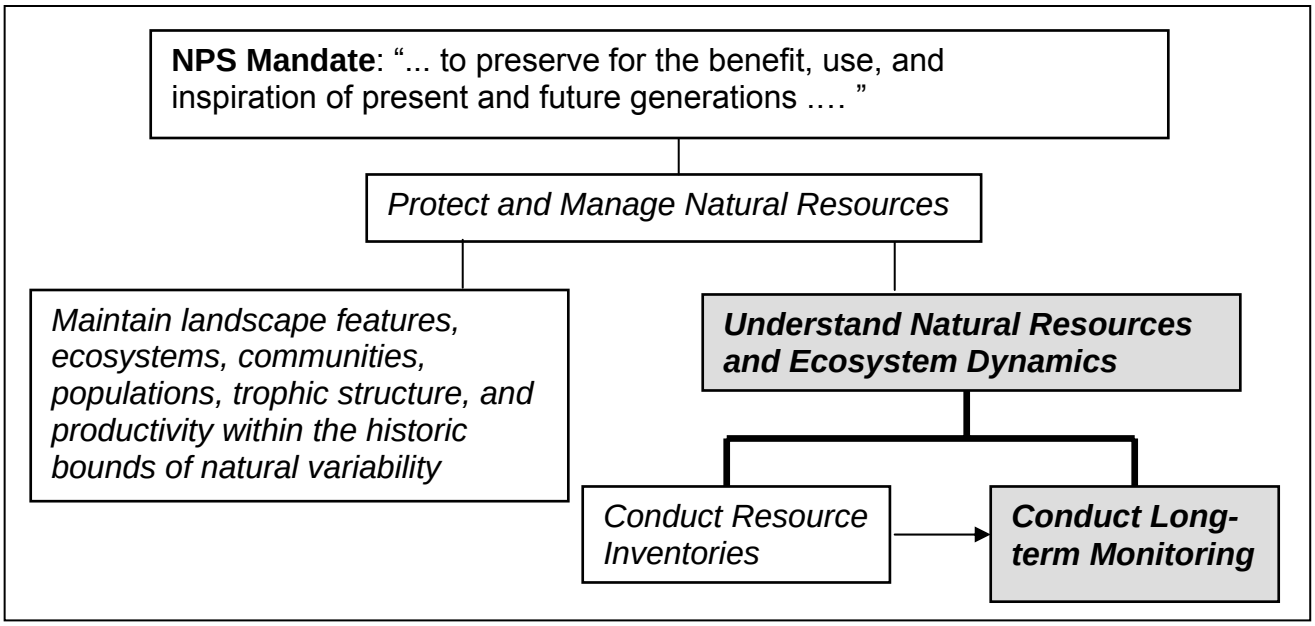


Figure 1-1. Relationship between park mandates, protecting resources, and long-term monitoring.

Applications of Information Gained from Monitoring

The most widely identified application of monitoring information 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 the effects of park visitors trampling riparian vegetation can help to determine whether changes in visitor management strategies are needed to prevent streambank erosion and deterioration of water quality.

Broad-scale ecosystem monitoring, as proposed in this plan, builds a holistic view of park landscapes. The monitoring also 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 the holistic view, managers can develop general principles and guidelines that can be applied broadly to a particular type of issue or problem. For example, understanding how coastal shorelines are responding to sea level rise might allow managers to predict the fate of public-use cabins, vessel mooring buoys, biological, or cultural resources and develop a network-wide strategy for taking a specific action or planning additional monitoring.

In large wilderness park units, an important application of monitoring information is simply to gain insight into "how complex park ecosystems work" (Croze 1982). By gathering data in 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 on a species.

Similarly, some authors suggest that it is important to document changes just for the sake of familiarity with the resources (Halvorson 1984, Croze 1982). The responsibility of resource managers includes being aware 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 vegetation 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 skeptical local governments, Native corporations, industries, or even more skeptical 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 free from local sources of pollution make recognizing the effects of long-range transport and deposition of air pollutants easier.

Finally, a monitoring program can provide basic background information that is needed by park researchers, public information offices, interpreters, and those wanting to know a little 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.

C. Southwest Alaska Network—Environmental Setting and Park-Specific Mandates: What physical and biological features make these park units special?

The Southwest Alaska Network consists of five units of the National Park Service (figure 1-2). Katmai National Park and Preserve (6,409 mi^2), Alagnak Wild River (48 mi^2) and Aniakchak National Monument and Preserve (942 mi^2) are managed as one administrative unit by a superintendent based in King Salmon. Lake Clark National Park and Preserve (6,254 mi^2) is managed by a superintendent based in Anchorage and support staff based Port Alsworth, while Kenai Fjords National Park (2,710 mi^2) is managed by a superintendent and support staff based in Seward. Collectively these units comprise 9.4 million acres, 11.6 percent of the land managed by the National Park

Service, 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 F).

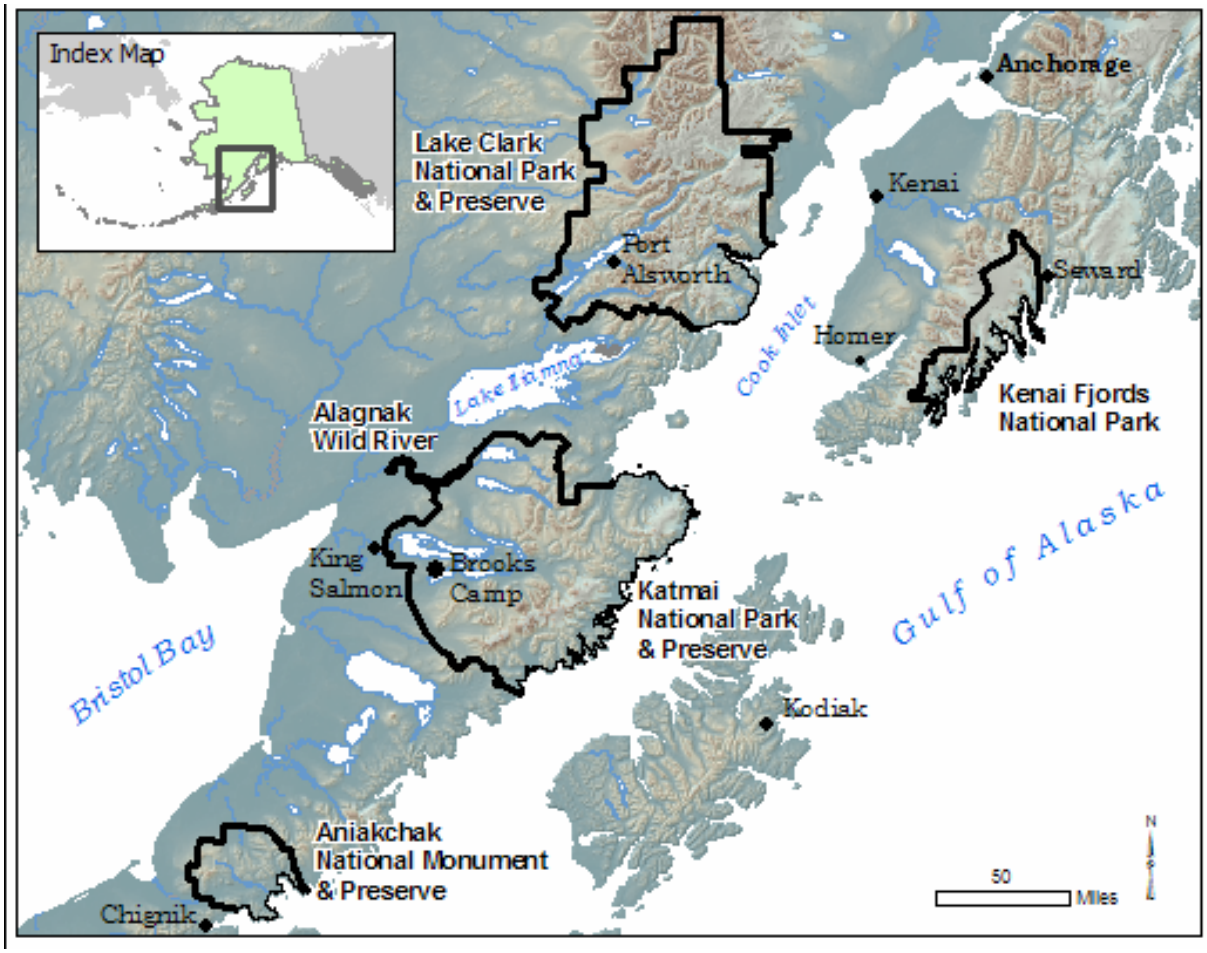


Figure 1-2. National park units of the Southwest Alaska Network.

1) Dynamic Landform Processes and Pattern - From steep glaciated fjords in the east to smoldering volcanoes on the western horizon, SWAN parks occur in one of the most geologically active regions of the continent. The network is located on an active tectonic shelf of the Pacific Ocean Plate in one of the most seismically active regions of the United States. During the 1964 earthquake, lands within the Kenai Fjords subsided three to six vertical feet, while in Lake Clark and Katmai, coastal lands rose. The network contains at least 17 "active" volcanoes. Katmai National Monument was created to preserve the famed 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 Volcano. Aniakchak National Monument was created in recognition of the unique geological significance of its 6-mile-wide, 2,000-foot-deep caldera formed 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. Much of Kenai Fjords is a landscape of ice and tidewater glaciers formed by the forces of the Harding and Grewingk-Yalik Icefields as they plunge into the sea. Ten of the 34 tidewater and hanging glaciers that emanate from Harding Icefield are in the park.

> ***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…." (ANILCA).*

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, pattern of animal colonization, and evolutionary processes.

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 Kenai Fjords to sparsely glaciated Aniakchak on the Alaska Peninsula. The networks' varied coastline, numerous freshwater sources, and diverse geomorphology generate many combinations of physical factors, creating a microcosm of the Northern Gulf of Alaska. Kenai Fjord's rocky headlands with extreme wave exposure place in sharp contrast the protected low-energy beaches and broad intertidal flats at Katmai and Lake Clark.

SWAN coastal waters in the northern Gulf of Alaska lie in one of the most biologically productive nearshore ecosystems in the world (Sambrotto and Lorenzen 1986). What makes this region so productive? In the Gulf of Alaska, high tides, frequent storms, and persistent currents stimulate strong, vertical mixing along the continental shelf. Mixing brings essential nutrients from the water column to the surface euphotic zone, where they support phytoplankton growth (Hood and Zimmerman 1986). Nutrient rich water upwelled by the Alaska Coastal Current affects the entire network coastline and contributes to high productivity (Burbank 1977, Lees et al. 1980).

> ***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)*

Some key ecological features of the network coastline include: 1) sheltered salt marshes and tidal flats that support lush, brackish vegetation and large populations of benthic organisms and serve as important feeding and resting areas for brown bears (*Ursus arctos*), shorebirds, and fish; 2) cliffs, headlands, and islands that support seabird rookeries and marine mammal haulouts; 3) eelgrass and kelp beds that provide herring spawning areas and a nursery substrate that supports the base of the nearshore food chain; and 4) tidally influenced coastal freshwater streams that support wild stocks of anadromous salmon.

3) Aquatic Systems, Anadromous Fish, and Ecological Interrelationships - Wild anadromous fishes link the ocean, fresh water, and land in important functional ways, supporting a complex food web that crosses the land-water interface (Willson et al. 1998). The interrelationship between sockeye salmon (*Oncorhynchus nerka)*, brown bears *(Ursus arctos horribilis)*, and the structure and function of both aquatic and terrestrial ecosystems is a flagship ecological resource 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. This includes 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 Katmai. Aquatic systems in the western portions of Katmai and Lake Clark are so extensive that they form the template upon which biological systems at all levels are organized.

> ***Mandate: Lake Clark National Park and Preserve -*** *"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)*

Aquatic systems in the network are pristine in the sense that: a) natural watershed processes are operating, including disturbances such as floods and seasonal changes in flow; b) water quality is, by national standards, unimpaired (there are no designated [303(d), Clean Water Act] surface waters, although biogeochemical cycles have in all likelihood introduced unknown amounts of contaminants); and c) aquatic fauna diversity and productivity vary naturally in both time and space. Aquatic and terrestrial animals have likely had a very long, and probably co-evolutionary, relationship with salmon in each of these parks (Willson et al 1998; Gende 2002; Schindler 2003). For instance, studies in other areas have attributed higher growth rates or reproductive success in eagles, bears, and mink 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.

4) Wilderness-dependent Large Mammal Species and Species Interactions - Despite hunting and other human activities, all parks in this 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. Some key wilderness-dependent interactions include wolf-ungulate, brown bear-ungulate, carnivore-carnivore, predator-scavenger, and cyclic lynx-snowshoe hare (*Lepus americanus)* 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."*

Davis and Halvorson (1988) considered national park ecosystems to be "miner's canaries" and nowhere is this concept 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 spatial areas 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 persistence of wolverine 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.

5) Ecoregion and Biological Diversity - Southwest Alaska parks are a place *where land and water meet.* Lake Clark National Park is often called "one park, four Alaskas," referring to the diversity of landscapes relative to area. Although not as dramatic, this feature is shared by each of the network parks, which collectively span three Alaska climatic zones and 11 ecoregions (appendix F). This landscape diversity is a product of the interaction of climate, terrain, and tectonics. Network parks exhibit examples of the major stages of Alaska's history, including significant ongoing geological processes

> ***Mandate: Alagnak National 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)*

in the development of landforms and examples representing significant ongoing ecological and biological processes in the evolution and development of terrestrial, freshwater, and coastal ecosystems and their biotic communities.

Landscape diversity provides the template for relatively high biological diversity. Consequently, this region of Alaska is a crossroad for many species of plants and animals. Some have described peninsulas as resembling a chain of islands upon which species may “hop” in order to disperse from mainland populations to the distal ends of the peninsula (Noss and Cooperrider 1994). Numerous species of animals such as Dall sheep *(Ovis dalli),* black bear *(Ursus americanus*), and trumpeter swans *(Olor buccinator),* and plant communities such as coastal rainforest and boreal forest, reach the limits of their statewide range in southwest network parks.

Climate change and its influence on the distribution of plants and animals in this 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. Peninsula landmasses are likely to respond to climate change more rapidly and severely than insular areas because of a greater coast/interior ratio (Suffling and Scott 2002). Colonization by new species, distribution shifts by existing species, or changes in life cycle patterns such as the timing of migrations, all have implications for park management and resource protection.

D. Formation of the Network and Approach to Planning a Monitoring Program

The Southwest Alaska Network is following the basic approach to designing a monitoring program, which involves five steps, described in detail in the Recommended Approach for Developing a Network Monitoring Program:

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.
4. Select indicators and specific monitoring objectives for each.
5. Determine the appropriate sampling design and sampling protocols.

These steps are incorporated into a three-phase planning and design process that has been established for the NPS monitoring program. Phase 1 of the process (described in this report) involves defining goals and objectives; beginning the process of identifying, evaluating, and synthesizing existing data; developing draft conceptual models; and completing other background work that must be done before the initial selection of ecological indicators (table 1-1).

Table 1-1. Overall timeline for the Southwest Alaska Network 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

The Southwest Alaska network received initial funding for biological inventories in FY2001 and vital signs monitoring-Phase I funding in FY2002. A biological inventory coordinator began work in May 2001, and a network inventory and monitoring (I&M) coordinator in November 2001 (table 1-2). Subsequent staff additions included a data manager in March 2002 and an aquatic ecologist in November 2002. Initial planning efforts began in January and February 2002 with the formation of a board of directors and a technical committee. Both the board and technical committee developed and adopted a charter.

The three-member SWAN Board of Directors consists of two superintendents representing the park units and the Alaska Regional Inventory and Monitoring (I&M) coordinator. The Southwest Alaska Network I&M coordinator and the Alaska regional science advisor serve as non-voting members of the board. The seven-member technical committee consists of the chiefs of resource management from each park unit in the network and the SWAN I&M coordinator (chairman). The committee also includes three advisors who do not directly work for the parks: NPS Alaska Region I&M coordinator, NPS-AKSO regional ecologist, and a USGS-Alaska Science Center fish and wildlife biologist who serves as a liaison to NPS for long-term monitoring.

Table 1-2. Summary of events in the organization of the Southwest Alaska Network and planning during Phase 1.

Date	Event
2001	
November	Network coordinator entered on duty.
2002	
January	Board of directors established, first board meeting held, BOD charter approved.
February	Technical committee (TC) established, TC charter approved, data manager entered on duty.
March-May	Technical committee meetings held to develop strategy for Phase I

Date	Event
	planning.
June-July	Prepared for coastal scoping workshop.
August	Held coastal nearshore scoping workshop.
September	Prepared for freshwater scoping workshop.
November	Held freshwater scoping workshop; aquatic ecologist (term) entered on duty.
December	Prepared freshwater scoping workshop summary.
2003	
January-February	Developed baseline survey and pilot project study plans.
March	Prepared for terrestrial scoping workshops.
April	Held terrestrial vegetation and fauna scoping workshop.
June-August	Prepared Phase I report.

During March and May 2002, the 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: 1) 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); 2) logistical challenges of meeting as a group because park staff are based in three different rural Alaska locations; and 3) a desire by technical committee members to participate collectively as a single team throughout the planning process.

Scoping Workshops - In light of these considerations, the technical committee elected to use 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: 1) review/refine conceptual ecosystem models and monitoring questions; 2) identify drivers of change and why it is important to understand them; and 3) 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.

Most workshops had a community or ecosystem focus and workshops were ordered in sequence: ocean⇒ freshwater⇒ terrestrial (table 1-3). 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 “flow” with the process. The workshop summaries created 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 or "notebook" was mailed to participants one month before the workshop to familiarize them with the landscape and stimulate more discussion and comment (appendix E).

Table 1-3. 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 Southwest Alaska network.

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

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. Summary reports were sent to participants and posted on the network website (appendix F). Workshop notebooks and summary reports also were circulated for technical review and comment by scientists who did not attend the workshops (table 1-4). 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 1-4. Technical reviewers of scoping workshop summaries, Southwest Alaska Network.

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	Marine intertidal ecology and monitoring, population dynamics of benthic marine invertebrates
Mark W. Oswood Professor of Zoology University of Alaska - Inst of Arctic Biology Bonanza Creek LTER	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; plant-animal interactions; effects of climate change on subalpine plant communities
Michael Shephard Ecologist US Forest Service State and Private Forestry	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	Large mammal population dynamics, forest wildlife habitat relationships, conservation of landscape biodiversity

Issues affecting water quality, 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 included: a) identifying and evaluating existing monitoring efforts, historic data, and information needs; b) developing a list of biological, chemical, and physical parameters for monitoring; and c) determining watershed and water body features. 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*.

Data Mining - The purpose of data mining was to find and catalog data and information relating to natural resources in the park or its vicinity to support the development of a monitoring plan. Data mining has been completed for Kenai Fjords National Park and Lake Clark National Park and Preserve. A follow-up to the Information Management Plan and modifications to the bibliography database for these two parks was completed in 2004. Data mining for the Alagnak River, Aniakchak, and Katmai, is scheduled for fall 2004.

Products from data mining primarily consist of two types of documentation: a bibliography and metadata. The bibliography documents formal and informal reports,

articles, and books; whereas metadata information documents databases, geographic information system (GIS) data, and spreadsheets. Both of these documents will be searchable using the National Park Service, NPS Focus website (http://focus.nps.gov/).

To organize the above documents, network data managers developed a natural resource directory structure based on park staff needs. It drafted an information management plan for the parks to help with future projects and products. The plan explains the flow of information throughout a project and addresses backups of the natural resource computer files, data security and maintenance, project organization, and hardcopy document management.

Legacy data with very little known information about them were also organized and documented, but with less strict standards. This consisted of creating computer readme.txt files, documenting what is known about the information, and creating a "parking lot" directory of past employees' projects. It also consisted of general documentation of hardcopy file folders of past employees.

A completed list of metadata records and a bibliography database are useful products; but because they are difficult to digest and fully comprehend, a summary report of the data was generated consisting of the title, date, data type, publisher, and abstract. This summary is interactive and available on the SWAN website. A bibliography listing of each park was also generated into a report; it is also available as a .pdf file on the SWAN website: http://www.nature.nps.gov/im/units/swan/index.cfm
or it can be searched through the NatureBIB website (password required): https://science1.nature.nps.gov/naturebib/.

For the benefit of other data managers and park staff and to document the steps used in this project, "cheat sheets" were developed to provide direct technical instructions to accomplish a particular task. The sheets are included as appendixes in the Data Mining Summary Report (appendix H).

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 resource 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 (appendix D).

E. Monitoring Goals, Objectives, and Questions

The overall goal of natural resource monitoring in parks is 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://www.nature.nps.gov/im/monitor/#GoalsObj).

NPS Servicewide 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 monitoring program of the Southwest Alaska Network will be designed around the five broad, servicewide goals. This network of relatively undisturbed wilderness parks is, however, a unique resource and offers unique opportunities to learn about ecological systems minimally affected by humans. In recognition of this, servicewide goals 1 and 3 establish the primary framework for the monitoring in SWAN because they emphasize: a) establishing baseline reference conditions representing the current status of park and preserve ecosystems; and b) understanding 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 1-5). Objectives and questions were developed by the SWAN Technical Committee and revised based on review of conceptual ecosystem models, suggestions from scientists that participated in the scoping workshops, and comments from technical reviewers of the workshop summaries. Monitoring questions may be modified or additional questions posed as the list of attributes proposed for monitoring is narrowed during Phase II planning.

Table 1-5. Monitoring objectives and questions, Southwest Alaska Network.

Climate and Weather

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

1. What is the annual variability in quantity, timing and form of precipitation in network park ecoregions?

2. What are the patterns of direction, strength, and timing for storm tracks and wind? How do these affect storm surges on coastal systems?

3. What are the ranges and timing of seasonal temperature fluctuations?

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

1. How are current climate trends contributing to glacial retreat (and possible advances)?

2. 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 A. Understand how movements of the North Pacific and North American plates are affecting park terrains.

1. How does ongoing earthquake activity and resultant uplift and subsidence affect park lands, especially coastal zones?

2. What are the short and long term/ongoing effects of volcanism and ash (re)deposition on park ecosystems?

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

1. How rapidly are glaciers retreating now, relative to former eras? How are icefields changing in area and extent?

2. How are refugia and nunataks affecting patterns of plant and animal colonization?

3. How are changes in fresh water balance and sediment loads from glacial streams affecting coastal estuaries and large lake systems?

Marine Coastline- fjords and bays

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

1. What are annual trends in salinity and freshwater inflows?

2. Is sediment supply adequate to maintain estuarine habitats?

3. How is the relative composition of shorezone habitats changing (physical morphology and biotic communities)?

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

1. Is the distribution of coastal salt marshes changing, or are vegetation zones within salt marshes migrating?

2. How does the distribution and relative abundance of marine mammals fluctuate spatially or temporally?

3. How are changes in nearshore coastal food resources affecting species that live in the supratidal but forage in estuaries and the intertidal?

4. Are key species successfully reproducing?

Aquatic Systems- large rivers and lakes

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

1. How is water quality, including temperature, dissolved oxygen, conductivity and pH changing temporally?

2. How are the thermal dynamics of large lakes changing in relation to the duration or lack of winter ice cover, changes in seasonal runoff, and storm frequency/intensity?

3. How are seasonal discharge and sediment regimes of rivers shifting? (i.e., higher winter flows and lower spring and summer flows?)

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

1. How is environmental warming affecting the physical and biological structure of lakes?

2. How are aquatic and riparian plant and animal communities responding to changes in the duration and extent of ice cover, lake levels, or sediment regimes?

3. How is anadromous salmon abundance and productivity changing?

4. How is the composition and abundance of resident fish changing? How are changes in resident fish influenced by cycles of salmon abundance?

Ecoregion and Biological Diversity

Objective A. Document rates and types of change in vegetation in response to environmental factors and human effects

1. How are vegetation communities changing across the SWAN region in response to the primary environmental drivers of climate, natural disturbances, biotic interactions, and human activities?

Objective B. Observe and understand ecological relationships and how the occurrence and distribution of fauna species and communities is changing.

1. Are species range shifts occurring, and are they occurring evenly among habitats?

2. Do nonnative species occur and are they increasing in distribution?

3. How is the composition of bird and mammal communities changing?

Wilderness dependent wildlife and species interactions

Objective A. Understand how species sensitive to humans are responding to habitat fragmentation, harvest, and increased human presence within or near parks.

1. How is the distribution and/or relative abundance of large and medium sized carnivores changing?

2. How are assemblages of carnivore prey species and vegetation communities changing temporally and spatially?

3. How is habitat connectivity changing for wide ranging wilderness species such as wolves?

Human Activities

Objective A. Understand how park and preserve ecosystems are affected by local and regional human activities.

