Central Alaska Network

Vital Signs Monitoring Plan

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CENTRAL ALASKA NETWORK

PLAN FOR VITAL SIGNS MONITORING

August 2005

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The vital signs monitoring plan for the Central Alaska Network meets all program requirements and is approved for implementation.

Steven G. Fancy
Monitoring Program Leader

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Preface

This document concerns three national parks in central Alaska: Denali National Park and Preserve, Wrangell-St. Elias National Park and Preserve, and Yukon-Charley Rivers National Preserve. Together these parks form the Central Alaska Network (CAKN), which has been created for the purpose of establishing and carrying out an ecological inventory and monitoring program. Development of monitoring programs to be carried out over long periods of time requires a significant investment in strategic planning over several years. Establishment of the monitoring portion of the CAKN program has been directed by national-level guidance and culminates in the publication of a peer-reviewed monitoring plan. The monitoring plan for each network is to be written in three phases, corresponding to three phases of program development, over a period of roughly three to four years.

The first report, the Phase I report, is a preliminary look at the initial chapters of the monitoring plan and describes the parks within the network and the resources therein. The Phase II report builds on the Phase I report by outlining an initial list of prioritized Vital Signs chosen by the network. Finally, the Phase III report provides the implementation and staffing plans for the program and also constitutes a first draft of the CAKN Vital Signs Monitoring Plan. The Phase III Report was peer reviewed by the National Monitoring Coordinator and a science panel of peer review in December 2004. The Phase III Report was revised accordingly and resubmitted to the National Monitoring Coordinator for final approval in September 2005. Final approval of the Phase III Report advances the Central Alaska Network to the final stage of program planning with the establishment of a Vital Signs Monitoring Plan.

This document is the Vital Signs Monitoring Plan for the Central Alaska Network.

Executive Summary

Chapter 1.
Introduction and Background

Denali National Park and Preserve, Wrangell-St. Elias National Park and Preserve, and Yukon-Charley Rivers National Preserve have been organized into the Central Alaska Network (CAKN) for the purposes of carrying out ecological monitoring activities under the National Park Services' Vital Signs Monitoring program.

The Phase III Report is the initial draft of the Vital Signs Monitoring Plan for the Central Alaska Network. It includes updated material from the Phase I and II documents. This report, and draft protocols for 11 of the network's Vital Signs, were peer reviewed early in 2005. Review comments were incorporated into the document bringing the network to the final stage of having a Vital Signs Monitoring Plan. Implementation of the program will formally begin in FY 2006.

The broad goals of the CAKN monitoring program are to: (1) better understand the dynamic nature and condition of park ecosystems; and (2) provide reference points for comparisons with other, altered environments. The focus of the CAKN program will be to monitor ecosystems in order to detect change in ecological components and in the relationships among the components.

Water quality monitoring is fully integrated within the CAKN monitoring program. A monitoring program for lentic (non-moving water) has been determined, and the program for lotic systems (moving water) is under development.

Chapter 2.
Conceptual Models

The CAKN has developed conceptual models to guide the development of the monitoring program. These models nest within one or more of more components of the model, which then provide a unifying framework for integrated, interdisciplinary monitoring.

Chapter 3.
Vital Signs

There are 36 identified Vital Signs for the CAKN, which represent a systems-based approach to monitoring, and these are presented within the Vital Signs Framework as developed by the National Park Service Vital Signs Monitoring program. Three vital signs refer to air and climate, two refer to geology and soils, four refer to water, four refer to human use, five refer to ecosystem pattern and processes, and 18 refer to biological integrity.

Chapter 4.
Sampling Design

An overall statistical sampling design has been developed for the CAKN. Details of the sampling design are described in Chapter 4 for the ten full protocols the network has generated. Where possible, sampling for the ten initial vital signs has been collocated. A grid-based sampling design for vegetation structure and composition, passerine birds, snow depth, and moose is described. A list-based sampling design is described for water resources and associated parameters, wolves, and golden eagles. Index sites will be used for peregrine falcons, climate and snowpack, and air quality.