1. How are methods and locations of human access changing?

2. How are visitor numbers and activities changing and which resources are at risk from these changes?

3. What land developments are occurring near and on park lands and how do these affect park resources?

5. Are hydrocarbons and other toxins bioaccumulating in marine invertebrates or freshwater fish?

Objective B. Understand how park and preserve ecosystems are affected by global human development activities.

1. How are network ecosystems responding to global climate change?

2. How are changes in the north Pacific Ocean and Bering Sea affecting animals in and near park lands?

3. How are far field human development activities affecting air and water quality in and surrounding network parks?

4. Are atmospherically deposited or biotransported pollutants such as PCB's and methyl mercury accumulating in fish; and do their concentrations show geographic gradients?

F. Conceptual Foundation for Monitoring

The Southwest Alaska Network 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 what is “normal” and “abnormal” for each ecosystem. 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 Alaska, where biological processes are relatively slow and intrinsic dynamics of populations are high. In consideration of this, our conceptual foundation provides a guide for monitoring and research:

The Southwest Alaska Network 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) <u>Landscape-based monitoring</u>: 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 Southwest Alaska Network 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 kinds of 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 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 on the landscape for a long time, constraining processes or species occurrence and abundance for decades or centuries (Dale et al. 2000).

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

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 subarctic national parks, where biological processes are relatively slow and intrinsic fluctuations of populations are high, long-term observations are particularly necessary in order to separate human-induced change from naturally occurring processes.

In the past, natural resource research and management in Alaska parks has been characterized by short-term (1-3 year) projects and in some 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. Without long-term records, park managers cannot interpret the data they have collected and the *"invisible present"* persists.

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 Kenai Fjords looks very different and has a different biotic community structure than a rocky shoreline at Lake Clark.

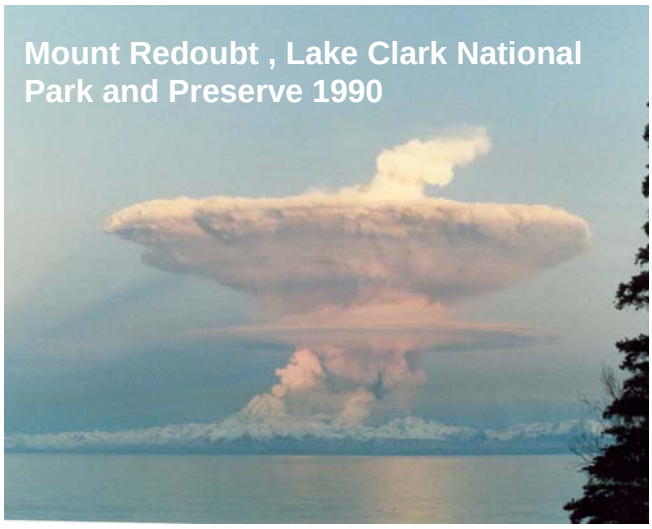
> *"Even though . . . site-specific trends enhance our ecological insights, they rarely answer many questions of significance about larger… systems." (Urquhart et al. 1998)*

Ecological systems are characterized by multiple drivers acting at multiple scales; complex patterns of spatial variability; and thresholds leading to the unexpected. 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, costs, and often in response to management issues that are perceived to be "localized." In field surveys, park biologists often make observations at different "places" 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 wide (network) spatial 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).

A reciprocal relationship often exists 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, park monitoring programs that target a few parameters or a single entity ,such as moose 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 make 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) are all critical to the development of strategies for monitoring.



A disturbance is an event that disrupts ecological systems and changes landscape patterns. 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). Disturbance can impose both temporal and spatial heterogeneity on ecological systems.

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 the Southwest Alaska Network. In addition, human-induced disturbances, such as oil spills, have similar potential to exert sudden, widespread, and long-term change.

d) Species Principle - Species respond to change, signal change, or directly affect ecological systems and landscapes in diverse ways**.** “Indicator species” (such as harbor seals) 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) have greater effects on ecological processes than would be predicted from their abundance or biomass alone (Power et al. 1996). “Ecological engineers” (such as beaver) 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) 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.

The recent (2002) discovery of Giant Kelp (*Macrocystis pyrifera*) along the Kenai Fjords coast is an example of the importance of the 'species principle.' Giant Perennial Kelp is a north Pacific endemic limited in distribution by winter sea surface temperatures. Until this recent finding, this species was unknown west of Glacier Bay, several hundred miles to the east. The presence of Giant Kelp off the Kenai Fjords coast represents a major range expansion and 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.

The impacts of changes in the abundance and distribution of focal species are diverse. Keystone species 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 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 the ecosystems. 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).

2) <u>Issues-oriented monitoring</u>: *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 reflect the status of network ecosystems and are 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 (appendix C). 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* (appendix B). 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 affecting ecosystems 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.

CHAPTER 2. CONCEPTUAL MODELS

A. Introduction

Conceptual models are visual or narrative summaries that describe the important components of an ecosystem and the interactions among them. Conceptual models help us develop a “mental picture,” that is often difficult to convey in words. 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.

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.

Developing conceptual models helps us gain an understanding of how park ecosystems work and promotes communication among scientists and park managers. For example, during a scoping workshop that focused on physical landscape drivers, participants exchanged ideas about how climate and landforms interact to influence ecosystem processes in the network. By illustrating the perceived relationships in diagram form, the participants reached a better understanding of the range of physical forces, how they operate, and how they influence biological communities.

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 are 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 formation of landforms. A narrower perspective, such as a trophic food web, is useful to illustrate the processes responsible for the formation of habitat types and ecological functions such as primary and secondary production. Specific models produced for scoping workshops included:

- 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 to 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 E, monitoring goals, objectives, and questions).

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 the 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 Southwest Alaska Network 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). 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 the 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 are all crucial to developing strategies for long-term monitoring.

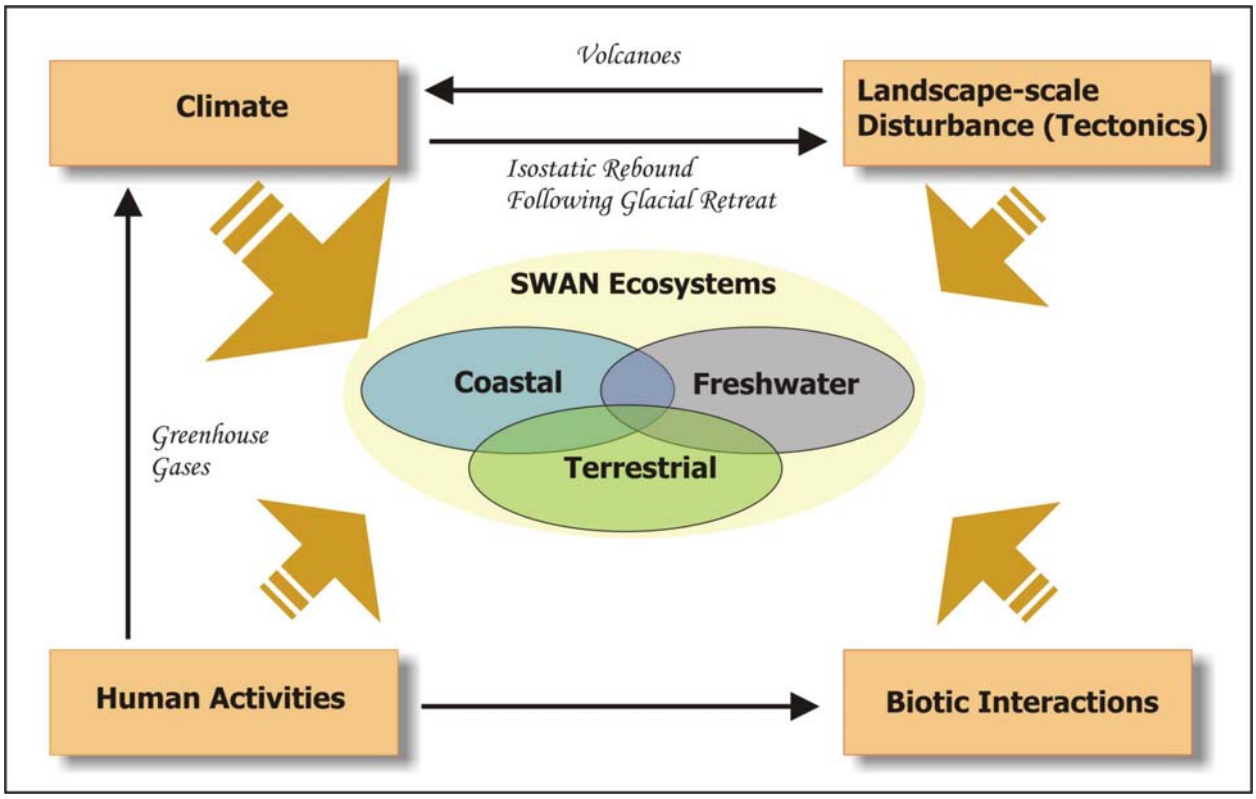
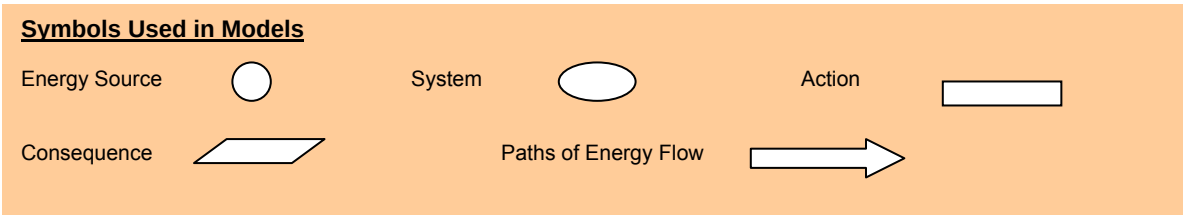


Figure 2-1. Holistic model. Major driving forces shaping park ecosystems are climate, landscape-scale disturbance, biotic interactions, and human activities. The model depicts the close linkages between the primary subsystems (coastal, freshwater, terrestrial) of park ecosystems and feedbacks between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



B. Landscape Drivers of Change

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). Because climate involves patterns of temperature and precipitation, the hydrologic cycle is the primary ecosystem driver, impacting both aquatic and terrestrial plants and animal communities, as well as the physical processes within the landscape. Understanding

the patterns of precipitation, flow, and storage of water is therefore central to understanding climate as a driving force in SWAN ecosystems.

Southwest Alaska Network parks are aligned along the Northern Gulf of Alaska where the climate is dominated by maritime influences. Characteristics of this maritime climate include low annual temperature flux, a relatively warm average annual temperature (above freezing), and high amounts of precipitation. 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.

Maritime influences interact with topography to create patterns of precipitation and wind. Topography in network parks is 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 2-3) and results in orographic precipitation on the windward side of the mountains and rain shadows on the leeward side.

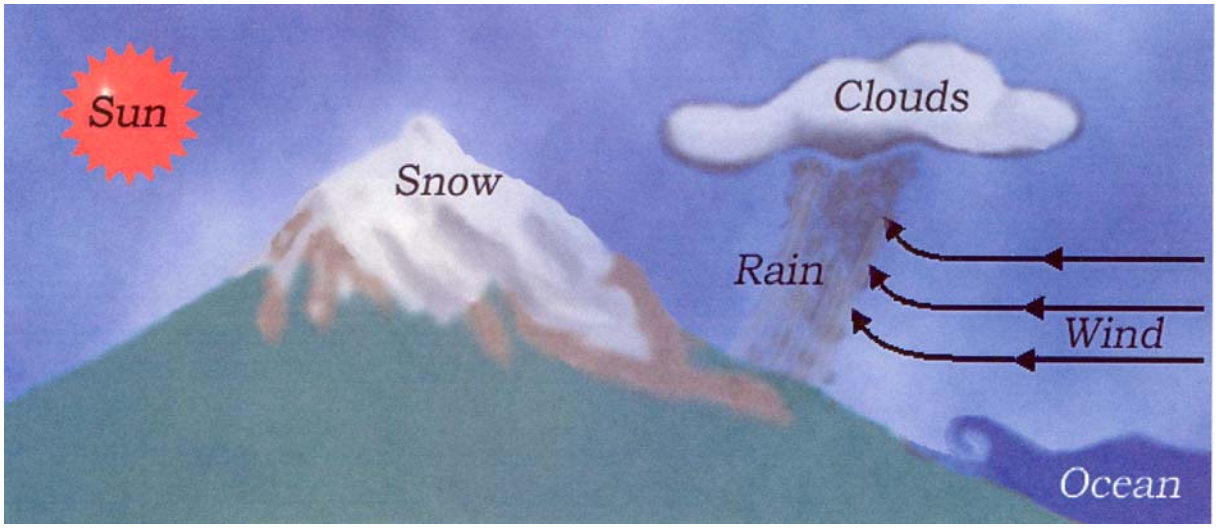


Figure 2-3. Physical interaction between topography and maritime air masses along the Northern Gulf of Alaska.

Coastal mountain ranges along the Northern Gulf of Alaska are distinguished by being one of the snowiest places on the planet. Coastal areas of Katmai, Kenai Fjords, and Lake Clark have the right combination of winter precipitation and oceanic air currents, as well as steep temperature and elevational gradients to generate impressive snowfall. The interplay among wind, topography, and snowfall creates a heterogeneous snow distribution. This affects vegetation and biotic processes by determining the local abundance of water 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 radiation via topographic position relative to incident insolation.

Topographic control of water inputs to lakes

Topographic position of lakes within a drainage system has a large influence on the relative importance of precipitation as compared to groundwater flow as inputs to lakes. This, in turn, has implications for water chemistry and biological processes affected by water chemistry.

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 network region demonstrate the annual climate patterns that result from these interactions between the dominant Aleutian Low winter storm system and network landforms. 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 (figure 2-4). Port Alsworth, located on Lake Clark, is cold and dry and has a continental climate similar to sites in Interior Alaska.

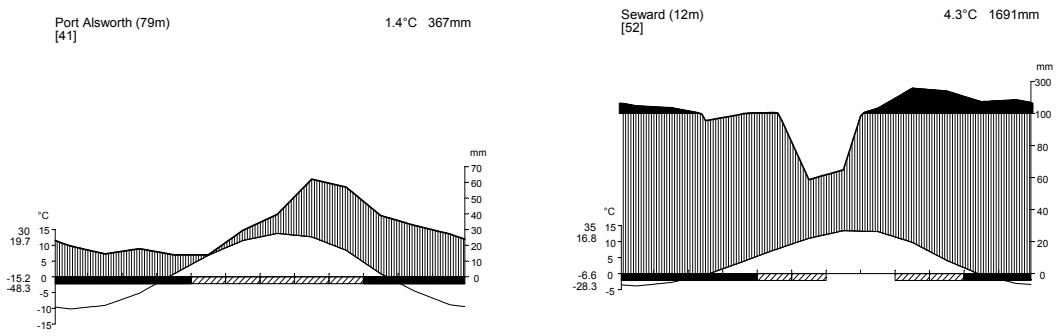


Figure 2-4. Walter Climate Charts (Walter 1963) depicting climatic variation in the SWAN. [Charts show long-term averages for precipitation and temperature for each month of the year (x-axis).] Note the warm average annual temperature and high amounts of precipitation at Seward, Alaska, located near the northern boundary of Kenai Fjords National Park. The drop in precipitation that occurs in summer reflects weakening of the Arctic High and a shift in storm track direction, such that Seward is in the lee of summer storms. In contrast, Port Alsworth, on the west side of Lake Clark National Park and Preserve, is in the rain shadow of the Chigmit Mountains, and has a cold, dry climate similar to many other 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. submitted). Instead of moving SE to NW, the storms now originate in the west, and move east. Within the 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, the Southwest Alaska Network is being affected by post-Pleistocene warming. The entire network was glaciated during the Pleistocene (Hamilton and Nelson 1989). The current pattern of glacier distribution in network parks reflects widespread retreat during the Holocene (the most recent geologic period). Aniakchak, located at the southern end of the network, has one small glacier on the interior caldera wall. Farther north in Katmai, glaciers are restricted to the higher mountains. Lake Clark includes both mountain and valley glaciers while Kenai Fjords 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 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. 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, paleo-ecological studies recently initiated by the network (2003-2005) will broaden our understanding of how current

ecological characteristics 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, and landslides) create and maintain a shifting mosaic of landscape patterns (figure 2-5).

Southwest Alaska Network parks lie on the border where two continental plates meet. Network parks are on the outer edge of the North American Plate, where it borders the Pacific Plate. The Pacific Plate is moving in a northwest direction at a rate of 5-8 cm per year, subducting (diving) under the North American Plate. The diving action of the Pacific Plate results in numerous earthquakes and contributes to the many active volcanoes in the region. Explosive volcanic eruptions, such as Katmai'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 and lakes can be partly or completely filled with pyroclastic debris, and massive deposits of debris avalanches and pyroclastic flows can overwhelm valleys.

During the 1964 Alaska earthquake, some portions of the Lake Clark and Katmai coastline subsided by more than six feet. To the east, uplift as much as 30 feet 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 are experiencing isostatic rebound caused by glacier retreat.

The tectonically active history of Southwest Alaska Network 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 successsional processes. The slower, smaller changes in land height due to isostatic rebound are also important, especially for the coastal zone. Although the annual changes might be small (measured in millimeters), the changes accumulate over decades and up to centuries.

On the annual/decadal scale, smaller scale disturbances such as flooding, windstorms, landslides, and insect outbreaks can be major drivers of ecosystem structure and function. Fire, which is a major disturbance elsewhere in Alaska, is 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 miles/hour) cause large-scale forest blowdown in Lake Clark, Kenai Fjords, and portions of Katmai. Depending on intensity, they can create single-generation stands of trees with uniform canopies or multi-

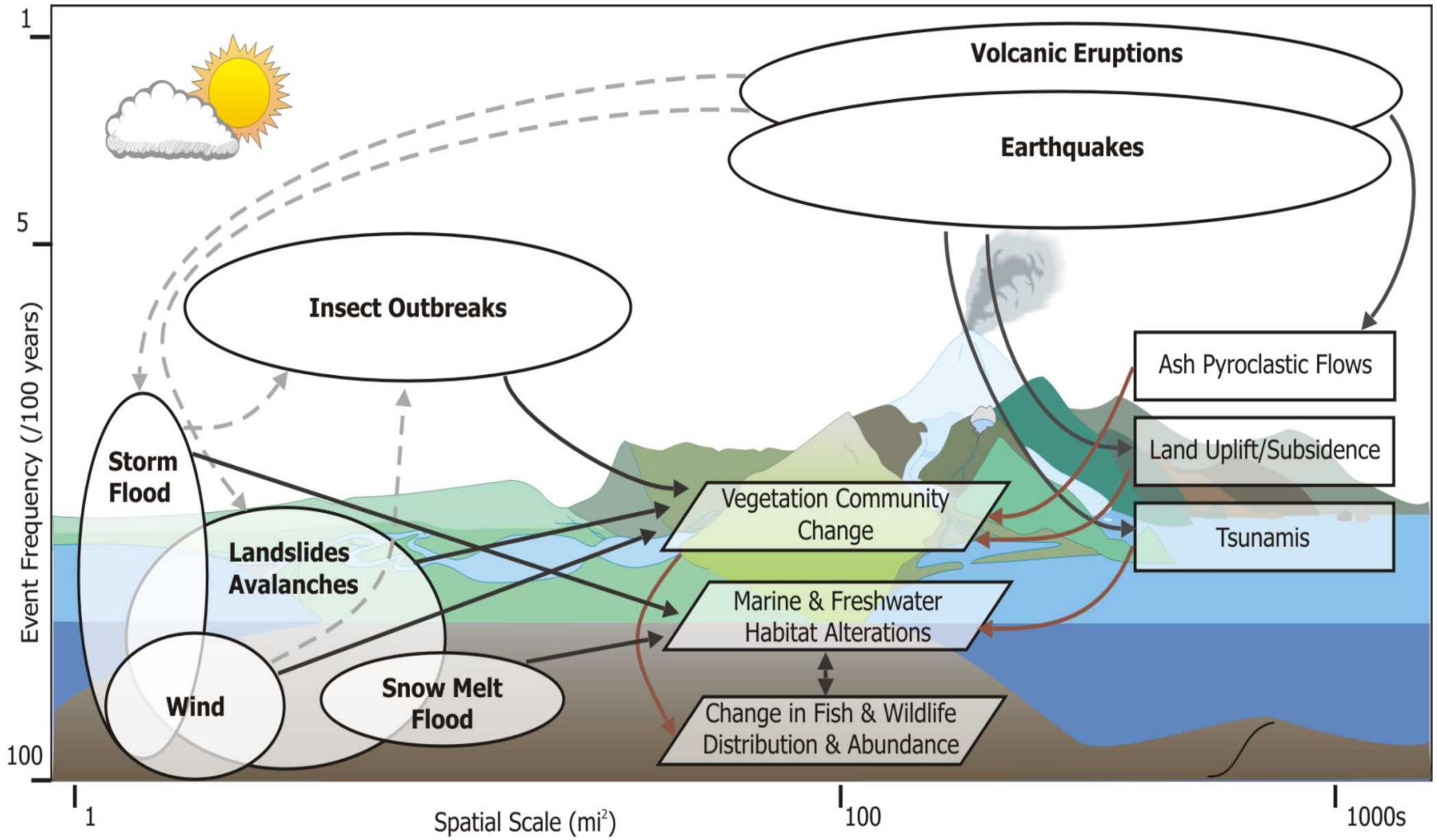


Figure 2-5. Landscape Disturbance Model. Frequency, scale, and consequences of natural disturbances in the Southwest Alaska Network. Large-scale disturbances (volcanic eruptions, earthquakes, tsunamis) and more frequent smaller-scale disturbances (insect outbreaks, floods, and landslides) create and maintain a shifting mosaic of landscape patterns.

generation stands with diverse canopy and size structures. These catastrophic winds can affect site productivity through tree uprooting and subsequent soil churning, exposure of mineral soil seedbeds, and create 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 network parks, but are important centers of biodiversity as they provide temporary refuges for pioneer species not found elsewhere. Landslides also promote downhill migration of nutrients and soil organic matter across the landscape.

The spruce bark beetle is the most significant natural mortality agent of mature spruce in Alaska, besides fire. Bark beetles are native species, and they play an important role in the ecosystem. For example, large-scale infestations have a significant influence on fish and wildlife habitats by changing their structure and function. Bark beetle-caused tree mortality provides important habitat for some species of wildlife, provides coarse woody debris to streams, and contributes to nutrient recycling. 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. Most 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. Hence, insect outbreaks originate and are most intense in areas prone to intense winds, such as Lake Clark Pass.

The SWAN is one of the few large landscapes on this continent where natural disturbance regimes exist relatively free from anthropogenic influence. Long-term monitoring presents a unique opportunity to determine the frequency, probability, variation, and patterns of disturbance and how plants and animals respond to changes in their habitat.

3. Biotic Interactions

Biotic interactions embody the “species concept” of landscape ecology discussed in chapter 1. Plants and animals regulate the flows of energy and nutrients in ecosystems through their consumption and digestion, as well as through their behaviors and death. Plants and animals also indirectly control these flows by regulating the population dynamics of other organisms with which they interact through competition, predation, herbivory, parasitism, mutualism, and commensalism. 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 2-6). Greater detail is presented in food web models for marine, terrestrial, and freshwater ecosystems (appendix G).

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 E). For example, brown bears influence coastal intertidal 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 mineral availability when they dig in montane meadows (Tardiff and Standford 1998). Moose alter succession of the forest, soil chemistry, and even the number and type of insects found where moose live (Rozell 2002).

The influx of anadromous salmon dramatically affects the trophic structure and functioning of the freshwater community. Most 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 fertilizer 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. Nutrients pass from the bodies of salmon into the soil and then into riparian vegetation and ultimately farther up the terrestrial food chain.

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, can alter ecosystem functioning, change species composition, 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.

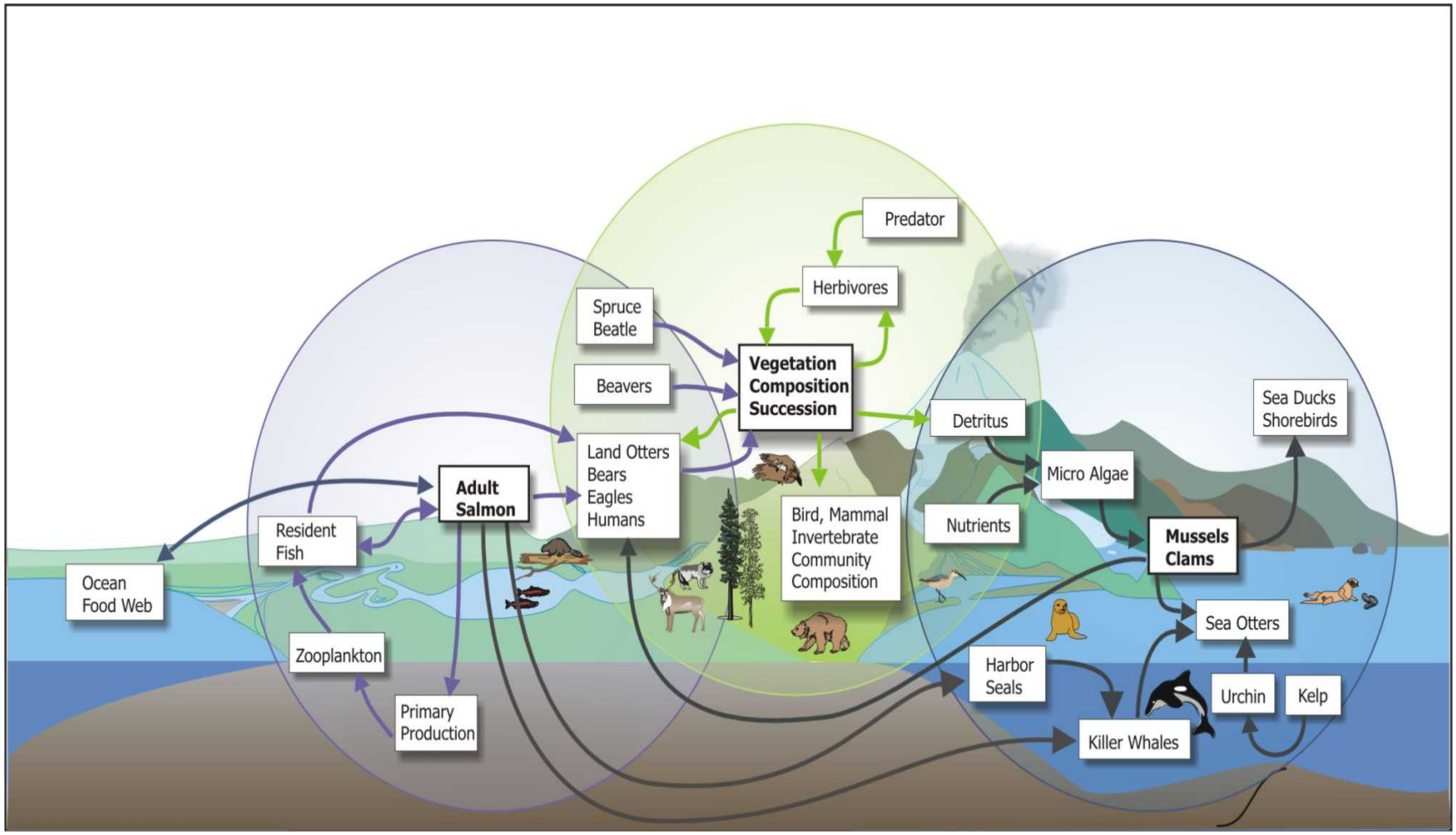


Figure 2-6. Biotic Interactions Model. ▪ Some important biological interactions in the Southwest Alaska Network involve the transport of nutrients by mobile species; ▪ herbivore-predator interactions that maintain a heterogeneous distribution of resources; ▪ "ecosystem engineers," such as beavers and clams, that structure habitats and influence the distribution and abundance of other species; ▪ and species, such as the spruce bark beetle, that create or modify disturbance regimes.

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 life cycle characteristics, role in nitrogen-fixing, widespread distribution, and increasing abundance. Alder is a pioneer species that aggressively colonizes disturbed or newly exposed soil. Once established, it can also invade other vegetation types. Very few other plants can survive under the canopy of alder, and its foliage and stems are avoided by most herbivores. Thus, the presence of alder determines plant and animal communities, and it can play an important role in ecosystem dynamics.

4. Human Activities (Stressors)

Human activities are drivers that can act as stressors and are important agents of change in Southwest Alaska Network ecosystems. During our workshops, conceptual models of human activities were refined to show relationships and interactions among stressors (figure 2-7). For example, climate warming due to anthropogenic greenhouse gases could increase susceptibility 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.

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: (1) effects on biogeochemical cycling, and (2) effects on biodiversity (Vitousek et al. 1997). For Southwest Alaska Network 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).

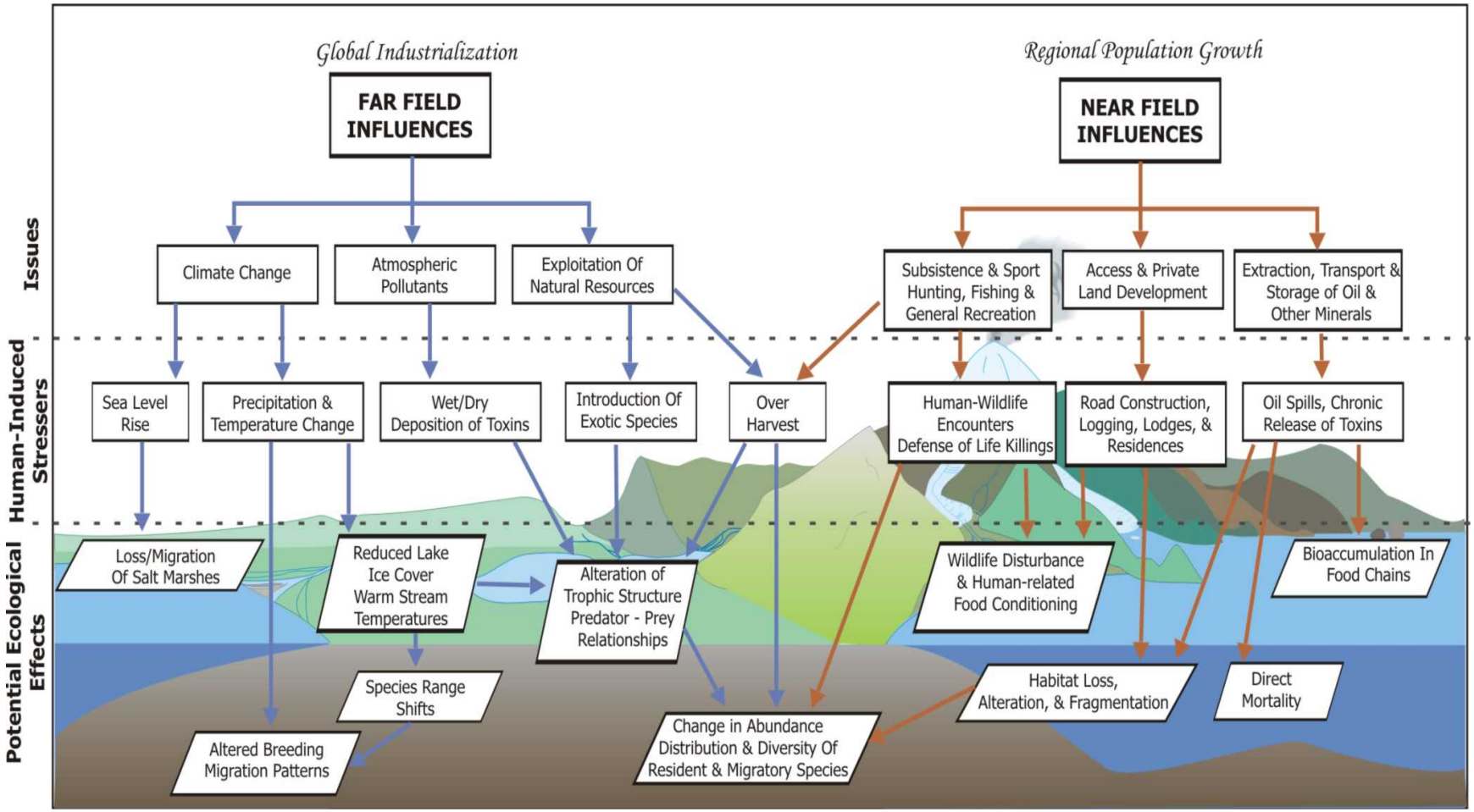


Figure 2-7. Human Activities Model. Far-field and near-field issues that act as stressors to affect ecosystems in the Southwest Alaska Network. Far-field human-related issues are manifested as climate change, long-distance air pollution, depletion of migratory species, and introduction of exotic species. . 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.

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 sped up 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 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 2-8). 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 snow-pack and shorter snow season. Changes in snow amount will lead to significant shifts in the timing and amount of runoff in network river basins, most of which originate in mountains and uplands.

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. As a result of a longer growing season and higher temperatures, montane alpine areas will shrink because of upward migration of tree species. Changes in temperature, precipitation, snow pack, storm frequency, and fire could affect the distribution, abundance, growth, and productivity of plants and animals. New populations of species may move into some areas and existing populations might move out or be lost. Some animal populations may become stranded 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. Because anticipation of changes improves our capacity to protect park resources, it behooves us to increase our understanding about the responses of plants and animals to a changing climate.

Air pollution - Long-distance transport and deposition of air pollutants such as persistent organic pollutants (POP) is an emerging concern in Alaska national parks. POPs are organic, human-made, highly toxic compounds. They persist in the environment and bioaccumulate in living organisms. They are able to travel long distances around the globe and migrate to northern climates because of

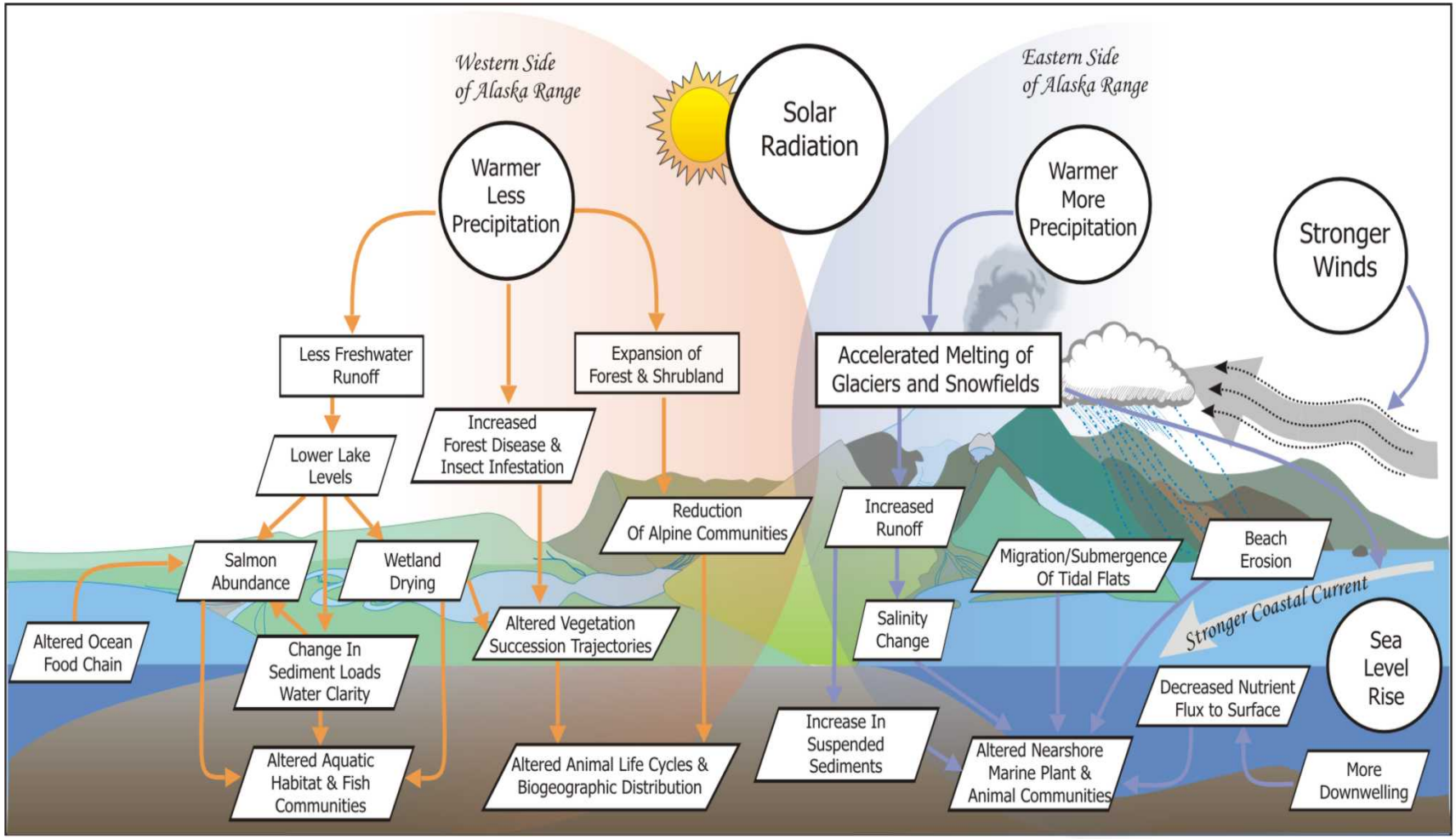


Figure 2-8. Climate Warming Model. Manifestations of a warming climate on Southwest Alaska Network ecosystems, habitats, plants, and animals. . Warming is likely to alter the hydrologic cycle in SWAN and influence processes that have created and maintained park ecosystems. Some anticipated changes include sea-level rise, greater storm intensity and frequency, altered patterns of seasonal runoff, rapid glacial retreat, and shorter duration of lake ice cover.

strong south-to-north air flows. The Arctic is, therefore, a potential contaminant storage reservoir and/or sink. Due to a constellation of different factors related to atmospheric patterns, the behavior of contaminants in the environment, temperature, and other factors 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.

Exotic Species - Invited experts attending our scoping workshops emphasized the importance of not underestimating the potential for invasive species to act as stressors for Southwest Alaska Network 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 (appendix J).

Of particular concern for the Southwest Network 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 the Southwest Alaska Network, 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 nuisance species, the same cannot be said of the invasive plants in the terrestrial environment. Inventories of exotic plants in selected national parks in Alaska have been conducted recently (Densmore et al. 2001). In the road-accessible Exit Glacier area of Kenai Fjords and in areas of constant human use at Katmai, Densmore et al. (2001) found several exotic weeds. Densmore et al. (2001) concluded that the parks most vulnerable to invasion by exotic plants are those, such as the Southwest Alaska Network, with moderate maritime climates.

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*) that breed on the Pribilof Islands winter in Cook Inlet and forage on coastal intertidal flats at Lake Clark National Park. 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 U.S., Mexico, Central and South America, the South Pacific, and Asia.

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 2-7). 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 Katmai'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 gallons of oil per year via the Trans Alaska 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 gallons) 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 gallons 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 vessel *Exxon Valdez* grounded in Prince William Sound, rupturing cargo tanks

and spilling approximately 11 million gallons of crude oil into the sea. The coastlines of Kenai Fjords, Katmai, and Aniakchak were oiled by this spill. Industrial practices have improved since the spill; but transport of North Slope crude oil via tankers in Prince William Sound still occurs, so the potential for additional spills exists. Clean up of the *Exxon Valdez* oil spill introduced people to the Katmai and Kenai Fjords coastlines, and increased subsequent public use, demonstrating an unanticipated interaction between stressors.

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.

Consumptive harvest of plants and animals by humans - Consumptive uses of plants and animals is permitted in Lake Clark, Aniakchak, and portions of Katmai under the Alaska National Interest Lands Conservation Act (ANILCA). This act allows for hunting, trapping, fishing, and the harvest of plant material in national parks and preserves and for subsistence uses by local rural residents. In national parks and preserves, ANILCA also requires the National Park Service, 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, sportfishing occurs in parks and preserves and sporthunting 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 performance 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: (1) direct impact to physical resources, plants, and animals from actions such as vehicle use and camping, and (2) indirect impacts, such as the disturbance or displacement of wildlife from actions like 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 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 and photography from both small fixed-wing aircraft and charter boat tours have increased greatly in the last decade in SWAN parks. These activities have the capacity to disturb bears and other wildlife over wider regions than fixed-point activities like camping and fishing.

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 trans-oceanic 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 1-160 acre parcels owned by an individual or a single business, to large contiguous parcels (>10,000 acres) that are owned by Native regional and village corporations. The network of private inholding arose from ANILCA, Alaska Native Claims Settlement Act (ANCSA), 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 Lake Clark and Kenai Fjords. In Lake Clark National Park and Preserve approximately 617,000 acres are in private or state ownership or are being adjudicated. This includes approximately 75 percent of the shoreline of Lake Clark and more than 90 percent of the park's Cook Inlet coastline. At Kenai Fjords, private economic development potentially could occur on 42,000 acres 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 inholding are at risk when development occurs. Most concerns of water quality are imbedded in private land development.

Access - Access is a common theme among near-field influences. Access concerns include the landing and beaching of floatplanes on lake shores and riverbanks, landing of wheeled planes on beaches and gravel bars, beaching of boats, concentrated camping sites associated with boating, and use of all-terrain and 4-wheel drive vehicles off roads. Access methods may involve disturbance of fish and wildlife and disruption of habitat and may provide the means for overharvest, poaching, and defense of life and property killings.

Because some network parks are surrounded by private lands, it is not inconceivable that they could become “islands in space,” as are many parks in the continental U.S. 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 Lake Clark and Katmai. In 2003, the State of Alaska allocated $10 million to study road development, including the construction of a 182-mile road linking King Salmon and Chignik on the Alaska Peninsula (figure 1-2).

C. 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 (figure 2-9), heat exchange, sediment and nutrient transport, and the actions of producers and consumers.

Storage and release of snow pack 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 it affects 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.

Figure 2-9. Precipitation falls on the land; water flows over the landscape; and it carves channels that carry water, nutrients, and sediment to other larger water bodies, and eventually to the ocean. In the process, water links ecosystems and creates habitats that form the biophysical foundation for living communities in the Southwest Alaska Network, including those of humans.

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 2-10). The 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 glacier 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 the 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 based on 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.

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 them in estuaries at the land-sea ecotone. 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 (appendix G). 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 Kenai Fjords and Katmai, 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 meso scale regimes of temperature and wind.

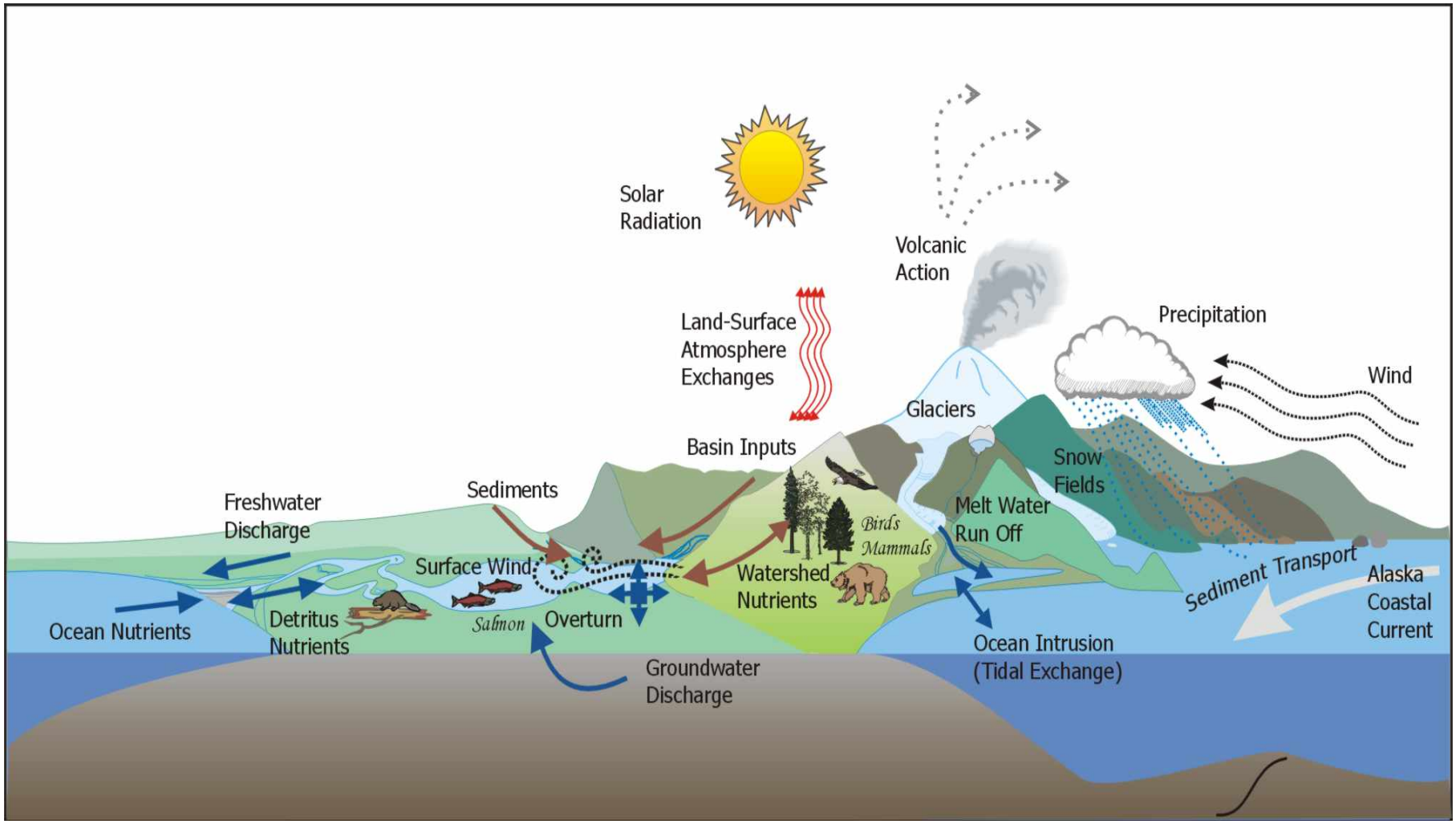


Figure 2-10. Ecosystem Interactions Model. Key linkages and interactions between the atmosphere, ocean, and land in the Southwest Alaska Network. Hydrologic and biochemical interactions with terrestrial and aquatic ecosystems control the formation of habitats and distribution of plants and animals.

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 salt water 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, 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 that we also look across the landscape to understand how systems interact.

D. Conclusions

Conceptual models explain our understanding of landscape-scale drivers and ecological interactions and how they may affect selected natural resource processes and components of the SWAN parks. The point of preparing and presenting these conceptual models is to: 1) BEGIN the discussion of the attributes, functions, and linkages described by the models; 2) assist in the formulation of specific monitoring questions and hypotheses; and 3) provide a basis for identification and selection of ecological vital signs for long-term monitoring.

Climate interacts with landform to influence ecosystems through patterns of temperature and precipitation and the hydrologic cycle, which affects both aquatic and terrestrial plants and animal communities, as well as the physical processes within the landscape. Climate influences are strongly tied to conditions in the North Pacific, especially location and strength of the Aleutian Low winter storm system and the shift in storm track direction that occurs in summer. Various broader scale influences (i.e., geophysical processes at the poles and in the tropics) affect how these annual patterns play out in longer time scales. Climate drives the timing and amount of water entering SWAN ecosystems and is a determinant of fundamental properties of the ecosystems. Climate within the network, although dominated by maritime influence, is not uniform due to topography and the network's particular location relative to the annual shift in storm track direction.

Infrequent large-scale natural disturbances (volcanic eruptions, earthquakes, tsunamis) and more frequent smaller-scale disturbances (insect outbreaks, floods, landslides) create and maintain a shifting mosaic of landscape patterns. The tectonically active history of Southwest Alaska Network parks indicates that potentially catastrophic changes (e.g., major eruptions, major earthquakes) could occur in the future and have widespread effects on park ecosystems. These major-event, landscape-scale

disturbances have the ability to set the clock back on the landscape and set in motion successional processes.

Many biotic interactions important as potential agents of change in network parks involve trophic relations among species. Salmon act as a keystone species, and changes in salmon runs and their timing could affect the structure and function of network ecosystems. 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.

Human far-field influences related to global industrialization are drivers of change the network needs to keep in mind for several reasons. Some changes in park ecosystems may be explainable only with a broader perspective (e.g., global climate changes), and focusing only on changes due to regional or park-specific threats might overlook threats with even greater potential to disrupt park ecosystems (e.g., invasive species). Near-field influences with the potential to drive change in network parks act very similarly in their effects. These near-field influences act primarily through their effects on fish and wildlife populations and habitats. Most visitor use, private development, fish and wildlife harvest, and access concerns relate to disturbance of fish and wildlife during critical life history phases, destruction or fragmentation of habitats, and overharvest. The other near-field influence, regional oil and gas development, would drive change through oil spills, which also act to disrupt fish and wildlife and their habitats.

Ecosystem connectivity is an important feature of the SWAN landscape. Some of the critical linkages involve water movement, heat exchange, sediment and nutrient transport, and the actions of producers and consumers. Climate, landscape-scale disturbance, biotic interactions, and human activities are drivers of change having the greatest relative impact on network parks. These drivers control the structure and processes in coastal, freshwater, and terrestrial ecosystems.

CHAPTER 3. SELECTION AND PRIORITIZATION OF VITAL SIGNS

A. Introduction

The National Park Service 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, 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

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, animals, and their habitats in SWAN. Consequently, the overall condition or "health" 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).

In this chapter we describe the process used to identify, organize, and prioritize a candidate set of vital signs for the SWAN. As described above, these vital signs are intended to characterize ecosystem condition and signal change across multiple scales of space and time. We explain how these candidate vital signs are linked to park resource management and protection issues, conceptual ecosystem models, and the network's monitoring objectives and questions. Finally, we provide some general information on each vital sign, including definition, importance, possible metrics, and how it relates to other vital signs in the context of an integrated monitoring program.

B. Vital Signs Selection

1) Framework - Considerable research and evaluation of ecological indicators has been done during the past decade. This includes several large-scale national level initiatives, as well as many regional and landscape level efforts by governmental and non-governmental organizations. An initial step in developing an approach for selecting vital signs was to review those existing models. Some of the literature and programs reviewed included:

- *Inventory and Prototype Monitoring of Natural Resources in Selected National Park System Units 1999-2000*, NPS, http://science.nature.nps.gov/im/monitor/vsmAdmin.htm#Prototypes
- *Criteria and Indicators: A Hierarchical Tool for Indicator Selection*, USDA Forest Service, 2002 http://www.fs.fed.us/institute/monitoring/framework_factsheet.htm
- *Ecological Indicators for the Nation*, National Research Council (NRC) 2000 http://www.biodiversitypartners.org/im/02.html
- *The State of the Nation's Ecosystems*, the Heinz Center 2002 http://www.heinzctr.org/ecosystems/
- *Categorization and Monitoring of Special Aquatic Habitats in the Sierra Nevada, California,* Pacific Analytics 2001 http://www.statpros.com/Final_Report.pdf
- *Gulf of Alaska Ecosystem Monitoring and Research (GEM) program*, *Exxon Valdez* Oil Spill Trustee Council, 2002 http://www.evostc.state.ak.us/gem/
- *The role of Biological Indicators in a State Water Quality Management Process*, Yoder 1998
- *Ecological Indicators for Narragansett Bay and Its Watersheds*, Kleinschmidt 2003 http://www.ci.uri.edu/Projects/PNB/Chafee-HUD/Indicators_Final.pdf
- *Selection of Indicators for Great Lakes Basin Ecosystem Health*, Bertram 2000 http://www.on.ec.gc.ca/solec/pdf/mainpaper-v4.pdf

Many of the indicator frameworks we reviewed are organized according to a set of predetermined goals or management questions that reflect key resource management issues associated with an ecosystem or ecoregion. Frameworks advocated in the recent Heinz's Center Report (The State of the Nation's Ecosystems, 2002) and The Partnership for Narragansett Bay Report (Ecological Indicators for Narragansett Bay and Its Watershed, 2003) focus on a hierarchy of physical, chemical, and biological indicators. They also use a set of ecosystem characteristics to organize and categorize ecological indicators.

The vital signs selection framework, adopted by the SWAN Technical Committee in May 2002, builds on these two examples and is described and illustrated in the *Goals Section* of each scoping workshop notebook, appendix E. We used this framework and professional judgment to identify candidate vital signs. Conceptual ecosystem models were used to aid selection and to ensure ecological relevance, particularly if the vital sign was a surrogate for the target process or resource. Candidate vital signs were also evaluated for their potential to contribute information as part of an “integrated set” designed to address multiple monitoring questions and to complement vital signs and metrics at other scales and levels of biological organization. Redundancy was permitted, particularly if it improved the likelihood of detecting and understanding changes or provided some unique and critical information.

2) Identification and Organization - Candidate vital signs were chosen during a series of scoping workshops held between August 2002 and April 2003 (chapter 1). These

workshops were "managed" brainstorming sessions built around three objectives; a) review and refine draft conceptual ecosystem models, monitoring objectives, and monitoring questions; b) identify natural and human-related drivers of change and why it is important to understand them; and c) identify candidate vital signs to monitor that provide informative signals about ecosystem condition. Workshop participants included a diverse group of experts; and developing a list of vital signs was not a difficult process, although knowing when to quit proved challenging.

Scoping workshop notebooks were a key element 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 played a role in reinforcing the importance of specific ecosystem drivers or components across systems and helping to generate an integrated set of vial signs. Vital signs identified at one workshop were often reexamined in greater detail at subsequent workshops.

Candidate lists of vital signs were summarized after each workshop (appendix F). In October 2003, the SWAN Technical Committee assigned three members to review and merge the vital signs into a single list. The TC empowered this "vital signs workgroup" to edit candidate vital signs that were not widely supported by experts during the workshops or by technical reviewers of the workshop summaries. The workgroup also revised and merged the network's monitoring objectives and questions to incorporate suggestions by workshop participants; and in some cases consolidate questions.

The initial combined list that emerged from the scoping workshops contained 61 vital signs. This list was reduced to 38 after duplicate entries were removed, similar indicators were merged under a single vital sign, or weakly supported vital signs removed (table 3-1). Vital signs considered, but not included:

Candidate Vital Sign	Rationale for Not Considering at this Time
Fire	localized occurrence in one network park unit
Floods	captured by other hydrologic vital signs
Landslides	localized occurrence
Relative sea level	captured by shoreline position
Fish kills	captured under ancillary event documentation
Wood frog	narrow distribution in network, captured by ancillary observations
Phytoplankton diversity	weak support by workshop experts and difficult to measure
Rocky intertidal Invertebrates	high interannual variability
Sea lion distribution	wide-ranging pelagic species not tied to near coastal
Native insect diversity	weak support by workshop experts and difficult to measure
Pika, Marmot	unknown distribution
Soundscapes	narrow application

The remaining 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.

Table 3-1. Draft vital signs and rankings, Southwest Alaska Network.

No.	*Rank*	*Category and Vital Sign*	*No.*	*Rank*	*Category and Vital Sign*
Climate			***Marine Biota***		
1	**5**	**Weather and climate**	**19**	**3**	**Shorezone habitat**
Geologic and Hydrologic Processes			**20**	**10**	**Saltmarsh**
2	**24**	**Lake and coastal ice**	**21**	**21**	**Kelp and eelgrass**
3	**15**	**Glaciers**	**22**	**16**	**Marine intertidal invertebrates**
4	**13**	**Snow cover**	**23**	**20**	**Sea otter and harbor seal**
5	**29**	**Streamflow**	**24**	**26**	**River otter**
6	**34**	**Stream and lake suspended sediments**	**25**	**31**	**Seabirds**
7	**37**	**River channel morphology**	***Terrestrial Biota***		
8	**27**	**Surface water hydrology**	**26**	**4**	**Vegetation Composition / Structure / Phenology**
9	**25**	**Coastal shoreline position**	**27**	**11**	**Sensitive vegetation Communities**
Chemical			**28**	**2**	**Brown and black bear**
10	**18**	**Water quality**	**29**	**12**	**Large and medium carnivores**
11	**35**	**Air quality**	**30**	**38**	**Landbirds**
Disturbance Regimes			**31**	**9**	**Ungulates**
12	**32**	**Earthquake activity**	**32**	**22**	**Bald eagle**
13	**17**	**Volcanic activity**	***Human (Stressors)***		
14	**19**	**Insect & disease outbreaks**	**33**	**8**	**Land cover and land-use change**
Freshwater Biota			**34**	**6**	**Visitor use**
15	**23**	**Resident fish**	**35**	**7**	**Resource harvest for subsistence and sport**
16	**1**	**Salmon**	**36**	**36**	**Marine debris and animal carcasses**
17	**30**	**Beaver**	**37**	**28**	**Bioaccumulated toxic contaminants**
18	**33**	**Aquatic birds**	**38**	**14**	**Exotic Species**

We had many options for organizing ecological indicators (Bertram and Stadler-Salt 2000), but we chose to build on the format presented in the holistic model of the network (figure 3-3). This organization is useful because it categorizes vital signs into "driving variables" (natural and human-related) and "response variables" (ecosystems, communities, and species). Climate, disturbance regimes, and geologic and hydrologic processes are uncontrollable driving variables that influence ecosystems. Human activities are controllable variables that can act as stressors to ecosystems. Biological and ecological conditions, such the existence and areal extent of a plant community or relative abundance of a species of animal, represent response variables. In the statistical context, both uncontrolled and controlled driving variables are the

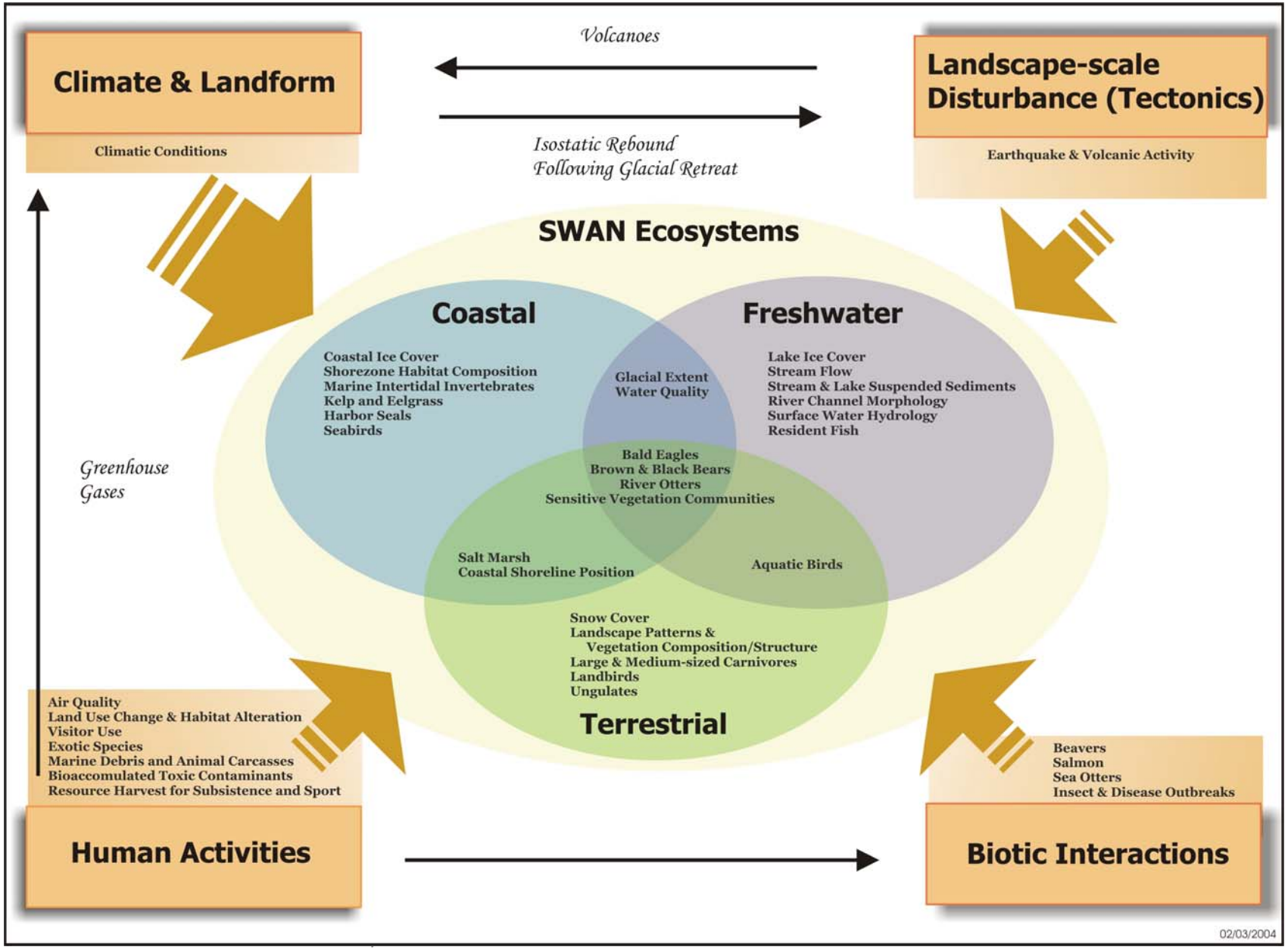


Figure 3-3. Holistic conceptual model, depicting drivers, ecosystems, and draft vital signs, Southwest Alaska Network.

independent (explaining or predictor) variables, while response variables are the dependent (effect or response) variables. Water and air quality are often considered intermediate variables that can play both roles, depending on the question under consideration (Vos et.al 2000).

Collectively, vitals signs drawn from all categories improve diagnostic power of monitoring and provide context and insight into the mechanisms of change. This feature distinguishes vital signs monitoring from programs that focus only on response variables, such many national bird monitoring programs.

During scoping workshops, monitoring objectives, questions, and conceptual ecosystem models were intended to focus discussions and assist in the identification of vital signs. To evaluate how well the list of vital signs addresses monitoring objectives, we assigned vital signs to relevant monitoring questions (table 3-2). In most cases multiple vital signs provide information of direct or indirect relevance to an individual monitoring question. No "unmatched" questions or vital signs emerged during this evaluation.

Recently, an NPS program-wide organization framework for vital signs was developed to facilitate communication and reporting among all 32 networks (table 3-3). The framework consists of three levels (Level 1, Level 2, and Level 3 categories) within which all network vital signs are grouped.

3) Prioritization of Vital Signs- The SWAN Technical Committee met on December 17-18, 2003, to review and prioritize the draft vital signs. In preparation for this meeting, the vital signs workgroup produced several summary documents:

- List of vital signs by category
- Ecosystem conceptual models from chapter 2 with vital signs highlighted
- Revised holistic model (figure 3-3) with vital signs inserted
- Natural resource protection issues paired with vital signs (appendix B) http://www.nature.nps.gov/im/units/swan/index.cfm?theme=monitoring_plan#appendices
- Monitoring objectives and questions paired with vital signs (table 3-2)
- One-page definition and statement of importance for each vital sign (appendix K)

During session one of the prioritization meeting, the technical committee reviewed each vital sign in the context of why it was selected and how it contributes 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. However, for some vital signs, such as river otter, committee members acknowledged that more information is needed on network-wide distribution and scope of inference as an "indicator" before final confirmation. In some cases vital signs were assigned to a different category or changes were made to the "possible metrics" listed for a vital sign. Committee members elected to rank water quality level 2 parameters and adopt the "core suite" without ranking.

Table 3-2. Relationship of candidate vital signs to monitoring objectives and questions.

SWAN Monitoring Objectives and Questions	Candidate Set of Vital Signs
Climate and Weather	
Objective A. Understand the natural range of variation in weather patterns across the SWAN parks.	
1. What is the annual variability in quantity, timing and form of precipitation in network park ecoregions?	Climatological conditions, streamflow, landscape patterns and vegetation composition/structure, sensitive communities
2. What are the patterns of direction, strength, and timing for storm tracks and wind? How do these affect storm surges on coastal systems?	Climatological conditions, shorezone habitats, coastal shoreline position
3. What are the ranges and timing of seasonal temperature fluctuations?	Climatological conditions, landscape patterns, and vegetation composition/structure
Objective B. Understand general climate trends in network parks, including changes due to Pleistocene ice retreat and global climate change.	
1. How are current climate trends contributing to glacial retreat (and possible advances)?	Climatological conditions, glacial extent
2. 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?	Climatological conditions, lake and coastal ice, snow cover, streamflow
Dynamic Landform Processes and Patterns	
Objective A. Understand how movements of the North Pacific and North American plates are affecting park terrains.	
1. How do ongoing earthquake activity and resultant uplift and subsidence affect park lands, especially coastal zones?	Earthquakes, coastal shoreline positions, shorezone habitats, salt marshes, kelp and eelgrass, marine intertidal invertebrates, sensitive communities
2. What are the short and long term/ongoing effects of volcanism and ash (re)deposition on park ecosystems?	Volcanoes, suspended sediments, water quality, air quality, landscape/landcover changes, sensitive communities
Objective B. Understand effects of Pleistocene and Little Ice Age glaciations on SWAN ecosystems.	

SWAN Monitoring Objectives and Questions	Candidate Set of Vital Signs
1. How rapidly are glaciers retreating now, relative to former eras? How are icefields changing in area and extent?	Glacial extent, snow cover, sensitive communities, landscape/landcover changes
2. How are refugia and nunataks affecting patterns of plant and animal colonization?	Sensitive communities, landscape/landcover changes, landbirds, ungulates
3. How are changes in freshwater balance and sediment loads from glacial streams affecting coastal estuaries and large lake systems?	Streamflow, suspended sediments, surface hydrology, coastal shorelines, water quality, resident fish, salmon, marine intertidal invertebrates
Marine Coastline - fjords and bays	
Objective A. Understand long-term changes in the physical and chemical features of coastal habitats	
1. What are annual trends in salinity and freshwater inflows?	Water quality, shorezone habitats, marine intertidal invertebrates, streamflow
2. Are sediment supply and rates of accretion adequate to maintain estuarine habitats?	Water quality, shorezone habitats, suspended sediments, salt marshes, kelp and eelgrass
3. How is the relative composition of shorezone habitats changing (physical morphology and biotic communities)?	Earthquakes, shoreline position, shorezone habitats, salt marshes, kelp and eelgrass, marine invertebrates, sensitive communities
Objective B. Understand how key marine species and communities are responding to changes in habitat	
1. Is the distribution of coastal salt marshes changing, or are vegetation zones within salt marshes migrating?	Earthquakes, salt marshes, shorezone habitats, sensitive communities
2. How does the distribution and relative abundance of marine mammals fluctuate spatially or temporally?	Sea otters and harbor seals
3. How are changes in nearshore coastal food resources affecting species that live in the supratidal, but forage in estuaries and the intertidal?	Sea otters and harbor seals, river otters, marine invertebrates, seabirds
4. Are key species successfully reproducing?	Bald eagles, seabirds

SWAN Monitoring Objectives and Questions	Candidate Set of Vital Signs
Aquatic Systems- large rivers and lakes	
Objective A. Understand long-term changes in the physical and chemical features of large rivers and lake systems.	
1. How is water quality, including temperature, dissolved oxygen, conductivity and pH, changing temporally?	Water quality, resident fish, salmon
2. How are the thermal dynamics of large lakes changing in relation to the duration or lack of winter ice cover, changes in seasonal runoff, and storm frequency/intensity?	Lake and coastal ice, climatic conditions, streamflow, suspended sediments
3. How are seasonal discharge and sediment regimes of rivers shifting? (i.e., higher winter flows and lower spring and summer flows?)	Streamflow, river channel morphology, suspended sediments, resident fish, salmon
Objective B. Understand how ecological relationships are changing in rivers, lakes, and wetlands.	
1. How is environmental warming affecting the physical and biological structure of lakes?	Climatological conditions, lake and coastal ice, surface hydrology, water quality, resident fish, salmon
2. How are aquatic and riparian plant and animal communities responding to changes in the duration and extent of ice cover, lake levels, or sediment regimes?	Sensitive communities, resident fish, salmon, beavers, aquatic birds, suspended sediments, streamflows, lake and coastal ice
3. How are anadromous salmon abundance and productivity changing?	Salmon
4. How is the composition and abundance of resident fish changing? How are changes in resident fish influenced by cycles of salmon abundance?	Resident fish, salmon
Ecoregion and Biological Diversity	
Objective A. Document rates and types of change in vegetation in response to environmental factors and human effects.	
1. 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?	Landscape/landcover changes, sensitive communities, climatological conditions, earthquakes, volcanoes, insect and diseases, land-use changes, visitor uses, exotic species
Objective B. Observe and understand ecological relationships and how the occurrence and distribution of fauna species and communities are changing.	

SWAN Monitoring Objectives and Questions	Candidate Set of Vital Signs
1. Are species range shifts occurring, and are they occurring evenly among habitats?	Landscape/landcover changes, carnivores, ungulates, landbirds
2. Do nonnative species occur, and is their distribution increasing?	Exotic species, sensitive communities
3. How is the composition of bird and mammal communities changing?	Sea otter and harbor seals, river otters, seabirds, carnivores, landbirds, ungulates, bald eagles, subsistence patterns
Wilderness dependent wildlife and species interactions	
Objective A. Understand how species sensitive to humans are responding to habitat fragmentation, harvest, and increased human presence within or near parks.	
1. How are the distribution and/or relative abundance of large and medium sized carnivores changing?	Carnivores, subsistence patterns, brown and black bears
2. How are assemblages of carnivore prey species and vegetation communities changing temporally and spatially?	Landscape/landcover changes, sensitive communities, ungulates, salmon
3. How is habitat connectivity changing for wide ranging wilderness species such as wolves?	Landscape/landcover changes, Land-use changes, Visitor use, Carnivores, Bears
Human Activities	
Objective A. Understand how park and preserve ecosystems are affected by local and regional human activities.	
1. How are methods and locations of human access changing?	Land-use changes, visitor uses, landscape/landcover changes
2. How are visitor numbers and activities changing, and which resources are at risk from these changes?	Visitor uses, sensitive communities, brown and black bear DLPs, carnivores
3. What land developments are occurring near and on park lands, and how do these affect park resources?	Land-use changes, exotic species, sensitive communities, carnivores, brown and black bear DLPs
5. Are hydrocarbons and other toxins bioaccumulating in marine invertebrates or freshwater fish?	Bioaccumulated toxins, marine debris and animal carcasses
Objective B. Understand how park and preserve ecosystems are affected by global human development activities.	

SWAN Monitoring Objectives and Questions	Candidate Set of Vital Signs
1. How are network ecosystems responding to global climate change?	Climatological conditions, landscape/landcover changes, air quality,
2. How are changes in the north Pacific Ocean and Bering Sea affecting animals in and near park lands?	Climatological conditions, salmon, seabirds, sea otter and harbor seals, bald eagles, marine debris
3. How are far field human development activities affecting air and water quality in and surrounding network parks?	Water quality, air quality
4. Are atmospherically deposited or biotransported pollutants, such as PCB's and methyl mercury accumulating in fish; and do their concentrations show geographic gradients?	Bioaccumulated toxins, resident fish, salmon

Table 3-3. Southwest Alaska Network vital signs in the context of the program-wide vital signs organization framework of the National Park Service.

Southwest Alaska Network									
Level 1	**Level 2**	**Level 3**	**SWAN VS Name**	**Measures**	**ALAG**	**ANIA**	**KATM**	**KEFJ**	**LACL**
Air and Climate	Air Quality	IMPROVE-Visibility and particulate matter	**Visibility and particulate matter**	IMPROVE suite for visibility and fine particles		X			X
	Weather and Climate	Weather and Climate	**Weather and Climate**	Air temperature, precipitation, surface wind, solar radiation, relative humidity, snow depth	X	X	X	X	X
			Snow cover	Landscape-scale patterning; snow-cover date and snow-free date	X	X	X	X	X
Geology and Soils	Geomorphology	Glacial features and processes	**Glaciers**	Areal extent of glacial ice, photo points of selected glaciers		X	X	X	X
		Coastal / oceanographic features and processes	**Geomorphic coastal change**	Georeferenced position of the shoreline, beach profiles		X	X	X	X
		Marine features and processes	**Shorezone habitat**	Type and area (km) of coastline habitat classified by physical and biological criteria (i.e. sand flat, mud flat, bedrock platform)		X	X	X	X
		Stream / river channel characteristics	**River channel morphology**	Channel cross sectional profile	X	X	X	X	X
		Lake features and processes	**Lake and coastal ice**	Areal extent and duration of Ice cover	X	X	X	X	X
	Subsurface Geologic Processes	Volcanic features and processes	**Volcanic activity**	Frequency, intensity		X	X		X
		Seismic activity	**Earthquake activity**	Frequency, intensity	X	X	X	X	X

Southwest Alaska Network									
Level 1	**Level 2**	**Level 3**	**SWAN VS Name**	**Measures**	**ALAG**	**ANIA**	**KATM**	**KEFJ**	**LACL**
Water	Hydrology	Surface water dynamics	**Surface water hydrology**	Areal extent and variability in surface water area	X	X	X	X	X
			Stream and lake suspended sediments	Areal extent, patterns, and phenology of turbidity	X	X	X	X	X
			Streamflow	Discharge or gauge/stage height	X	X	X	X	X
		Water chemistry	**Water quality core parameters**	Temperature; conductivity; pH; DO, (salinity ppt); nitrate, nitrite, phosphorous, organic nitrogen, dissolved organic carbon (DOC), chloride, silica, sulfate, chlorophyll, total suspended solids (TSS); volcanic markers	X	X	X	X	X
Biological Integrity	Invasive Species	Invasive/Exotic plants	**Invasive/Exotic plants**	Occurrence and distribution of non-indigenous plants	X	X	X	X	X
		Invasive/Exotic animals	**Invasive/Exotic animals**	Occurrence and distribution of non-indigenous animals	X	X	X	X	X
	Infestations and Disease	Insect pests	**Insect and disease outbreaks**	Species, timing, and areal extent	X	X	X	X	X
	Focal Species or Communities	Marine communities	**Kelp and eelgrass**	Presence and distribution		X	X	X	X
		Marsh/Estuary communities	**Saltmarsh**	Extent and composition, sediment accumulation rate		X	X	X	X
		Marine invertebrates	**Marine intertidal invertebrates**	Composition and distribution of infauna		X	X	X	X
		Fishes	**Resident fish**	Composition, abundance, and distribution	X	X	X	X	X
			Salmon	Abundance of adult spawners	X	X	X	X	X
		Birds	**Landbirds**	Composition and distribution patterns	X	X	X	X	X
			Aquatic birds	Selected species presence and distribution	X	X	X	X	X
			Bald eagle	Occurrence and productivity	X	X	X	X	X
			Seabirds	Occurrence, colony size, or productivity of Kittiwakes, Guillemots, Gulls, Kittlitz's		X	X	X	X

Southwest Alaska Network									
Level 1	**Level 2**	**Level 3**	**SWAN VS Name**	**Measures**	**ALAG**	**ANIA**	**KATM**	**KEFJ**	**LACL**
				Murrelet					
		Mammals	**Beaver**	Presence and distribution of active colonies	X	X	X	X	X
			River otter	Occurrence and relative abundance	X	X	X	X	X
			Brown and black bear	Abundance and sex-age composition at concentration sites; Defense of Life and Property Killings	X	X	X	X	X
			Large and medium carnivores	Occurrence and distribution of wolf, wolverine, lynx, and marten	X	X	X	X	X
			Ungulates	Distribution patterns of moose, caribou, Dall sheep, and mountain goats	X	X	X	X	X
			Sea otter and harbor seal	Distribution and relative abundance		X	X	X	X
		Vegetation communities	**Vegetation Composition / Structure / Phenology**	Species composition, spatial distribution, spatial extent, onset of greenness, senescence of greenness, snow free date, snow-cover date, berry production (biomass)	X	X	X	X	X
		Terrestrial communities	**Sensitive Vegetation Communities**	Areal extent and composition of refugia, alpine, riparian, south-facing steppe bluffs	X	X	X	X	X
Human use	Non-point Source Human Effects	Non-point source human effects	**Bioaccumulated toxic contaminants**	Type and level of concentration	X	X	X	X	X
			Marine debris and animal carcasses	Location and type of debris or carcass, frequency of occurrence	X	X	X	X	X
	Consumptive Use	Consumptive use	**Resource harvest for subsistence and sport**	Type and number of permits, species and volume of resource harvested	X	X	X		X
	Visitor and Recreation Use	Visitor usage	**Visitor use**	Type, level, and distribution	X	X	X	X	X
Ecosystem Pattern and Processes	Land Cover / Land Use	Land cover / Land use	**Landcover and land-use change**	Type, location, and areal extent of land cover types; areal extent and relative proportions of land use types on park and adjacent lands	X	X	X	X	X

During session 2, 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 the network considered most important without considering in detail the methods of measurement or their feasibility. The ranking is not intended to establish a numerical order in which vital signs will be implemented. For many vital signs, feasibility is closely tied to sampling design and will be addressed during Phase 3 planning. Prioritization criteria used by other national programs, including other NPS-Vital Signs Monitoring Networks, were modified for use by SWAN (figure 3-2).

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]

http://science.nature.nps.gov/im/monitor/docs/CriteriaExamples.doc

Figure 3-2. Criteria the Southwestern Alaska Network used to rank draft list of vital signs.

A Microsoft Access database was prepared to summarize scores and produce a ranking. Vital signs were ranked overall and within categories. Summary statistics were generated to assist in evaluating which vital signs accounted for the greatest deviation among committee members. During the final session (day 2), committee members reviewed and discussed the overall ranking and individual scores. Given the importance of several key focal species in SWAN, it is not surprising that salmon and bears emerged as the highest ranked vital signs. Coastal and terrestrial habitats ranked third and fourth, followed by human activities that affect habitats and animals. Physical processes and disturbance regimes, despite their importance as drivers of change, were not ranked among the top 10 vital signs.

Bird assemblages consistently ranked lowest in each biota category, and some vital signs that may be relatively simple and inexpensive to monitor were ranked low. At the close of discussions, committee members agreed to adopt this ranking contingent upon a 30-day review by themselves and other staff in their parks. No changes were submitted after this internal park review.

Following TC approval of the vital signs a preliminary draft of sections A and B of this chapter was prepared. This draft, along with appendix K, was provided to the board of directors in early February 2004. During March, a one 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 vital signs. Park-based meetings were chosen, instead of one meeting at a central location because it 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 board of directors.

Board members expressed satisfaction with the network's vital sign selection process and outcome. Questions centered around the challenges and costs of monitoring in large remote parks, vital signs that are currently being monitored by partnering agencies, the relationship of concurrently funded pilot projects to the list of vital signs, and the directions the planning process will take next. 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 year as new information becomes available. Board members approved the list of vital signs and signed the Phase II report.

C. Conclusions

Candidate vital signs were chosen during a series of scoping workshops held between August 2002 and April 2003. The initial combined list that emerged from the scoping workshops contained 61 vital signs. This list was reduced to 38 after duplicate entries were removed, similar indicators were merged under a single vital sign, or weakly supported vital signs removed. The technical committee reviewed each vital sign in the context of 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 draft list of vital signs in March 2004.

D. Plans for Phase III

During the next year we will review and evaluate vital signs based on feasibility. Vital signs will be retained if we think they can be measured with sufficient resolution and

provide the information required to detect or predict changes in a timely fashion. Compelling reasons for adding vital signs to the list will also be considered. Other planning efforts will address chapters 4-10 and include:

- an overall sampling design framework;
- development of sampling protocols or protocol development summaries;
- a data management plan for entering, editing, storing, and archiving data collected by the various components of the monitoring program, including metadata procedures;
- administrative and staffing framework;
- implementation strategy and schedule;
- and a budget projection for operational monitoring,

ACKNOWLEDGMENTS

This report represents the contributions of many people. We acknowledge SWAN Technical Committee members Ian Martin, Shelley Hall, Troy Hamon, Judy Putera, and Page Spencer. Wendy Bryden, Mike Tetreau, Tammy Olson, Joe Miller, Bill Thompson, Amy Miller, Laurel Bennett and other network park staff assisted by assembling information or attending meetings. We also thank Bruce Giffen, Joel Cusick, Blain Anderson, Nancy Deschu, Janis Kozlowski, and other staff of the Alaska Regional Office; Central, Arctic, and Southeast Alaska Network staff; and the many guests from other agencies and universities who attended and participated in scoping workshops. Special thanks to Thetus Smith for editing this report and to Alaska Region I&M Coordinator Sara Wesser for the many roles she played in assisting this network.

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

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

ANILCA is the Alaska National Interest Lands Conservation Act or Public Law 96-487 - Dec. 2, 1980, that 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 >.

Attributes are any living or nonliving features or processes 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 Indicator. 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."

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.

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 decision making and land-management practice that considers the full suite of organisms and processes characterizing and comprising 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.

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.

Function is the role that any process, species, population, or physical attribute plays in the interrelation between living and non-living components of ecosystems.

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 - 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 differs from inventory in adding the dimension of time, and the general purpose of monitoring is to detect changes or trends in a resource. Elzinga et al. (1998) defined monitoring as "The collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective." 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.

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 (a) foreign to that system or (b) 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 is a unidirectional change.

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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APPENDIXES

A. Network Park Ecological Profiles

Ecological profiles contain detailed information on network parks that was compiled from resource management plans, published and unpublished park reports, and interviews with current and former park staff. Profiles have a common format and include sections on physical resources, biological resources, ecoregion descriptions, former and current natural resource management projects, and resource protection issues.

B. Resource Management Issues Summary

Issues summaries were prepared by natural resource staff of network parks during 2002. The summary is presented in table format with resource issues on the y-axis and ecosystems on the x-axis. The table depicts the relationship between issues and park/preserve ecosystems and provides an index to the frequency with which common issues recur across the landscape. Issues of greatest concern often correspond to those with the highest scores.

C. Past and Present Resource Monitoring Summary

Monitoring summaries were prepared by natural resource staff of network parks during 2002. The summary lists all current and former “monitoring” conducted in parks including starting date, duration, objective(s), and the format and location of data or reports.

D. Monitoring by Other Agencies and Partnership Opportunities

Collaborative monitoring opportunities are identified for physical and biological resources in coastal, terrestrial, and freshwater ecosystems. Federal, state, local, and private entities are listed along with their mission, description of current monitoring, and how they might interface with vital signs monitoring by the Southwest Alaska Network.

E. Scoping Workshop Notebooks

Notebooks contain pre-workshop background material, such as ecological profiles of the parks, preliminary monitoring questions, and maps. Notebooks were mailed to participants one month before the workshop to familiarize them with the workshop and solicit comments on the contents. Participants were encouraged to make written comments in their notebooks and return them to network staff at the conclusion of the workshops.

F. Scoping Workshop Summaries

Scoping workshop discussions were recorded and compiled into a workshop summary report. Summaries contain comments and recommendations by invited experts, revised conceptual models, and lists of drivers and candidate vital signs for monitoring. Draft summary reports were sent to participants and the SWAN Technical Committee for review. After revision they were circulated for technical review and comment by scientists who did not attend the workshops.

G. Food Webs

Food web models were constructed for coastal, freshwater, and terrestrial ecosystems using standard, bottom-up energy flow circuit diagrams. Models were presented and discussed at scoping workshops and underwent numerous

revisions.

H. Data Mining Summary Report.

This report summarizes the progress during Phase I, including revision of electronic directory structure for KEFJ and LACL, development of metadata for both parks, and updates of the NPS bibliography and Nature BIB.

I. Network Maps

Maps were prepared for meetings and scoping workshops. Maps included in this appendix depict park unit boundaries, park ecoregions, park landcover, precipitation patterns, and geology.

J. Exotic Species Threats

This Aquatic Nuisance Species Management Plan (Alaska Department of Fish and Game 2002) identifies the most important species of immediate concern for Alaska.

K. Vital Sign Descriptions

Each vital sign is defined and discussed with respect to significance, proposed metrics, and ranking. Information is also provided on methods, limitations, current monitoring, and related vital signs.

APPENDIX K.

Vital Sign Descriptions- *What is this Vital Sign and Why Is It Important?*

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Climatic

Vital Sign 1: Weather and Climate

BRIEF DESCRIPTION: Basic climatological measurements include: temperature (maximum, minimum and average), precipitation, wind (direction and speed), relative humidity, and snow depth.

SIGNIFICANCE: Because climate is a basic driver of all ecological systems, these measurements are important for understanding the relationship between climate and other components of biotic and abiotic systems. Without climate data, it is impossible to appreciate the causes of a variety of ecosystem changes—from vegetative cover changes to shifts in aquatic systems. In fact, the most important components of useful climatological measurements are the length and accuracy of the data. Maintenance of climate stations, therefore, is extremely important in order to assure high-quality data.

PROPOSED METRIC: Air temperature (maximum, minimum and average), precipitation, surface wind (direction and speed), relative humidity, and snow depth

RANK: overall 5, within category 1

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Automated weather stations with satellite up link. Frequency: generally hourly average, max, and min

LIMITATIONS OF DATA AND MONITORING: Mesoscale and network applications may require modeling based on meager high elevation and coastal data sets.

CURRENT MONITORING: KATM and ANIA lack any type of weather station within their boundaries. KEFJ has one NWS COOP weather station located near Exit Glacier and LACL has weather stations at Stoney Strip (RAWS) and in Port Alsworth (RAWS, NWS COOP). A detailed evaluation of all climatic monitoring in southwestern Alaska has been completed: http://www.nature.nps.gov/im/units/swan/Documents/Maps/SWAN_WeatherStationAssessment.pdf

In FY04 a cooperative weather station with the NOAA River Forecast Center will be installed on the Harding Icefield, and a modeling project was funded to identify and prioritize areas for potential weather station deployment.

KEY REFERENCES:

Stenseth, N. C., A. Mysterud, G. Ottersen, J. W. Hurrell, K.-S. Chan, and M. Lima, 2002: Ecological effects of climate fluctuations. *Science,* 297, 1292-1296.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Climate is related to all other physical and biological issues and vital signs.

OVERALL ASSESSMENT: It is essential to understand the influence of climate variability on biotic and abiotic systems.

Geologic and Hydrologic Processes

Vital Sign 2: Lake and Coastal Ice

BRIEF DESCRIPTION: This vital sign refers to lake ice formation, contiguous ice cover, broken ice cover, ice thickness, and duration of ice cover. It also includes anchor ice that forms in coastal intertidal zones and estuaries as a result of tidal inundation.

SIGNIFICANCE: Lake ice is an important hydrologic variable which increases in significance with latitude and elevation, and produces a diverse array of impacts on physical, chemical, and ecological processes. Formation and movement of coastal sea ice may affect prey and predators directly by bulldozing intertidal habitats and controlling access to open water or preferred habitats; or indirectly, as changes in the sea-ice cover affect other species that serve as food. Lake ice formation, thickness and break-up are also key indicators of regional climate especially in data-sparse regions which characterize much of the network.

PROPOSED METRIC: Areal extent and duration of ice cover

RANK: overall 24, within category 2

TYPES OF MONITORING SITES: lakes, coastal shorezone

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: The presence of ice cover on the earth is relatively easy to detect from satellites due to the large change in a landscape's reflection, emission, and transmission characteristics.

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: NOAA Pacific Alaska River Forecast Center has an observer network and database with records for Big River Lakes and Port Alsworth (LACL), King Salmon Creek (KATM) and two ice depth records for the Bradley River (near KEFJ).

KEY REFERENCES:

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RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Climatological conditions,

OVERALL ASSESSMENT: Dates of the formation of ice on inland water bodies in autumn and its melting in spring are a simple inexpensive means of tracking a key driver of ecological change in freshwater systems.

Vital Sign 3: Glaciers

BRIEF DESCRIPTION: Glacial extent refers to surface area coverage of ice on the land. Advance occurs when a mountain glacier's terminus extends farther down valley than previous measurements, while glacial retreat occurs when the position of a mountain glacier's terminus is farther up valley than previous measurements or when a glacier ablates more material at its terminus than it transports into that region (NSIDC 2003).

SIGNIFICANCE: Glaciers are highly sensitive, natural, large-scale, representative indicators of the energy balance of both mountains and lowlands within SWAN. Glaciers are often referred to as natural "water towers" because of their capacity to store water for extended periods and to exert control on the surface water cycle through timing of discharge, volume and variability, and delivery of sediments.

PROPOSED METRIC: Areal extent of glacial ice, photo points of selected glaciers

RANK: overall 15, within category 2

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Methodological tools for efficiently tracking glacial extent include the analysis of satellite imagery, aerophotogrammetry and digital terrain information of various scales. Photo point documentation is commonly used for terminus monitoring. Frequency: 5-10 yrs

LIMITATIONS OF DATA AND MONITORING: Measurement of ice sheet margin may not provide timely information on volume changes.

CURRENT MONITORING: KEFJ has been monitoring the terminus position of Exit Glacier since 1987. The Geophysical Institute of the University of Alaska Fairbanks has conducted mass balance and volume change monitoring on Exit Glacier throughout the 1990's using airborne laser profiling techniques.

A glacial terminus photopoint project is being conducted by USGS in KEFJ in the summer of 2004, repeating photography taken by USGS glaciologist D.F. Higgins in 1909.

KEY REFERENCES:

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UNEP/GEMS, 1992. *Glaciers and the environment.* United Nations Environment Programme, Environment Library 9.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Glaciers are interrelated with virtually every physical driver in SWAN. Glacier forelands newly exposed in front of receding glaciers provide excellent natural laboratories to study plant succession and ecological relationships.

OVERALL ASSESSMENT: Fluctuations in glaciers are among the most sensitive indicators of climatic change. Knowledge of glacial changes is fundamental to understanding coastal, freshwater, and terrestrial ecosystems in SWAN.

Vital Sign 4: Snow Cover (area and phenology)

BRIEF DESCRIPTION: Snow cover refers to onset of snow accumulation, duration, and melt-off (disappearance). Snow cover duration determines the start and length of the growing season, and snow depth, structure and composition define subnivean temperatures and water and nutrient input.

SIGNIFICANCE: Snow is the dominant environmental factor in mountainous regions for more than half of the year. The properties of the snow cover influence the processes and species composition of subarctic ecosystems. Snow represents a major store of water which is released in the spring melt period and snow is an insulator that mediates the depths to which the soil freezes. In the alpine and subalpine, snow pack protects vegetation from the abrasive and dehydrating effects of wind, and wind driven snow, effectively limiting the height of woody vegetation to that of the snow pack. Snow also protects vegetation from excessive frost heaving. Vegetation community composition is strongly influenced by the relative duration of snow burial and exposure to wind and frost heaving.

PROPOSED METRIC: Landscape-scale patterning, snow-cover date and snow-free date

RANK: overall 13, within category 1

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Satellite coverage, weekly for annual coverage

LIMITATIONS OF DATA AND MONITORING: Like all components of the climate system, snow cover exhibits considerable variation from one year to the next in response to the natural variability of atmospheric circulation patterns which affect both snowfall and temperature.

CURRENT MONITORING: none, NRCS has four snow courses in Lake Clark and two in or near Katmai, but these measure snow accumulations and not area or phenology. A summary of all snow courses in Southwest Alaska has been completed:
http://www.nature.nps.gov/im/units/swan/Documents/Maps/SWAN_Weather_NRCS.pdf

KEY REFERENCES:

Brown, R.D., 2000: Northern Hemisphere snow cover variability and change, 1915-1997. *J. Climate* (in press).

Goodison, B.E. and A.E. Walker. 1993: Use of snow cover derived from satellite passive microwave data as an indicator of climate change. *Annals of Glaciology*, 17: 137-142.

Groisman, P. Ya, T.R. Karl, and R.W. Knight. 1994: Changes of snow cover, temperature and radiative heat balance over the Northern Hemisphere. *J. Climate*, 7, 1633-1656.

Robinson, D.A., K.F. Dewey and R.R. Heim. 1993. Global snow cover monitoring: an update. *Bull. Am. Meteorol. Soc.*, 74,, 1689-1696.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Climate, surface hydrology, vegetation composition and structure.

OVERALL ASSESSMENT: Snow cover duration is a valuable indicator of temporal variation in growing season for plants and the breeding season for birds in subarctic and alpine ecosystems. Studies on snow-vegetation interactions suggest that changes in snow cover have as important effects as changes in summer climate.

Vital Sign 5: Streamflow

BRIEF DESCRIPTION: Streamflow refers to the volume of water passing a point of reference (discharge) and varies with precipitation, surface temperature, and other climatic factors. For most streams (rivers), the highest water discharge is found close to the sea.

SIGNIFICANCE: Streamflow directly reflects climatic variation. Stream systems play a key role in the regulation and maintenance of biodiversity. Changes in streams and streamflow are indicators of changes in basin dynamics and land use.

PROPOSED METRIC: Discharge or gauge / stage height

RANK: overall 29, within category 5

SPATIAL SCALE: basin/watershed

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: There are standard techniques for measuring streamflow. Where more quantitative data are not available, study of changes in biomass distribution (especially woody plants) can provide reliable qualitative measures of hydrologic and geomorphic events spanning the past several hundred years

LIMITATIONS OF DATA AND MONITORING: Streams in flood, and on deltas, and alluvial plains, such as glacial outwash, are difficult to gauge. The effectiveness of streamflow as an indicator depends strongly on a well- designed, systematic network of monitoring stations.

CURRENT MONITORING: KEFJ: Resurrection River, Exit Creek, Nuka R* LACL: Johnson River, Iliamna River*. Historical locations: KATM: Brooks River, Alagnak River, Eskimo Creek*; KEFJ: Nuka R, Bradley R*; LACL: Tanalian River, Tazimina*, Newhalen*, Kvichak*, Chakachamna* (* ouside park boundary). The location of USGS stream gaging stations in Southwest Alaska have been identified and summarized: http://www.nature.nps.gov/im/units/swan/Documents/Maps/SWAN_Weather_GagingStations.pdf

One of the products of a SWAN hydrographic modeling project, scheduled for completion in FY04, will be a list of potential stream gaging sites.

KEY REFERENCES:

Baker, V.R., R.C.Kochel and P.C.Patton (eds.) 1988. *Flood geomorphology* . New York: John Wiley and Sons.

Osterkamp, W.R. and S.A.Schumm 1996. Geoindicators for river and river-valley monitoring. In Berger, A.R. and W.J.Iams (eds.). *Geoindicators: Assessing rapid environmental changes in earth systems* :83-100. Rotterdam: A.A. Balkema.

Wolman, W.G. and H.C.Riggs 1990. *Surface water hydrology* . The Geology of North America, Volume 0-1, Boulder, CO: Geological Society of America.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Streamflow affects virtually all other environmental issues connected with water.

OVERALL ASSESSMENT: Streamflow is of fundamental importance to virtually all environmental monitoring.

Vital Sign 6: Stream and Lake Suspended Sediments

BRIEF DESCRIPTION: Suspended sediments are the load of sediment (in suspension and as bed load of silt, sand, and gravel) transported by streams into lakes and eventually into the sea. Loads of suspended sediment reflect upland erosion and glacial recession within the drainage basin and the volume of suspended sediment is primarily discharge dependent (Brabets 1997). In the spring, as streamflow increases, there is a corresponding increase in suspended sediment. Flow and sediment transport are maintained through the summer as glacial meltwater and rainfall runoff enter the river. In the fall, as glacial melt ceases, streamflow and suspended sediment declines.

SIGNIFICANCE: Changes in sediment load reflect changes in basin conditions, including climate, soils, erosion rates, vegetation, topography and land use. For example, high turbidity caused by glacial flour attenuates light, scours the substratum, and affects many freshwater ecosystem processes including primary productivity and structure of the biotic community. Changes in suspended sediment dynamics associated with glacial recession may force a biophysical regime shift in freshwater ecosystems that could affect focal species such as salmon.

PROPOSED METRIC: Areal extent, patterns, and phenology of turbidity

RANK: overall 34, within category 6

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Extensive: Satellite imagery has been effectively used to track suspended sediments because reflectance of water increases with increased suspended sediment concentrations. Intensive: Optical backscatterance sensors can be used to measure suspended-solids concentration (SSC) in surface waters. seasonal/annual

LIMITATIONS OF DATA AND MONITORING: Sediment discharge may increase or decrease due to natural cycles of stream development under conditions of stable climate.

CURRENT MONITORING: None

KEY REFERENCES:

Brabets, T. P. 1997. *Geomorphology of the lower Copper River, Alaska.* U.S. Geological Survey Professional Paper 1581, 89 p.

Guy, H.P. and V.W. Norman 1970. *Field methods for measurement of fluvial sediment.* US Geological Survey Techniques of Water Resources Investigation, Book 3, Chapter C-2.

Osterkamp, W.R. and S.A. Schumm 1996. Geoindicators for river and river-valley monitoring. In Berger, A.R. and W.J.Iams (eds.). *Geoindicators: Assessing rapid environmental changes in earth systems*:83-100. Rotterdam: A.A. Balkema.

Wolman, W.G. and H.C. Riggs 1990. *Surface water hydrology*. The Geology of North America Volume 0-1, Boulder, Colorado: Geological Society of America. (especially paper by Meade, R.H., T.R. Yuzyk and T.J. Day Movement and storage of sediment in rivers of the United States and Canada, p255-280).

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Stream sediment storage and load affects virtually all ecosystem functions in drainage basins and along coastlines fed by stream sediment.
OVERALL ASSESSMENT: Stream sediment storage and load is of extreme importance in determining the transport of erosion products through and out of drainage basins.

Vital Sign 7: River Channel Morphology

BRIEF DESCRIPTION: River channel morphology is the cross-sectional shape and longitudinal profile of a river and is the result of a complex interaction of the geologic setting, hydraulic factors, and environmental factors. Morphology of stream channels and types of pattern (braided, meandering, straight) and sinuosity are significantly affected by changes in flow rate and sediment discharge, and by the type of sediment load in terms of the ratio of suspended to bed load.

SIGNIFICANCE: Channel dimensions reflect magnitude of water and sediment discharges. In the absence of hydrologic and streamflow records, an understanding of stream morphology can help delineate environmental changes of many kinds. Changes in stream pattern, which can be very rapid in glacial streams, place significant limits on land use, such as on islands in braided streams and meander plains, or along banks undergoing erosion.

PROPOSED METRIC: Channel cross sectional profile

RANK: overall 37, within category 7

SPATIAL SCALE: mesoscale / regional

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Repeated ground and/or areal surveys of channel patterns and cross- sections, using streamflow gauges, channel cross-section monuments, and other automated and manual loggers. Frequency depends on observed rate of change, but no less than once every 5 years.

LIMITATIONS OF DATA AND MONITORING: It is difficult to gauge stream change without historical records. Floods may destroy observation sites.

CURRENT MONITORING: In LACL cross-sections were measured at the Johnson River gaging site and as part of a 3-year study at 3 locations on the Crescent River. Historic cross-sections exist for the Tlikakila River.

KEY REFERENCES:

Chang, H.H. 1988. *Fluvial processes in river engineering*. New York: John Wiley and Sons.

Osterkamp, W.R. and E.R. Hedman 1982. *Perennial-streamflow characteristics related to channel geometry and sediment in Missouri River basin* . U.S. Geological Survey Professional Paper 1241.

Osterkamp, W.R. and S.A. Schumm 1996. Geoindicators for river and river-valley monitoring. In Berger, A.R. and W.J.Iams (eds.). *Geoindicators: Assessing rapid environmental changes in earth systems* :83-100. Rotterdam: A.A. Balkema.

Schumm, S.A. and B.R. Winkley (eds.) 1994. *The variability of large alluvial rivers* . New York: American Society of Civil Engineers Press.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Condition of riverine ecosystems; stability of islands and channels, and jurisdictional boundaries defined by rivers.

OVERALL ASSESSMENT: Monitoring stream channel morphology can be useful when no data are available on sediment load, flow rates and other hydrologic parameters.

Vital Sign 8: Surface Water Hydrology (Lake Levels)

BRIEF DESCRIPTION: Surface hydrology refers to water level (depth), areal extent, timing of inundation, and water persistence. Some lakes receive their water mainly from precipitation, some are dominated by runoff from snowmelt and glaciers, and others are controlled by groundwater systems.

SIGNIFICANCE: Surface hydrologic factors account for more than 50% of the variation found in aquatic plant and animal populations (Keddy 2000). Lakes are dynamic systems that are sensitive to local climate and to land-use changes in the surrounding landscape. On a time scale ranging from days to millennia, the areal extent and depth of water in lakes are indicators of changes in climatic parameters such as precipitation, radiation, temperature and wind speed. Records of lake dynamics in historic and pre-historic periods provide baseline data on past responses to climate change. With the establishment of threshold values, lakes may provide an early warning of shallow groundwater depletion.

PROPOSED METRIC: Areal extent and variability in surface water area

RANK: overall 27, within category 4

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Lake levels are generally measured with shoreline gauges. Areal extent is assessed primarily using successive air photos, supplemented with ground- level surveys, radar altimetry, and satellite images. Lake level and lake water composition monthly to annual. Areal extent every 5 years.

LIMITATIONS OF DATA AND MONITORING: Limited by availability of gauge data, resolution of photographic and satellite images, and by climatic records for baseline data. SWAN lakes show seasonal water level changes of up to 3 meters.

CURRENT MONITORING: None

KEY REFERENCES:

Gierlowski-Kordesch, E and K. Kelts (eds.) 1994. *Global geological record of lake basins.* Volume 1. Cambridge: Cambridge University Press.

Keddy, P.A. 2000. *Wetland ecology: principles and conservation*. Cambridge University Press, Cambridge.

Mason, I.M., M.A.J. Guzkowska, C.G. Rapley and F.A. Street-Perrott. 1994. The response of lake levels and areas to climate change. *Climatic Change* 27: 161-197.

Vance, R.E. and S.A. Wolfe 1996. Geological indicators of water resources in semi- arid environments: Southwestern interior of Canada. In Berger, A.R. and W.J. Iams (eds.). *Geoindicators: Assessing rapid environmental changes in earth systems*:237-250. Rotterdam: A.A. Balkema.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Lake levels are important for regional hydrological investigations, and for a wide range of issues concerning lakeshore land use.

OVERALL ASSESSMENT: Monitoring lake levels and extent provides a convenient and simple indicator of changes in climate and hydrological conditions.

Vital Sign 9: Geomorphic Coastal Change

BRIEF DESCRIPTION: Shoreline position is the mean high water (MHW) contour, ideally found as "the intersection of the plane of mean high water with the shore." The position of the shoreline along ocean coasts varies over a broad spectrum of time scales in response to shoreline erosion (retreat) or accretion (advance), changes in water level, and land uplift or subsidence

SIGNIFICANCE: Changes in the position of the shoreline affect the composition, relative abundance, and distribution of coastal habitats. Shoreline position has jurisdictional implications for park management and affects cabins and other structures along the coast.

PROPOSED METRIC: Georeferenced position of the shoreline, beach profile

RANK: overall 25, within category 3

SPATIAL SCALE: patch to mesoscale / network to regional

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Conventional ground survey and other methods (simple rod and tape profiles, leveling, electronic total-station surveys, air photos. GPS techniques are being developed to efficiently extract shoreline position from topographic data collected by airborne LIDAR, specifically NASA's Airborne Topographic Mapper (ATM). Seasonal, before and after storms. Semi-annual or annual, once seasonal variability is established

LIMITATIONS OF DATA AND MONITORING: Results can be site specific, temporally and spatially discontinuous. Changes in relative sea level and in sediment supply are critical factors in coastal evolution and in the response of shorelines to environmental change. In some cases sediment supply may be controlled by processes external to the coastal system, such as volcanic eruptions, glacier- burst floods, or changes in ice regimes.

CURRENT MONITORING: Twelve beach profiles transects (conventional ground survey methods) were established along the LACL coastline in 1992 and resurveyed in 1994.

KEY REFERENCES:

Berger, A.R. and W.J.Iams (eds.). 1996. *Geoindicators: Assessing rapid environmental changes in earth systems.* Rotterdam: A.A. Balkema. (see papers by Forbes and Liverman, Morton, and Young et al.).

Carter, R.W.G. 1988. *Coastal environments: an introduction to the physical, ecological and cultural systems of coastlines.* London: Academic Press.

Carter, R.W.G. and C.D. Woodroffe (eds.). 1994. *Coastal evolution: Late Quaternary shoreline morphodynamics.* Cambridge: Cambridge University Press. (especially paper by Cowell and Thom on coastal morphodynamics).

Godschalk, D.R., D.J. Brower and T. Beatley 1989. *Catastrophic coastal storms and hazard mitigation and development management.* Raleigh NC: Duke University Press.

Pilkey, O.H., R.A. Morton, J.T. Kelley and S. Penland 1989. *Coastal land loss.* Washington, American Geophysical Union.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Changes in the shoreline affect the distribution and functioning of salt marsh, estuarine and littoral ecosystems, as well as the planning and management of coastal resources and park facilities.

OVERALL ASSESSMENT: The shoreline position is perhaps the most important geoindicator for low-lying coastal shorelines and islands. Quantitative methods are best for predicting future shoreline movements. Qualitative indicators of shoreline position and morphology are practical, inexpensive, and rapid guides to coastal erosion.

Chemical

Vital Sign 10: Water Quality Core Parameters

BRIEF DESCRIPTION: The quality of surface water in rivers and streams, lakes, ponds and wetlands is determined by interactions with soil, transported solids (organics, sediments), rocks, groundwater and the atmosphere. It may also be significantly affected by industrial, mineral and energy extraction, urban and other human actions, as well as by atmospheric inputs.

Level 1 Core Field Parameters (dissolved oxygen, pH, specific conductance, water temperature, and discharge) provide instant information about the condition of a water body and also provide the metadata from which all other water quality parameters may be scientifically interpreted. They are required by the NPS Water Resources Division.

Level 2 Major Ions, which provide important geochemical data, include the dissolved cations of calcium, magnesium, sodium, and potassium and the major anions of sulfate, chloride, and those contributing to alkalinity. **Nutrients** (nitrogen, ammonia, phosphorus, and potassium), while essential for animal and plant growth, can, in excess, indicate undesirable eutrophication or the presence of animal wastes in water bodies. These nutrients are frequently very low in SWAN water bodies. Chlorophyll-a is a representation of the productivity of the water body, while DOC (dissolved organic carbon) integrates watershed and water body productivity, since much of the carbon is allochthonous. DOC is generally proportional to the amount of wetlands in a watershed, and is affected by climate change. DOC in many of the streams in Aniakchak, and in Surprise Lake, was below the detection level of the technique used. **Trace Elements** (including arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc) occur naturally only in minor amounts but easily become toxic to biota if their concentrations in water and sediments are increased due to anthropogenic activities. Silicon and iron are geo-chemical indicators.

SIGNIFICANCE: The chemistry (quality) of water reflects inputs from the atmosphere, from soil and water-rock reactions (weathering), as well as from pollutant sources such as mining, land clearance, acid precipitation, domestic and industrial wastes.

PROPOSED METRIC: Temperature, conductivity, pH, DO, (salinity ppt), nitrate, nitrite, phosphorus, organic nitrogen, dissolved organic carbon (DOC), chloride, silica, sulfate, chlorophyll, total suspended solids (TSS)

RANK: overall 18, within category 1

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Sampling and analysis for water quality determination varies with site conditions and the constituents to be measured.

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: Level 1 indicators are currently being collected at Johnson River in LACL.

KEY REFERENCES:

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: There are many causes of changes in the quality of surface water, including acid precipitation, residential development, mining, and volcanic eruptions.

OVERALL ASSESSMENT: Surface water quality is one of the most fundamentally important environmental variables to be monitored. It is also of value as an indicator of short-term improvement or deterioration in the environment.

Vital Sign 11: Visibility and Particulate Matter (IMPROVE)

BRIEF DESCRIPTION: Air Quality refers to the presence and concentrations of various pollutants in the ambient air. The Interagency Monitoring of Protected Visual Environments Program (IMPROVE) is a long-term, cooperative visibility monitoring effort among the EPA, NOAA, NPS, USFS, USFWS, and state air agencies. For aerosols, measurements include particle size, and the mass concentrations of aerosol species that include sulfates, nitrates, organic carbon, inorganic carbon, earth crustal components, ions, and other major and trace elements.

SIGNIFICANCE: Poor air quality affects both natural environments and human health.
SWAN park units are exposed to potential air pollution through long range transport from the Far East, through passing air and ship traffic, from local sources such as wood burning stoves or diesel generators, and through proximity to industrial development, such as the hydrocarbon industry in Cook Inlet. Air pollution has been shown to cause lake acidification, vegetation change, and changes in nutrient cycling.

PROPOSED METRIC: IMPROVE suite for visibility and fine particles

RANK: overall 35, within category 2

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: The IMPROVE site uses air compressors to pump air from the outside through a series of filters. These filters collect particulate matter that is suspended in the atmosphere including sulfur, nitrogen, hydrogen, carbon, and metals such as zinc, lead, and mercury. Frequency: continuous

LIMITATIONS OF DATA AND MONITORING: Air quality conditions at IMPROVE monitoring sites at Tuxedni Channel and Simeonof may have limited spatial relevance to parks in the networks and expanding the number of stations may be prohibitively expensive.

CURRENT MONITORING: None by NPS in SWAN park units. The U.S. Fish and Wildlife Service has an IMPROVE site on the Cook Inlet coast at a private inholding within the Lake Clark boundary, and a second site on the Simeonof Islands, which may be representative of the Aniakchak airshed. An IMPROVE station was operated at King Salmon from 1987-1993.

KEY REFERENCES:
Eldred, R.A., Cahill, T.A., Wilkenson, L.K., et al. Measurements of fine particles and their chemical components in the IMPROVE/NPS networks, in Transactions of the International Specialty Conference on Visibility and Fine Particles, Air and Waste Management Association: Pittsburgh, PA, 1990; pp 187-196.

IMPROVE website: http://vista.cira.colostate.edu/improve/

Alaska IMPROVE data:
http://vista.cira.colostate.edu/improve/Web/MetadataBrowser/MetadataBrowser.aspx?StateCode=AK&Program=IMPROVE&Measure=Aerosol

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Oil and gas operations, mining, sensitive vegetation communities

OVERALL ASSESSMENT: Air quality monitoring reveals trends in the quantity of significant pollutants in the atmosphere by documenting the highest average concentration recorded during the year. Knowing these maximum values is useful because the potential adverse effects of contaminants on plants and animals usually increase with its concentration.

Disturbance Regimes

Vital Sign 12: Earthquake Activity (Frequency, Intensity)

BRIEF DESCRIPTION: Earthquake activity refers to frequency, magnitude and location of earthquakes in southcentral Alaska.

SIGNIFICANCE: Earthquakes can result in temporary or permanent changes in the landscape, depending on the magnitude of the earthquake, the location of its epicenter, and local soil and rock conditions. Earthquake surface effects include uplift or subsidence, surface faulting, landslides and debris flows, liquefaction, ground shaking, and tsunamis (`tidal' waves caused by undersea tremors). Alaska is characterized by high seismicity due to the active subduction of the Pacific plate beneath the North American plate (~5-7 cm/year), and is the most seismically active region in the United States by a large margin. Numerous faults run through SWAN parks, including the Castle Mountain/Lake Clark/Bruin Bay fault complex within LACL, and the Aleutian Megathrust fault which arcs along the northern Gulf of Alaska, offshore of Kenai Fjords, Katmai and Aniakchak.

PROPOSED METRIC: Frequency, intensity

RANK: overall 32, within category 3

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Specific locations (latitude, longitude and location), date (month, day, year), time, depth (m) and magnitude (according to the Richter scale) are available through the Alaska Earthquake Information Center. Frequency: continuous

LIMITATIONS OF DATA AND MONITORING: Monitoring seismicity will identify where earthquakes are likely to occur and their potential magnitude, but not when they might be expected, nor any physical effects, such as subsidence or uplift.

CURRENT MONITORING: The Alaska Earthquake Information Center (AEIC) operates a seismic network of more than 300 seismic stations distributed throughout Alaska, receiving and archiving waveform data from all stations in near-real-time. The National Park Service (NPS) is considering a proposal by the U.S. Geological Survey -Alaska Volcano Observatory (AVO) to improve seismic monitoring networks in SWAN. In Katmai National Park three new digital seismic stations would be installed and three existing analog seismometers would be upgraded to the new digital technology. In Lake Clark National Park, two analog seismometers on the flanks of Redoubt Volcano would be upgraded to the new digital technology. In Aniakchak National Monument a single station would be converted to the new digital technology. The new technology greatly improves the detection of seismic activity indicative of volcanic activity, and would lead to timely hazard forecasts to protect the general public.

KEY REFERENCES:

Cox T., and R. Hansen. **Seismic Networks in Alaska**, http://www.giseis.alaska.edu/Seis/html_docs/fact_sheets.html

Page, R.A., N.N. Biswas, J.C. Lahr, and H. Pulpan. 1991. Seismicity of Continental Alaska, *in* Slemmons, D.B., E.R. Engdahl, M.D. Zoback, and D.D. Blackwell, eds., Neotectonics of North America: Boulder, Colorado, Geological Society of America, Decade Map Volume 1.

Labay, K, and Haeussler, P.J. 2001. *GIS Coverages of the Castle Mountain Fault, South Central Alaska.* U.S. Geological Survey Open-File Report 01-504

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS:

OVERALL ASSESSMENT: Understanding earthquake activity is basic to understanding geologic processes that created and maintain network landscapes and seascapes.

Vital Sign 13: Volcanic Activity (Frequency, Intensity)

BRIEF DESCRIPTION: Volcanic activity refers to all the actions (geophysical, geochemical and neo-tectonic) that occur before, during and after an eruption. Eruptions are almost always preceded and accompanied by volcanic unrest, indicated by variations in the geophysical and geochemical state of the volcanic system. Such geoindicators commonly include changes in seismicity, ground deformation, nature and emission rate of volcanic gases, fumarole and/or ground temperature, and gravity and magnetic fields. Volcanic unrest can also be expressed by changes in temperature, composition, and level of crater lakes, and by anomalous melting or volume changes of glaciers and snow fields on volcanoes.

SIGNIFICANCE: Volcanic eruptions have shaped the landscape of SWAN parks for thousands of years, and indirectly, the flora and fauna and their distribution. Ash may smother vegetation, but depending on chemical composition, may also enrich the soil as well as aquatic systems. Ash also has detrimental effects on wildlife: fall from the 1931 eruption of Aniakchak reportedly killed reindeer and caribou at Nushagak, and swans and geese at Ugashik (Hubbard, 1932). Landslides induced by the 1912 Novarupta eruption may have barriered Dakavak Lake, preventing access by returning sockeye and creating a new kokanee population.

Other volcanic hazards, such as lava flows, pyroclastic flows, floods, and tsunamis, are of lesser concern for human risk, since SWAN volcanoes do not occur in immediate proximity to major population centers. However, flooding from the 1966 eruption of Redoubt nearly engulfed the Drift River oil tanker terminal, located on the coastal lowlands below the volcano. Of historical interest, the 1912 Novarupta eruption in Katmai forced the abandonment of Katmai village.

PROPOSED METRIC: Frequency, intensity

RANK: overall 17, within category 1

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Seismometers, satellite data

LIMITATIONS OF DATA AND MONITORING: Volcanic effects, such as depth and areal extent of ash or lava flows, will not be monitored.

CURRENT MONITORING: The Alaska Volcano Observatory (AVO) monitors seismic activity in real time at 24 volcanoes, including the following volcanoes in or near SWAN park units: Spurr, Redoubt, Iliamna, Augustine, Snowy, Griggs, Katmai, Novarupta, Trident, Mageik, Martin, and Aniakchak, In addition, AVO monitors volcanoes in Alaska and Kamchatka using Polar Orbiting and Geostationary satellite data. These systems include visible, infrared and microwave wavelength data.

KEY REFERENCES:

Ewert, J.J. and D.A.Swanson (eds.). 1993. *Monitoring volcanoes: techniques and strategies used by the staff of the Cascades Volcano Observatory 1980-1990* . U.S. Geological Survey Bulletin 1966.

McGuire, B., C.R.J. Kilburn and J. Murray (eds.). 1995. *Monitoring active volcanoes: strategies, procedures and techniques.* London: University College London Press.

Scarpa, R. and R.I. Tilling 1996. *Monitoring and mitigation of volcano hazards.* Berlin: Springer-Verlag.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: A major volcanic eruption has implications on all vital signs at the park or network scale.

OVERALL ASSESSMENT: Volcanic activity is of major ecological and management concern and much of the infrastructure for monitoring this vital sign is already in place.

Vital Sign 14: Insect and Disease Outbreaks

BRIEF DESCRIPTION: Insect outbreak refers to cyclic patterns of abundance of insects that kill or damage woody plants by feeding on leaves and burrowing into stems and trunks.

SIGNIFICANCE: Outbreaks of insects such as the spruce bark beetle (*Dendroctonus rufipennis*) can result in widespread changes in forest landcover. This can alter habitats through changes in hydrology and water chemistry, changes in woody debris inputs to streams, and changes and long-term shifts in wildlife habitat availability. For example, Harlequin ducks and river otters might experience positive short-term benefits as a result of a potential increase in nesting/denning sites created by dense undergrowth and downed wood. Bald eagles and marbled murrelets would experience a decrease in suitable nest sites where spruce is the dominant tree.

PROPOSED METRIC: Species, timing and areal extent of insect-related vegetation mortality

RANK: overall 19, within category 2

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: annual aerial surveys

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: The Alaska Department of Natural Resources (DNR) conducts aerial surveys each summer jointly with the U.S. Forest Service, Forest Health Protection and Alaska DNR, Division of Forestry to assess forest condition statewide.

KEY REFERENCES:

Fastie, C. L.; Berg, E. E.; Swetnam, T. W. 1999. The response of boreal forests to lethal outbreaks of spruce bark beetles on the Kenai Peninsula, Alaska.

Matthews, K., compiler. 1997. Forest Health Protection Report: Forest Insect and Disease Conditions in Alaska-1997. U.S. Department of Agriculture, U.S. Forest Service. General Technical Report R10-TP-70. 62p.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Vegetation community composition, climatological measurements

OVERALL ASSESSMENT: Insect and disease outbreaks can be extremely important disturbance factors; during outbreaks, woody vegetation is often killed over vast areas. Under climate change, damage patterns caused by insects and disease may change considerably, particularly those of insects whose temporal and spatial distributions strongly depend on climatic factors.

Freshwater Biota

Vital Sign 15: Resident Fish

BRIEF DESCRIPTION: The structure of a fish community is defined by the species present, their relative abundances, their life stages and size distributions, and their distributions in space and time.

SIGNIFICANCE: Fish possess several attributes of a good environmental indicator: they represent a variety of trophic levels (omnivores, insectivores, planktivores, and piscivores); have variable habitat requirements; extensive information is available on the biology and needs of many species; they integrate changes and disturbances that occur in the food chain; they are easy to collect and identify; and they lend themselves to the measurement of chronic or acute conditions caused by toxic substances. They are also of interest to decision-makers and the general public because of their economic and recreational value. Local extinction, range extension, or deviation in life-history strategies may result from minor changes in the physical or biological characteristic of freshwater habitat. These changes will in turn affect interspecies interactions such as competition, predator-prey relationships, and habitat partitioning.

PROPOSED METRIC: Composition, abundance, and distribution

RANK: overall 23, within category 2

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Commonly used survey techniques such as minnow traps, seines, electroshocker, gill nets, and fyke nets. Decadal, or as other vital signs suggest that changes may have occurred.

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: No current monitoring. The current fish inventory, as well as earlier work, has established baseline presence/absence of resident fish communities for selected water bodies within SWAN park units.

KEY REFERENCES:

Belpaire, C., Smolders, R., Vanden Auweele, I., Ercken, D., Breine, J., Van Thuyne, G. and Ollevier, F. 2000. An Index of Biotic Integrity characterizing fish populations and the ecological quality of Flandrian water bodies. Hydrobiologia, 434, 17-33.

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries, 6, 21-27.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Fish community structure is related to all hydogeological processes.

OVERALL ASSESSMENT: Because fish are of such economic and ecological importance, it is important to understand the condition of the fish community in lakes and rivers. This is useful in identifying watersheds where the fish community may be showing signs of impairment and can aide management in directing monitoring and protection activities.

Vital Sign 16: Salmon (Abundance)

BRIEF DESCRIPTION: Salmon abundance refers to the numbers of naturally spawning adult salmon returning to spawning areas.

SIGNIFICANCE: Sockeye salmon are a keystone species in the SWAN aquatic and terrestrial ecosystem. Nutrients from spawned-out salmon carcasses appear to play an important role in sustaining the productivity of riparian and lacustrine ecosystems including the perpetuation of future salmon runs (Kline et al. 1990, Gende et al. 2002, Schindler et al. 2003). Determination of adult spawner abundance information is a critical aspect of monitoring and protecting viable populations of this resource.

PROPOSED METRIC: Abundance of adult spawners (annual escapement or index to escapement)

RANK: overall 1, within category 1

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Aerial surveys, tower counts, weirs, sonar. Frequency: annual.

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: ADF&G has been monitoring escapement for all five species of salmon in the Aniakchak and Meshik River system through aerial surveys, and at Delight Lake through the use of a weir. ADF&G also maintains a counting tower for sockeye on the Naknek River, just outside the Katmai boundary. Crescent River escapement has traditionally been monitored by ADF&G through the use of a sonar site, although this site may be discontinued. For the past three years, USGS BRD has maintained a counting tower at a historic (1980-1984) U. of Washington Fisheries Research Institute tower site on the Newhalen River, but it is unlikely that this site will be funded in 2004. Finally, the Alagnak River escapement has been periodically monitored by ADF&G with special project money.

KEY REFERENCES:

Cederholm, C.J., D. H. Johnson, R. E. Bilby, L. G. Dominguez, A. M. Garrett, W. H. Graeber, E. L. Greda, M. D. Kunze, B. G. Marcot, J. F. Palmisano, R,. W. Plotnikoff, W. G. Pearcy, C. A. Simenstad, and P. C. Trotter. 2000. Pacific Salmon and Wildlife-Ecological Contexts, Relationships, and Implications for Management. Special Edition Technical Report. Prepared for D. H. Johnson and T. A. O'Neil (Managing directors), Wildlife Habitat Relationships in Oregon and Washington. Washington Department of Fish and Wildlife, Olympia, WA.

Gende, S. M., R. T. Edwards, M.F. Willson, and M.S. Wipfli. 2002. Pacific salmon in aquatic and terrestrial ecosystems. BioScience.

Kline, T.C., J.J. Goering, O.A. Mathisen, and P.H. Hoe. 1990. Recycling of Elements Transported Upstream by Runs of Pacific Salmon: ^{15}N and ^{13}C Evidence in Sashin Creek, Southeastern Alaska. Can. Jour. Fish. Aquat. Sci. 47:136-144.

Schindler, D.E., M.D. Scheuerell, J. W. Moore, S. M. Gende, T. B. Francis, and W. J. Palen. 2003. Pacific salmon and the ecology of coastal ecosystems. www.frontiersinecology.org. Accessed February 11, 2004.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Salmon influence the seasonal distribution and abundance of birds and mammals that prey on them (Cederholm et al 2000).

OVERALL ASSESSMENT: Salmon escapement (records of abundance of adults that complete their life cycle, and return to spawning grounds) provides crucial information on the state of marine, aquatic, and terrestrial ecosystems.

Vital Sign 17: Beaver (Presence and Distribution)

BRIEF DESCRIPTION: Beaver presence and distribution refers to the existence and location of active beaver colonies across park landscapes.

SIGNIFICANCE: Beaver ponds in various stages of creation and decay form a shifting mosaic of diverse vegetation communities across watersheds, playing a major role in shaping the landscape. The actions of beavers can influence temporal changes in streamflow, wetland size and hydroperiod, which consequently affects aquatic plants and animals. The occurrence of many aquatic animals such as loons, swans, river otter, and wood frogs is correlated with the presence of beaver ponds. Consequently, the presence of beavers is an indicator of biodiversity.

PROPOSED METRIC: Presence and distribution of active colonies

RANK: overall 30, within category 3

SPATIAL SCALE: basin / watershed

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: aerial surveys or photography. Frequency: 3-5 yrs

LIMITATIONS OF DATA AND MONITORING: Active beaver colonies tend to be cyclical, but some causes for these cycles may be related to human influence as well as changes in population of competitors for woody plants, predators and climate.

CURRENT MONITORING: None

KEY REFERENCES:

Johnston, C.A. and R.J. Naiman. 1990. The use of a geographic information system to analyze long-term landscape alteration by beaver. Landscape Ecology 4: 5-19.

Johnston, C.A., J. Pastor and R.J. Naiman. 1993. Effects of beaver and moose on boreal forest landscapes. pp. 236-254. In S.H. Cousins, R. Haines-Young, and D. Green (eds.) Landscape Ecology and Geographical Information Systems. Taylor and Francis, London.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: surface hydrology, wetland plants and animals. salmon occurrence

OVERALL ASSESSMENT: The presence or absence of active beaver ponds indicates the presence or absence of distinctive plants and animal assemblages (biodiversity) across park landscapes.

Vital Sign 18: Aquatic Birds (Selected Species Presence and Distribution)

BRIEF DESCRIPTION: Selected aquatic bird species include, but are not limited to, Trumpeter Swans (Cygnus buccinator), Harlequin Ducks (Histrionicus histrionicus), loons, American Dippers (Cinclus mexicanus) and Belted Kingfishers (Megaceryle alcyon).

SIGNIFICANCE: These species have similar foraging characteristics and habitat needs which makes them sensitive to changes in aquatic ecosystem habitat quality and availability. They will likely be among the first species to respond to changes associated with surface hydrology, glacier retreat, climatic warming, and bioaccumulated toxins.

PROPOSED METRIC: Selected species presence and distribution

RANK: overall 33, within category 4

TYPES OF MONITORING SITES:

SPATIAL SCALE: basin / watershed

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: ground surveys during point count methods, aerial surveys for waterfowl. Frequency: 3-5 yrs

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: Trumpeter swans as part of USFWS state-wide surveys at 5-year intervals. Harlequin Ducks have been surveyed in LACL and KATM (Bennett 1996, Goatcher et al. 1999).

KEY REFERENCES:

Bennett, A.J. 1996. Physical and Biological Resource Inventory of the Lake Clark National Park-Cook Inlet Coastline, 1994-96. Lake Clark National Park and Preserve Kenai Coastal Office. Kenai, AK. 137 pp.

Croonquist, M., and R. Brooks. 1991. Use of avian and mammalian guilds as indicators of cumulative impacts in riparian wetland areas. Environmental Management 15(5):701-714.

Gilbertson, M. 1990. Freshwater avian and mammalian predators as indicators of environmental quality. Environmental Monitor. Assess. 15(3):219-224.

Goatcher, B., Zwiefelhofer, D. and K. Scribner. 1999. Differentiation and Interchange of Harlequin Duck Populations Within the North Pacific. Exxon Valdez Oil Spill Trustee Council Restoration Project No. 97161, Final Report

O'Connell, T.J., L.E. Jackson, and R.P. Brooks. 1998. A bird community index of biotic integrity for the Mid-Atlantic Highlands. Environ. Monit. Assmt. 51:145-156.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Surface hydrology, river channel morphology, glacier retreat, sensitive vegetation communities, salt marsh, vegetation composition and structure, landcover.

OVERALL ASSESSMENT: Aquatic birds are ideal for use as an ecological indicator because their presence or absence tends to signal the status of conditions that are key to the proper functioning of aquatic ecosystems. Furthermore, this relationship is often associated with levels of human disturbance. In addition to providing an overall signal of ecosystem health, birds are also ideal because they are relatively easy to sample and their natural history is well described relative to other taxonomic groups in wetland ecosystems.

Marine Biota

Vital Sign 19: Shorezone Habitat

BRIEF DESCRIPTION: Shorezone habitats are distinctive features created by a combination of shoreline geomorphology and nearshore oceanic processes. Habitats include sand and mudflats, bedrock platforms, rocky intertidal, tidal marshes, river deltas, sand spits, beach and backshore areas, banks and bluffs, and marine riparian areas. These habitats are described and depicted in the Coastal Scoping Workshop Summary.
http://www.nature.nps.gov/im/units/swan/Documents/Workshops/CoastalWorkshop_sum.pdf
SIGNIFICANCE: The volume, composition, and interaction among habitats is partly responsible for maintaining trophic structure and productivity of the nearshore. There are strong physical and biological linkages in the shorezone that force predictable patterns in biological communities. The condition of the biota depends in part on the quality of the physical-chemical environment of estuaries and coastal marine waters; i.e., habitat. Habitat is in turn influenced by natural and catastrophic events, climate, and other factors including discharges, which contribute materials (sediment, nutrients, contaminants) to the water body. Information on the quality, quantity, and distribution of intertidal habitats is important to monitoring and protecting park coastlines.

PROPOSED METRIC: Type and area (km) of coastline habitat classified by physical and biological criteria (i.e. sand flat, mud flat, bedrock platform)

RANK: overall 3, within category 1

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: habitat mapping using tidally-coordinated aerial photography and targeted ground truthing. Frequency: 10 yrs

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: ShoreZone maps of all network parks 2001-2003. LACL coastal atlas 1995. ESI data for all parks.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Relative sea level, shoreline position, seagrass, marine invertebrates.

KEY REFERENCES:

Exxon Valdez Oil Spill Trustee Council. 2002. Detecting and Understanding Change in Nearshore Environments: Planning for Habitat Mapping in the Gulf of Alaska

Mann, D.H. 1996. Shore-Zone classification of Katmai National Park and Preserve and Kenai Fjords National Park. Report To National Park Service. Coop Agreement 14-48-0009-1582. 5 pgs.

Schoch, G.C., G.L. Eckert and T.A. Dean. 2002. Long-Term Monitoring in the Nearshore: Designing Studies to Detect Change and Assess Cause. EVOS Project Number 02395. Workshop summaries and recommendations:, Project Number: 02395, Workshop Summaries and Recommendations, November 9, 2001, Santa Barbara, California, January 24, 2002, Anchorage, Alaska.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Salt marsh, ice cover, sediment load

OVERALL ASSESSMENT: Monitoring changes in the volume and composition of shorezone habitats is pivotal to understanding and predicting changes in nearshore biodiversity that result from natural and human-related events.

Vital Sign 20: Saltmarsh

BRIEF DESCRIPTION: Salt marshes are distinctive coastal vegetated ecosystems where the upper elevation of occurrence is approximately the highest astronomical tide, while the lower limit is rarely below mean high water neap. In SWAN they occur as large extensive areas along the broad intertidal flats of KATM and LACL and smaller "pocket beach" marshes along deep fjords in KEFJ.

SIGNIFICANCE: Salt marshes are among the most productive ecosystems in the world and play a critical role in the ecology of SWAN coastal areas. Salt marshes filter terrestrial run-off, act as sinks for nutrients and greenhouse gases, provide nursery and feeding habitat for fish and shellfish species, and support large concentrations of brown bears and waterfowl. As an ecological indicator, salt marshes have long been viewed by ecologists as the model example of an ecosystem controlled by "bottom-up factors", e.g. nutrients and physical factors (Kennish 2001).

PROPOSED METRIC: Extent and composition**,** sediment accumulation rate

RANK: overall 10, within category 2

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: habitat mapping using tidally-coordinated aerial photography and targeted ground truthing. Numerous protocols are available for salt marsh monitoring. Frequency: 10 yrs

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: Salt marshes were mapped and classified at LACL in 1994.

KEY REFERENCES:

Kennish, M. J. 2001. Coastal Salt Marsh Systems in the U.S.: A Review of Anthropogenic Impacts. Journal of Coastal Research 17(3): 731-748. McAlister, W.H. and M.K. McAlister. 1995. Aransas: A naturalist's guide. University of Texas Press, Austin, Texas. USA

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: tectonic uplift, glacier retreat, sediment dynamics, relative sea level, brown bears.

OVERALL ASSESSMENT: Monitoring the response of salt marshes to environmental factors such as shoreline position, sea level rise, changing salinity, and human actions is crucial to understanding and protecting park coastlines.

Vital Sign 21: Kelp and Eelgrass

BRIEF DESCRIPTION: Eelgrass (*Zostera marina*) grows in beds (clusters) in low energy intertidal and shallow subtidal sandy mudflats. Kelp beds containing species such as split kelp (*Laminaria bongardiana*), bull kelp (*Nereocystis luetkeana*), brown algae *(Alaria fistulosa* and *Agarum cribrosum*), and ribbon or wing kelp (*Alaria crispa*) grow in rocky substrates.

SIGNIFICANCE: Kelp and eelgrass are "living habitats" that serve as a nutrient filter, provide understory and ground cover for planktivorous fish, clams, urchins, and a physical substrate for invertebrates, crustose corals, and algae. Kelp plants are the major primary producers in the marine coastal habitat. Within the euphotic zone (from high water to the depth of light penetration) kelps produce nearly 75% of the net carbon fixed. Eelgrass and many species of kelp have been declining world wide. Oil spills have negative effects on *Nereocystis* communities, and *Alaria* beds in the Aleutians are currently receding because of grazing by urchins. Other stresses include activities that disturb the beds directly such as dredging and anchor scars, events that reduce the ability for light to penetrate into the water column, such as runoff (increased turbidity) or nutrient addition. Mumford and others (1995) called for the subtidal populations to be surveyed as indicators of changes in water quality

PROPOSED METRIC: Presence and distribution (areal extent)

RANK: overall 21, within category 5

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Eelgrass and kelp is monitored in many regions as an indicator of nearshore habitat quality by comparing maps of resource abundance and distribution over time. Frequency: 5-10 yrs

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING:

KEY REFERENCES:

Asmus, H., and Asmus, R. 1999. The role of intertidal seagrass beds - organisms and fluxes at ecosystem level. Report of workshop of 7-13th August 1998. ECSA Bulletin, 30, 21-29.

The Partnership for Interdisciplinary Study of Coastal Oceans. Oregon State University, Stanford University, University of California Santa Barbara, and University of California Santa Cruz, http://www.piscoweb.org/

Intertidal Monitoring Program. Minerals Management Service, Ventura, California, http://www.mms.gov/omm/pacific/enviro/mint.htm

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Shorezone habitat, marine invertebrates, suspended sediments, oil spills, sea otter, water quality, land-use change and habitat alteration.

OVERALL ASSESSMENT: Seagrass habitat is a sensitive (nonresilient) indicator of shallow coastal intertidal and subtidal ecosystems because it is characterized and maintained by a biological matrix rather than physical structures or processes alone.

Vital Sign 22: Marine Intertidal Invertebrates (Soft Sediment Infauna)

BRIEF DESCRIPTION: Intertidal invertebrate community composition refers to species richness, species relative abundances, and heterogeneity of their spatial or temporal distributions. "Abiotic factors" known to influence community composition refers to sediment type, grain size and sorting; water quality parameters; and sediment organic properties (Total Organic Carbon and Total Nitrogen).

SIGNIFICANCE: Intertidal mudflats and sandflats support highly productive habitats and populations of littleneck clams (*Protothaca staminea*), surf clams (*Mactromeris polynyma)*, macomas (*Macoma* spp.), soft shelled clams (*Mya* spp.) and other invertebrates. These invertebrates, in turn, provide a critical prey resource for shorebirds, ducks, fish, bears, sea otters (*Enhydra lutris)*, and other marine invertebrate predators, as well as spawning and nursery habitats for forage fish and juvenile crustaceans. In addition to their trophic importance, bottom (benthic) organisms possess many characteristics that make them useful indicators of environmental stress in the nearshore marine environment. They have a wide range of physiological tolerances and feeding and reproductive modes, and therefore have the potential to respond to a wide array of environmental stressors. Because benthic organisms are relatively sedentary, they cannot escape sediment contamination. For these reasons, benthic organisms often show measurable responses to environmental stress.

PROPOSED METRIC: composition and distribution of infauna

RANK: overall 16, within category 3

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Changes in intertidal invertebrate assemblages can be assessed from time series analysis of species counts obtained from regular quadrat sampling. Frequency: 5-10 yrs

LIMITATIONS OF DATA AND MONITORING: Interpreting the CAUSES of change is often an experimental design issue and cannot be reached via simple monitoring.

CURRENT MONITORING: Individual surveys of benthic infauna in or near network parks have been done in the past, but most involved spatially-limited descriptive analysis of species presence, generally in connection with some existing or planned perturbation (off-shore oil and gas leases, Exxon Valdez Oil Spill, dredging).

KEY REFERENCES:

Roman, C., R. Irwin, R. Curry, M. Kolipinski, J. Portnoy, L. Cameron. 2003. White-Paper Report of the Park Service Vital Signs Workgroup for Monitoring Marine and Estuarine Environments. Workgroup Convened April 3-4, 2002, North Atlantic Coast CESU at the University of Rhode Island, Narragansett, RI,. IN REVIEW, http://www.nature.nps.gov/im/monitor/COREparam.doc.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Aquatic birds, relative sea level, suspended sediment, sea otters, harbor seal, contaminants

OVERALL ASSESSMENT: Changes in the abundance, diversity, biomass and species composition of intertidal invertebrates can indicate important changes in the coastal environments of which they are a part, and can have effects that cascade to other trophic levels.

Vital Sign 23: Sea Otter and Harbor Seal

BRIEF DESCRIPTION: Sea otter and harbor seal presence and distribution refers to locations of occurrence, patterns of distribution, and relative abundance. Sea otter and harbor seals are one of the most common marine mammals in the Gulf of Alaska (GOA), where they occur throughout the year.

SIGNIFICANCE: Sea otters are the textbook example of a "keystone" predator. 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 where the highest trophic level can determine the populations of the lower trophic levels. Like sea otters, harbor seals perform a dynamic role in the nearshore by transferring nutrients and energy and by regulating the abundance of other species. They may play a structural role by influencing the physical complexity of their environment; or they may synthesize the marine environment and serve as indicators of ecosystem change. Sea otters and seals are a key part of the marine ecosystem, and they are an important resource for Alaska Natives, for the tourism industry, and for everyone who enjoys watching wildlife.

PROPOSED METRIC: Distribution and relative abundance

RANK: overall 20, within category 4

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Sea otters and harbor seals have been surveyed using a wide variety of methods (ground counts, boat surveys, and various aerial surveys). Each method has inherent biases. Monitoring protocols exist for sea otter and harbor seal in the northern Gulf of Alaska. Frequency: 1-3 yrs

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: The USFWS surveyed portions of the Pacific coast of the Alaska Peninsula in 1992 and 2000.

KEY REFERENCES:

Bodkin, J. L, K. A. Kloecker, G. G. Esslinger, D. H. Monson, DeGroot, J. D., and J. Doherty. 2002. Sea otter studies in Glacier Bay National Park and Preserve. 2001 Annual Report. U.S. Geological Survey, Biological Resources Division, Anchorage, AK.

Bodkin, J. L. and D. H. Monson. 1999. Sea otter distribution and relative abundance, Cross Sound - Icy Strait survey summary. U.S. Geological Survey, Biological Resources Division, Anchorage, AK.

Frost, K. J., L. F. Lowry, R. J. Small, and S. J. Iverson. 1996. Monitoring, habitat use, and trophic interactions of harbor seals in Prince William Sound, Alaska. Exxon Valdez Oil Spill Restoration Project Annual Report (Restoration Projects 95064), Alaska Department of Fish and Game, Division Wildlife Conservation, Fairbanks, AK. 87 pp + appendices.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Coastal shorezone habitat, climate change, kelp and eelgrass, marine invertebrates, marine debris and animal carcasses, bioaccumulated toxic contaminants.

OVERALL ASSESSMENT: Sea otters and harbor seals are an indicator of the health of the nearshore marine ecosystem because they tend to be relatively sedentary in comparison to other marine mammals; eats large amounts of food; incidence of disease is correlated with contaminants; and they have broad appeal to the public.

Vital Sign 24: River Otter

BRIEF DESCRIPTION: River otter occurrence, distribution, and relative abundance based on field sign survey techniques.
.
SIGNIFICANCE: River otters in coastal environments of Alaska tend to select habitats close to the shore, where their chief food items are marine bottom-dwelling fishes (Larsen 1983, Bowyer et al. 1994). In the aftermath of the *Exxon Valdez* oil spill (EVOS), studies of coastal river otters (*Lontra canadensis*) in Prince William Sound indicated that they are a keystone species for the land-margin ecosystem and a "sentinel species" for monitoring levels of environmental contamination (Bowyer et al. 2003).

PROPOSED METRIC: Occurrence and relative abundance

RANK: overall 26, within category 6

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Relative abundance can be generated by surveying and documenting the distribution and use of latrine sites (Bowyer et al. 2003). Frequency: 2-5 yrs

LIMITATIONS OF DATA AND MONITORING: This technique may not have relevance along coastlines where otters have access to extensive riverine and freshwater wetland habitats. The current distribution of coastal river otter is not known in the SWAN.

CURRENT MONITORING: Prince William Sound and KEFJ

KEY REFERENCES:
Bowyer, R. T., W. J. Testa, and J. B. Faro. 1995. Habitat selection and home ranges of river otters in a marine environment: effect of the Exxon Valdez oil spill. Journal of Mammalogy 76:1-11.

Bowyer, R. T., G. M. Blundell, M. Ben-David, S. C. Jewett, T. A. Dean, and L. K. Duffy. 2003. Effects of the *Exxon* Valdez oil spill on river otters: injury and recovery of a sentinel species. Wildlife Monographs 153: 1–53.

Golden, H. N., and M. Ben-David. *In preparation*. Monitoring river otter latrines to index population trends: is it a reliable tool? Journal of Mammalogy 000: 000–000.

Larsen, D. N. 1983. Habitats, movements, and foods of river otters in coastal southeastern Alaska. Thesis, University of Alaska Fairbanks, Fairbanks, Alaska, USA.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Shorezone habitat, surface water hydrology, water quality, salmon, resident fish, bioaccumulated toxic contaminants

OVERALL ASSESSMENT: Coastal river otters are a resource limited species that may signal changes in productivity of the nearshore.

Vital Sign 25: Seabirds (Kittiwakes, Guillemots, Gulls, Kittlitz murrelet)

BRIEF DESCRIPTION: Seabirds are long-lived organisms that spend most of their lives at sea but nest on coastal cliffs and islands in colonies, usually of several species. Colonies occur along the coasts of all network parks.

SIGNIFICANCE: Seabirds respond to their marine environment over a variety of temporal and spatial scales and serve as indicators of ecological change in the nearshore marine environment (Golet et al. 2001, Diamond and Devlin 2003). Seabirds are predators near the top of marine food webs. Their abundance and population trends reflect the dynamics of the processes that maintain the integrity of the marine nearshore environment. For example, long-term studies have demonstrated that population size, breeding success and survival of black-legged kittiwakes (Rissa tridactyla) integrate changes in the marine ecosystem from sea-surface temperature through plankton and fish, over decadal time-scales (Aebischer et al, 1990). The Kittlitz's murrelet (Brachyramphus brevirostris) is a rare seabird that nests in alpine terrain and generally forages near tidewater glaciers during the breeding season. Affinity to tidewater glaciers (of which the lower elevation glaciers are receding rapidly) are reasons for concern about the long-term conservation of Kittlitz's murrelets Survey data from two core areas (Prince William Sound and Glacier Bay) suggest that populations have declined by 80-90% during the past 10-20 years.

PROPOSED METRIC: Occurrence, colony size or productivity of Kittiwakes, Guillemots, Gulls, Kittliz's Murrelet

RANK: overall 31, within category 7

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Established protocols exists. Frequency: 5-10 yrs

LIMITATIONS OF DATA AND MONITORING: CURRENT MONITORING: The U.S. Fish and Wildlife Service currently monitors selected seabird colonies throughout coastal Alaska, including Chiswell and Chisik Island colonies, off shore of KEFJ and LACL.

KEY REFERENCES:

Aebischer, N.J., J.C. Coulson, and J.M. Colehsook. 1990. Parallel long-term trends across four marine trophic levels and weather. Nature 147:753-755

Dimond A.W. and C.M. Devlin. 2003. Seabirds as indicators of changes in marine ecosystems: ecological monitoring on Machias Seal Island. Environmental Monitoring and Assessment 88:153-175

Golet, G. H., D. B. Irons, and D. P. Costa. 2000. Energy costs of chick rearing in Black-legged Kittiwakes. *Canadian Journal of Zoology* 78:982-991.

Golet, G. H., P. E. Seiser, A. D. McGuire, D. D. Roby, J. B. Fischer, K. J. Kuletz, D. B. Irons, T. A. Dean, S. C. Jewett, S. H. Newman. 2001. Long-term direct and indirect effects of the Exxon Valdez oil spill on Pigeon Guillemots in Prince William Sound, Alaska. *Marine Ecology Progress Series*. In press.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Shorezone habitat, surface water hydrology, water quality, salmon, resident fish, bioaccumulated toxic contaminants

OVERALL ASSESSMENT: Seabirds nest in colonies which are easy to locate and relatively straightforward to count; species exploit prey at specific trophic levels, allowing changes to different parts of the food-web to be detected within a single community; and techniques for estimating population size, and in many cases productivity, are well established.

Terrestrial Biota

Vital Sign 26: Vegetation Composition / Structure / Phenology

BRIEF DESCRIPTION: Landscape pattern refers to the arrangement of species and communities in a natural setting. Vegetation structure is the dominant life form of the community: forest, shrubland, tundra or barrens. More subtle changes in vegetation communities are reflected in their composition: the presence and relative occurrence of plant species in a community. This vital sign would track the changes in patterns of vegetation type and community structure across the landscape such as advancing timberline, alder invasion, or loss of lichen ground cover.

SIGNIFICANCE: Land cover and its spatial patterns are key ingredients in ecological monitoring that considers large regions and changes from natural and human-related events. Landscape pattern and vegetation communities integrate biotic and environmental factors in their structure and composition. Vegetation communities can reflect long term trends in climate, biotic interactions, or human uses. Climate trends would show as trees advancing into subalpine or down the Alaska Peninsula, or invading drying marshlands. Changes in biotic interaction may show as loss of lichen cover in the ground layer, or alder invading willow communities.

PROPOSED METRIC: Species composition, abundance, spatial distribution, spatial extent, onset of greenness, senescence of greenness, snow-cover date, berry production (biomass) (special focus on treeline, shrub/alder, Sphagnum expansion)

RANK: overall 4, within category 2

SPATIAL SCALE: landscape / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: remote sensing data, site visits, possible combination of methods across a random or systematic set of samples. Frequency: decadal

LMITATIONS OF DATA AND MONITORING: Variations in satellite sensors and classification procedures may be greater than actual variation in vegetation composition. Protocols need to be carefully developed to evaluate change over long term. Needs to be combined with other indicators.

CURRENT MONITORING: Baseline vegetation maps have been prepared for Lake Clark and Katmai; maps for Kenai Fjords and Aniakchak are in process.

KEY REFERENCES:

Gustafson, E. J. 1998. Quantifying landscape spatial pattern: what is the state of the art? Ecosystems 1:143-156

Wickham, J. D. and D. J. Norton. 1994. Mapping and analyzing landscape patterns. Landscape Ecology 9:7-23.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Climate change, glacial extent, snowcover, surface water hydrology, earthquake activity, volcanic activity, fish, birds, mammals, land-use change and habitat alteration.

OVERALL ASSESSMENT: Monitoring vegetation and landscape patterns is of fundamental importance to an integrated ecological monitoring program because changes in the amount and configuration of habitat controls the occurrence, distribution, and abundance of animals.

Vital Sign 27: Sensitive Vegetation Communities

BRIEF DESCRIPTION: This vital sign refers to vegetation communities which reflect environmental change more rapidly than the general landscape. Wetlands are very sensitive to differences in level and duration of surface moisture. Sitka spruce die off rapidly with salt water intrusion, and recolonize when salts have been leached from coastal soils. Sensitive communities would include salt and freshwater marshes, bogs/fens, supra-tidal zones, kettle lakes, alpine and subarctic timberline and glacial refugia.

SIGNIFICANCE: Some vegetation communities reflect environmental change faster than others. While changes may be occurring on landscape or ecosystem scales, their actual effects show up more rapidly in sensitive communities. Changes in species composition and areal extent or spatial location often indicate subtle changes in controlling environmental factors. Detecting changes in sensitive communities alerts managers to underlying trends at larger scales. Targeting selected sensitive communities at mesoscales helps to provide an "early warning system" for landscape level changes. Sites may include:

Alpine areas, subalpine ecotones, mountain tops
Aquatic areas (wetlands and emergent vegetation, bogs, kettle lakes)
Snowmelt areas
Refugia (ice-free or ash free zones in glacial or volcanic landscapes)
Treeline sites (alpine and subarctic)
Riparian zones
Periglacial zones
South-facing steppe bluffs
Volcanic deposition areas

PROPOSED METRIC: Areal extent and composition of refugia, alpine, riparian, and south-facing steppe bluff communities

RANK: overall 11, within category 4

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Actual methods would vary with the selected community. Generally, permanent plots would be periodically visited for data collection including plant species composition and site environmental factors. Large scale aerial photographs would be used to map changes in areal extent and location. Frequency: 5-10 year

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: USFWS has been monitoring potholes and marshes in the Kenai Wildlife Refuge. Baseline mapping for coastal salt marshes in Lake Clark was done in 1995.

KEY REFERENCES:

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Monitoring sensitive communities will indicate changes in tectonic uplift and subsidence, ground water levels and climate.

OVERALL ASSESSMENT: Changes in sensitive communities signal changes at greater spatial scales and because they are often nodes of high biodiversity signal changes in obligate plants and animals.

Vital Sign 28: Brown and Black Bear (Population Composition and Human-Related Killings

BRIEF DESCRIPTION: Brown and black bear population composition refers to relative abundance and sex and ratios at concentration areas. In Alaska it is legal to kill a bear in defense of life or property (DLP). Over 1,000 brown and black bears were killed in Alaska in defense of life or property between 1990 and 2001 (ADF&G unpubl). DLP killing are increasing throughout Alaska wherever human populations and resource development activities are expanding.

SIGNIFICANCE: Brown bears are excellent wilderness ecosystem indicator species because of key biological traits: a) they have few young; b) they range over large areas; c) they occur at low population densities; and d) they are prone to direct conflict with people. The combination of these biological traits interacting with people's proclivity to develop and use brown bear habitat usually results in compromised brown bear populations and habitat. As omnivores and apex predators, brown bears are one of the first species to be lost from an area as a result of land development activities. As human-bear interactions increase, mortality from DLP and other causes may exceed sustainable levels. Although legal hunting can be managed, DLP and illegal kills are difficult to manage in rural communities.

PROPOSED METRIC: Abundance and sex-age composition at concentration sites; Defence of Life and Property killings

RANK: overall 2, within category 1

SPATIAL SCALE: park

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Index counts at concentration areas, state DLP records, annual

LIMITATIONS OF DATA AND MONITORING: Index counts may not reflect population-level changes. Unreported kills are difficult to estimate.

CURRENT MONITORING: State records. Effort underway by Research and Biological Resources Team (NPS-Alaska Region) to develop a historical database of bear-human interactions including DLP killings in some SWAN parks.

KEY REFERENCES:

Mace, R.D., S.C. Minta, T.L. Manley and K.E. Aune. 1994. Estimating grizzly bear population size using camera sightings. Wildl. Soc. Bull. 22:74-83.

Using DNA for long-term monitoring. Workshop on Ecological and Conservation Applications of Bear Genetics, Workshop summary on International Association for Bear Research and Management Web site: http://www.bearbiology. com

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Salmon, ungulates, saltmarsh, vegetation composition and structure, visitor use.

OVERALL ASSESSMENT: Human land-use, depletion of salmon resources, and recreational growth are factors that can adversely affect bears and, in doing so, signal a loss of environmental quality affecting many species.

Vital Sign 29: Large and Medium Carnivores (Wolf, Wolverine, Lynx, Marten)

BRIEF DESCRIPTION: This vital sign refers to presence/absence and for some species may include relative abundance (density).

SIGNIFICANCE: Carnivores are important indicators of ecosystem integrity in National Parks in that they influence the structure and reflect the vigor of the trophic levels upon which they depend (Eisenberg 1989, Garrett L. K. and R. G. Wright. 2000). Because they are wide-ranging predators, habitat specialists, and dispersal limited species, they are also sensitive to the abundance and behavior of the humans with which they coexist. They are important components of ecosystems contributing to competition, resource partitioning and the overall structure of both herbivore and carnivore guilds. They are effective indicators because they reflect the terrestrial cumulative effects of changes in habitat, prey populations, and human harvest.

PROPOSED METRIC: Occurrence and distribution of wolf, wolverine, lynx, and marten

RANK: overall 12, within category 5

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: remote cameras, snow tracking transects and visual indices.

LIMITATIONS OF DATA AND MONITORING: These species are shy, inconspicuous, primarily nocturnal, and occur at low population densities.

CURRENT MONITORING: Pilot surveys occurring in 2004 on some species within SWAN.

KEY REFERENCES:

Garrett L. K. and R. G. Wright. 2000. Prioritizing the Research and Monitoring Needs of Terrestrial Mammals in National Parks. The George Wright Forum 17(1):80-92

Zielinski, William J.; Kucera, T.E. 1995 American Marten, Fisher, Lynx, and Wolverine: Survey Methods for Their Detection U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station; Gen. Tech. Rep. PSW-GTR-157: 163p.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Ungulates, vegetation composition and landscape patterns, resource harvest, land-use change and habitat alteration,

OVERALL ASSESSMENT: Large and medium carnivores are symbols of wilderness, and thriving populations serve as a indicator of naturally functioning wild ecosystems.

Vital Sign 30: Landbirds

BRIEF DESCRIPTION: Landbirds are smaller birds (exclusive of raptors and upland game birds) not usually associated with aquatic habitats. By contrast, aquatic birds include loons, waterfowl, and other surface water-dependent species.

SIGNIFICANCE: Birds select habitats based on their suitability, which makes them very useful as indicators of environmental changes. Landbirds respond to changes over many spatial scales. Their occurrence and reproductive success have been shown to be influenced by the nature and configuration of surrounding habitats. Most landbird species are dependent on specific habitat attributes, and habitat alterations, such as those brought about by natural disturbance or human activities, have considerable potential to affect landbird communities

From a sampling perspective, landbirds are one of the best tools for monitoring because: 1) they are the most easily and inexpensively detected and identified vertebrate animals, 2) a single survey method can cover many species, and 3) accounting for and maintaining many species with different requirements promotes conservation strategies at the landscape scale (Hutto and Young 2002)

PROPOSED METRIC: Composition and distribution patterns

RANK: overall 38, within category 7

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT:

LIMITATIONS OF DATA AND MONITORING: A linkage of bird populations and habitat changes (both natural and human-caused) is dependant upon our ability to measure both components.

CURRENT MONITORING: MAPS (Monitoring Avian Productivity and Survival) stations were operated in KATM in the mid-90's, and SWAN initiated a montane bird inventory project in 2003.

KEY REFERENCES:

Hutto, R. L., and J. S. Young. 2002. Regional landbird monitoring: perspectives from the northern Rocky Mountains. Wildlife Society Bulletin 30:738-750.

Barker, R. J., and J. R. Sauer. 1995. Statistical aspects of point count sampling. Pages 125-130 in C. J. Ralph, J. R. Sauer, and S. Droege, eds. Monitoring Bird Populations by Point Counts, USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-149.

Ralph, C. J., S. Droege, and J. R. Sauer. 1995. Managing and monitoring birds using point counts: standards and applications. Pages 161-168 in C. J. Ralph, J. R. Sauer, and S. Droege, eds. Monitoring Bird Populations by Point Counts, USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-149.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Climate change, vegetation composition and structure, land-use change and habitat alteration, insects outbreaks and disease.

OVERALL ASSESSMENT: Monitoring selected landbirds across habitats may be among the most cost-effective methods of assessing a broad-based element of ecosystem status in network parks.

Vital Sign: 31 Ungulates (Distribution, Patterns)

BRIEF DESCRIPTION: Ungulates in SWAN can include moose, caribou, Dall sheep and mountain goats. Distribution pattern refers to seasonal or resident occurrence across the landscape.

SIGNIFICANCE: The occurrence, distribution and seasonal movements of large ungulates and their predators are an ecologically defining element of the SWAN landscape. Ungulates are an important food source for many avian and mammalian predators including humans. During cycles of high abundance, they have the potential to influence the structure and function of the terrestrial ecosystems (Naiman 1988). Ungulate distribution patterns are anticipated to change in response to climatic changes that influence habitats.

PROPOSED METRIC: Distribution patterns of moose, caribou, Dall sheep, and mountain goats

RANK: overall 9, within category 3

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Direct (aerial) counts, indirect observation of sign (ground plots). 1-3 years

LIMITATIONS OF DATA AND MONITORING: Landscape scale distribution pattern may not signal localized population declines.

CURRENT MONITORING: ADF&G, NPS, and the U.S. Fish and Wildlife Service (USFWS), cooperatively work on surveying moose trend areas in Aniakchak and along the Park and Preserve boundary in Katmai, while NPS carries out moose trend surveys in the Lake Clark Preserve. Ideally, each area is surveyed every one to three years, but poor snow and weather conditions have sometimes hampered efforts to survey trend areas. Lake Clark has surveyed Dall sheep at 5-10 year intervals. ADF&G surveys the Mulchatna and Northern Alaska Peninsula caribou herds on an annual basis.

KEY REFERENCES:

Naiman, R. J. 1988. Animal influences on ecosystem dynamics. *BioScience* 38:750-752.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Brown and black bear, large and medium carnivores, human harvest, land-use change and habitat alteration.

OVERALL ASSESSMENT: Monitoring large-scale changes in distribution patters of ungulates signals movement bottlenecks, reproductive sinks, habitat changes, or other factors that could adversely affect metapopulation dynamics. Ungulates are of key ecological importance and are highly valued by humans.

Vital Sign: 32 Bald Eagle

BRIEF DESCRIPTION: Bald Eagle occurrence and productivity refers to nest locations, rates of occupancy, and rates of reproductive success.

SIGNIFICANCE: Bald Eagle occurrence and reproductive performance is an indicator of seasonal prey abundance, weather conditions, toxic contaminants, and human-related disturbance. Bald Eagles are ecologically significant because they can be keystone predators that regulate other bird populations. For example, juvenile eagles raid cormorant and kittiwake breeding colonies by scaring adults off their nests, and either taking young directly or allowing ravens and crows to gain access to nests.

PROPOSED METRIC: Occurrence and productivity

RANK: overall 22, within category 6

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Traditional monitoring methods for bald eagle breeding/nesting populations involve annual completion of 2 temporally separate surveys (collectively designated productivity surveys) to determine: 1) occupancy, and 2) results of all breeding attempts in the population. Frequency: annual

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: Active or intermittent monitoring at KATM, KEFJ and LACL. State-wide monitoring on national wildlife refuges and national forests.

KEY REFERENCES:

Anthony, R.G., M.G. Garrett, and F.B. Isaacs. 1999. Double-survey estimates of bald eagle populations in Oregon. Journal of Wildlife Management 63(3): 794-802

Bednarz, J.C. and K. Steenhof. 1999. The bald eagle; review of past monitoring efforts and suggestions for the future. pp. 56-57. . Raptor Research Foundation Annual Meeting, program and abstracts, November 3-7, 1999, La Paz, Baja California, Sur, Mexico.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Environmental contaminants, salmon, snow cover, climatological conditions, resident fish, and visitor use, seabirds.

OVERALL ASSESSMENT: The Bald Eagle is widely distributed in SWAN, respond rapidly to environmental changes, and is one of the most studied birds in North America. Monitoring protocols exist along with a great amount of natural life-history information, including the affects of various stressors on eagle reproductive performance.

Human (Stressors)

Vital Sign 33: Landcover and Land-Use Change (Due to Human Activities)

BRIEF DESCRIPTION: Land use change is a shift to a different land use or an intensification of an existing one. Land use changes can result in physical, chemical, or biological alterations of habitat, or injury to, plants animals and other components of the ecosystem. This vital sign would track effects of human use in the region on the (mostly) natural landscapes of the network. Particular foci would be changes in access patterns and methods, resource development in the region, including offshore developments, subsistence patterns, and activities associated with private in-holdings in and near park lands.

SIGNIFICANCE: Human activities have great potential to cause rapid, long term and permanent changes to ecosystems of SWAN. Land use change causes loss or alterations in habitat, biodiversity, and biogeochemical cycles. Alteration or fragmentation of ecosystems can hinder movements and dispersal of plants and animals. Species that require large, unbroken expanses of habitat are often most sensitive to the effects of fragmentation. In some cases, the effects of fragmentation on sensitive species are a direct result of changes in the size and arrangement of suitable habitats across the landscape. In others, impacts are due mainly to more frequent interactions of species with humans, or predators, or to other factors associated with an intruding land use.

PROPOSED METRIC: Type, location and areal extent of landcover types; areal extent and relative proportions of land use types on park and adjacent lands

RANK: overall 8, within category 3

SPATIAL SCALE: miniscale/ network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: public records, NPS patrols, media. Frequency: annual.

LIMITATIONS OF DATA AND MONITORING: will need some systematic protocol to detect new or expanding activities

CURRENT MONITORING: Nothing systematic, beyond normal park management activities and patrols

KEY REFERENCES:

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: water quality, air quality, sensitive vegetation communities, brown and black bear DLPs, large and medium carnivores, shorezone habitat, ungulates, visitor use, exotic species, resource harvest for subistence and sport.

OVERALL ASSESSMENT: Monitoring land use change by humans provides a direct measure of the near-field stressor most likely to have widespread and long-term adverse affects on park ecosystems.

Vital Sign 34: Visitor Use (Type, Level and Distribution)

BRIEF DESCRIPTION: This vital sign will address the number of visitors and their type of use by geographic area within park units. Day use is defined as individuals that use backcountry areas but do not remain overnight. This would include lodge guests as well as rental cabin use, and other self directed day use individuals. Backcountry overnight use is the number of individuals who use backcountry areas within park boundaries and do stay overnight.

SIGNIFICANCE: Human presence can have unexpected and significant effects on ecosystems and ecosystem processes. On a small scale, trampling increases erosion, and decreases habitat for small mammals (loss of cover, loss of food) and aquatic organisms (increased invertebrate drift, destruction of biofilm, loss of aquatic macrophytes). Human use 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 over fishing, or over harvest in focal areas. Human waste can add significant nutrients to often nutrient poor environments, and further tip the balance in favor of exotic species .

Data about visitor use is important because of the driving force humans have on ecosystems. Not only are total numbers of visitors important in understanding overall usage of park resources, but understanding the trends in visitor use can aid managers in minimizing the impacts of humans on sensitive animals and ecosystems.

PROPOSED METRIC: Type, level and distribution

RANK: overall 6, within category 1

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT:

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: Concessionaire permits require an annual activity report, which may contain some of this information.

KEY REFERENCES:

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Land-use change and habitat alteration, access, resource harvest, brown and black bear, freshwater fish, and exotic species.

OVERALL ASSESSMENT: Monitoring visitor use parameters provides basic information that park managers need to protect both park resources and visitor experience from impacts associated with visitor use, and provides context for the interpretation of visitor-related changes in other resources addressed by vital signs monitoring.

Vital Sign 35: Resource Harvest for Subsistence and Sport

BRIEF DESCRIPTION: Annual number and type of subsistence and sport harvest, and in Aniakchak, Katmai Preserve and Lake Clark. (Subsistence use is not allowed in Kenai Fjords, nor in Katmai National Park.) Sport wildlife harvest in Aniakchak, Katmai, and Lake Clark Preserves; subsistence gathering and sport fish take throughout all park units.

SIGNIFICANCE: The Alaska National Interest Lands Claim Settlement Act (ANILCA) of 1980 established by statute that subsistence hunting, fishing, and gathering would be legitimate activities on some 41,458,000 acres of new parklands, including lands within Aniakchak, Katmai, and Lake Clark. ANILCA also allowed sport harvest within Preserves; sport fishing is allowed in any National Park unit. 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. Brown bears are of particular concern, since they have low reproductive rates, yet in some park units, subsistence regulations allow for the annual take of one bear per subsistence hunter.

PROPOSED METRIC: Type and number of permits, species and volume of resource harvested

RANK: overall 7, within category 2

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Frequency: annual

LIMITATIONS OF DATA AND MONITORING: Harvest records are collected by both state and federal agencies, but no central database exists. State harvest units are large, and do not conform to park boundaries, so park specific harvest cannot be determined. Harvest records may not be representative of actual harvest. Although illegal harvest is assumed to be low within park boundaries, unreported harvest is often high, especially within Alaska.

CURRENT MONITORING: State and Federal agencies currently collect this data.

KEY REFERENCES:

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Ungulates, predators, brown and black bear, salmon, resident fish, land-use change, landscape patterns and vegetation composition and structure.

OVERALL ASSESSMENT: Subsistence and sport harvest parameters are a direct measure of human effects on species and ecosystems.

Vital Sign 36: Marine Debris and Animal Carcasses (Type, Frequency of Occurrence)

BRIEF DESCRIPTION: Marine debris refers to commercial fishing gear, galley waste and other trash from ships, recreational boaters, and offshore oil and gas exploration and production facilities. Animal carcasses refers to beach cast marine birds and mammals.

SIGNIFICANCE: Marine debris from commercial fishing gear is a chronic problem on SWAN coastlines. Debris washed ashore diminishes the scenic value of beaches, and while adrift or onshore can endanger marine wildlife. Marine debris also collects and transports oil and other pollutants onto beaches. Of particular concern is fishing gear and plastic debris which when discarded at sea can entangle and kill marine mammals, birds, and fish.

Beach cast carcass surveys have delivered useful information on the state, causes and the extent of die offs related to marine pollution and other causes. Usually the first sign of impact from spilled oil is the appearance of dead and dying birds and marine mammals on beaches.

PROPOSED METRIC: Location and type of debris or carcass, frequency of occurrence

RANK: overall 36, within category 6

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Beach transects. Protocols available for the Gulf of Alaska. Frequency:2-4 yrs

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: Marine debris surveys conducted at KATM in 1993-94.

KEY REFERENCES:

Ribic, C.A., T.R. Dixon, and I. Vining. 1992. *Marine Debris Survey Manual*. NOAA Technical Report NMFS 108. U.S. Department of Commerce, Springfield, VA

USEPA. 1998a. *Coastal Watersheds*. EPA 842-F-98-006. U.S. Environmental Protection Agency, Office of Water, Washington, DC. www.epa.gov/owow/oceans/factsheets/fact1.html., http://www.epa.gov/epahome/exitepa.htm, http://www.epa.gov/epahome/exitepa.htm Accessed April 2002.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Shorezone habitat, oil spills, ship groundings, visitor use, exotic species, land-use change and habitat alteration.

OVERALL ASSESSMENT: Marine debris monitoring provides a relatively inexpensive window into offshore events such as animal moralities and discharge of pollutants and provides baseline data for use during natural resource damage assessments after oil spills.

Vital Sign 37: Bioaccumulated Toxic Contaminants (Type and Level of Concentration)

BRIEF DESCRIPTION: Bioaccumulation refers to the increase in concentration of a pollutant from the environment to an organism. Biomagnification refers to the increase in concentration of a chemical over time as it passes upward through the food chain. Bioaccumulated toxic contaminants are chemical compounds such as organochlorines (DDT, PCB, dioxins, and other related chemicals), volatile and semivolatile organic compounds (components of gasoline, fuel oils, and lubricants, organic solvents, fumigants, some inert ingredients in pesticides), and toxic trace elements (arsenic, cadmium, copper, lead, mercury, nickel, selenium, and zinc). These chemicals are not readily metabolized or eliminated by organisms so concentrations increase with exposure.

SIGNIFICANCE: Since World War II, man made chemical compounds have proliferated, and are increasingly found in the environment. Many are easily transported over long distances by air, or water. and studies have shown that salmon can be a vector for introducing organic pollutants into freshwater systems (Krummel et al. 2003). These chemicals can be toxic, but also exhibit sub-lethal effects such as behavioral changes, genetic mutation, abnormal grown and reproductive failure.

PROPOSED METRIC: Type and level of concentration

RANK: overall 28, within category 5

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT:

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: None. In 1996, the Cook Inlet Regional Citizens Advisory Committee established baseline contaminant levels for *Macoma balthica* in Chinitna and Tuxedni Bays (Cook Inlet RCAC 1996). Contaminant analysis included polycyclic aromatic hydrocarbons, alkyulated homologues, trace metal analysis, and bivalve condition index. Frenzel (2000) analyzed sediment from the Kamishak (KATM) and Johnson Rivers (LACL) for organochlorines, semivolatile organic compounds and trace elements, including arsenic, cadmium, copper, lead, mercury, nickel, selenium, and zinc. Organochlorines were not detected. Frenzel (2000) also analyzed slimy sculpin from the Kamishak River for trace elements. Lake Clark National Park and Preserve has an active proposal for measuring mercury in northern pike

KEY REFERENCES:

Cook Inlet RCAC. 1996. Lake Clark National Park Bivalve Study – Data Report. Kinnetic Laboratories, Inc. 7pgs.

Krummel, E. M., R.W. Macdonald, L.E. Kimpe, I. Gregory-Eaves, M. J. Demers, J. P. Smol, B. Finney, and J. M. Blais. 2003. Delivery of pollutants by spawning salmon. Nature 425:255-256

Frenzel, S. 2000. Selected organic compounds and trace elements in streambed sediments and fish tissues, Cook Inlet Basin, Alaska. U.S. Geological Survey Water Resources Investigations Report 00-4004.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Atmospheric deposition of pollutants, oil spills, visitor use, land-use change and habitat alteration, bald eagle productivity, freshwater fish, marine invertebrates, marine debris and animal carcasses.

OVERALL ASSESSMENT: Monitoring bioaccumulated toxic contaminants is organisms such as freshwater fish and marine invertebrates are an indicator for habitat exposure to organic and inorganic contaminants. It is a direct measure of variation in chemical contaminants between sites, and contributes to the understanding of trends in contamination in SWAN.

Vital Sign 38: Invasive / Exotic Plants and Animals

BRIEF DESCRIPTION: An exotic species is any plant or animal that is not native (indigenous) to Southwesten Alaska. Exotic species monitoring will track non-native plant and animal species which are introduced in and near network parklands, whether intentionally or accidentally.

SIGNIFICANCE: Exotic species have the potential to disrupt native biological communities by competing with native species for space, food, and other resources; or by preying upon native species, especially juveniles. Of greatest immediate concern is the SWAN marine coastline. Vessels traveling the world's oceans pick up "hitchhiking" flora and fauna on their hulls and in their ballast water tanks. Resurrection Bay-Seward, Kachemak Bay-Homer, and the Kodiak Harbor have a high potential for invasions because they receive cruise ships, oil tankers, wood-chip, and other boat traffic from outside of Alaska. Hines and Ruiz (2002) recently identified 21 nonindigenous marine species in the Homer Harbor. Most commercial tour boats that visit SWAN are moored in Homer, Seward, or Kodiak.

Similarly, many private and commercial floatplanes that land in freshwater lakes originate in Anchorage, Homer, or Kodiak. These aircraft and their human passengers provide an avenue of transport for exotic plants and other organisms to reach remote regions of the parks. Increasing visitation rates, developments on private inholdings, and the general warming trend in climate all favor the likelihood of exotic species becoming introduced and established in network parks.

PROPOSED METRIC: Occurrence and distribution of non-indigenous plants and animals

RANK: overall 14, within category 4

SPATIAL SCALE: focus sites across network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Protocols are available to survey and record exotic plant species. Exotic invertebrates, animals, fish and birds will need similar protocols. Frequency: annual to decadal

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: Exotic plant surveys have been started in Katmai and Kenai Fjords. http://www.nature.nps.gov/im/units/swan/Documents/ReportsMonitoring/Phase_I_Report/AppendixJ_Exotic_Species_Threats.pdf

KEY REFERENCES:

Alaska Department of Fish and Game. 2002. Alaska aquatic nuisance species management plan. Juneau, AK. 103 pp

Hines A H. and G. M. Ruiz. 2002. Marine Invasive Species and Biodiversity of South Central Alaska Unpubl., Smithsonian Environmental Research Center, Edgewater, Maryland

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Climatological conditions, insect and disease outbreaks, landscape patterns and vegetation composition, sensitive vegetation communities, land-use changes.

OVERALL ASSESSMENT: The destination of boats, aircraft, and people within SWAN corresponds to habitats that are also the most hospitable for the establishment of exotic species, i.e., coastal bays and estuaries, freshwater lakes and wetlands.