Chapter 5.
Sampling Protocols

Protocol Development Summaries for the 36 vital signs appear in Appendix L. Each summary explains the reasons why the vital sign was selected, sets forth specific monitoring objectives, and describes how the network plans to monitor the vital sign. Included with this report is a CD with the draft protocols for ten Vital Signs: Climate, Snowpack, Air Quality, Vegetation Structure and Function, Passerine Birds, Water Quality-Shallow Lakes and Ponds, Golden Eagles, Peregrine Falcons, Wolves, and Moose.

Chapter 6.
Data Management

The data management plan for the Central Alaska Network serves as the overarching strategy to ensure that data collected by the program are subjected to rigorous quality assurance and control procedures and that these data are made available to others for management decision making, research, and education. The data management plan for the network is fully described at www.nature.nps.gov/im/units/cakn/DataMgt.htm.

Chapter 7.
Data Analysis and Reporting

Prompt data analysis and reporting are central tenets for the CAKN. The network will provide sufficient funding for these activities to ensure that by March each year the previous phenological year (Oct.–Sept.) is reported on. An annual integrated "State of the Parks" report is also a main component for the reporting of the program. Individuals responsible for data analysis and reporting for each Vital Sign are identified.

Chapter 8.
Administration and Implementation of the Monitoring Program

The network has developed a three-year plan for administration and implementation of the monitoring program. This plan includes: a staffing plan, how network operations are integrated with other park operations, key partnerships, how in-house field work will be carried out, and the periodic review process for the program. The network relies strongly on existing park personnel as principal investigators for each Vital Sign. Key partnerships include the U.S. Geological Survey Biological Resource Division, the Western Regional Climate Center, the U.S. Department of Agriculture Natural Resources Conservation Service, the Alaska Bird Observatory, and the University of Alaska Fairbanks Institute of Arctic Biology.

Chapter 9. Schedule

A schedule for development and implementation of each vital sign has been determined. Monitoring of ten vital signs will begin in FY 2006, and monitoring of the remaining 26 vital signs will phase in through FY 2010.

Chapter 10. Budget

Annual funding for the CAKN is $1,215,000 with an additional $98,000 coming from the National Park Service Water Resources Division for water quality monitoring. During the first year of implementation (FY 2006), 47% of the budget will be spent on personnel (permanent, term and seasonal), 33% on information/data management, and 39% on Operations and Equipment.

Chapter 1
Introduction and Background

The Central Alaska Network (CAKN) is composed of Denali National Park and Preserve, Wrangell-St. Elias National Park and Preserve, and Yukon-Charley Rivers National Preserve (hereafter Denali, Wrangell, and Yukon-Charley). CAKN is one of the 32 networks included in the Servicewide Inventory and Monitoring program and one of four networks in Alaska (Fig. 1-1). Park units within the CAKN contain over 8.8 million hectares (21.7 million acres) of parklands, with 4.7 million hectares (11.8 million acres) of designated wilderness. Yukon-Charley Rivers National Preserve contains 735,000 hectares (1,815,370 acres; 72 percent of total area) of suitable wilderness. Management is the same as if it were designated wilderness. Based on total area, the CAKN represents 25 percent of the land in the national park system.

1.1 Purposes of the Vital Signs Monitoring Program

The purposes of the Vital Signs Monitoring Program in the National Park Service relate directly to the purposes of the national park system. In this section, we review the justifications for integrating natural resource monitoring, set by enabling legislation for the NPS overall and for CAKN parks specifically, that establish the importance of a program to monitor natural resource conditions.

1.1.1 Justification for Integrated Natural Resource Monitoring

Knowing the condition of natural resources in national parks is fundamental to the NPS's ability to manage park resources "unimpaired for the enjoyment of future generations." National park managers across the country are confronted with increasingly complex and challenging issues that require a broad-based understanding of the status and trends of park resources as a basis for making decisions and working with other agencies and the public for the benefit of park resources. For years, managers and scientists have sought a way to characterize and determine trends in the condition of parks and other protected areas to assess the efficacy of management practices and restoration efforts and to provide early warning of impending threats. The challenge of protecting and managing a park's natural resources requires a multiagency, ecosystem approach because most parks are open systems, with threats such as air and water pollution or invasive species originating outside of the park's boundaries. An ecosystem approach is also needed because no single spatial or temporal scale is appropriate for all system components and processes; the appropriate scale for understanding and effectively managing

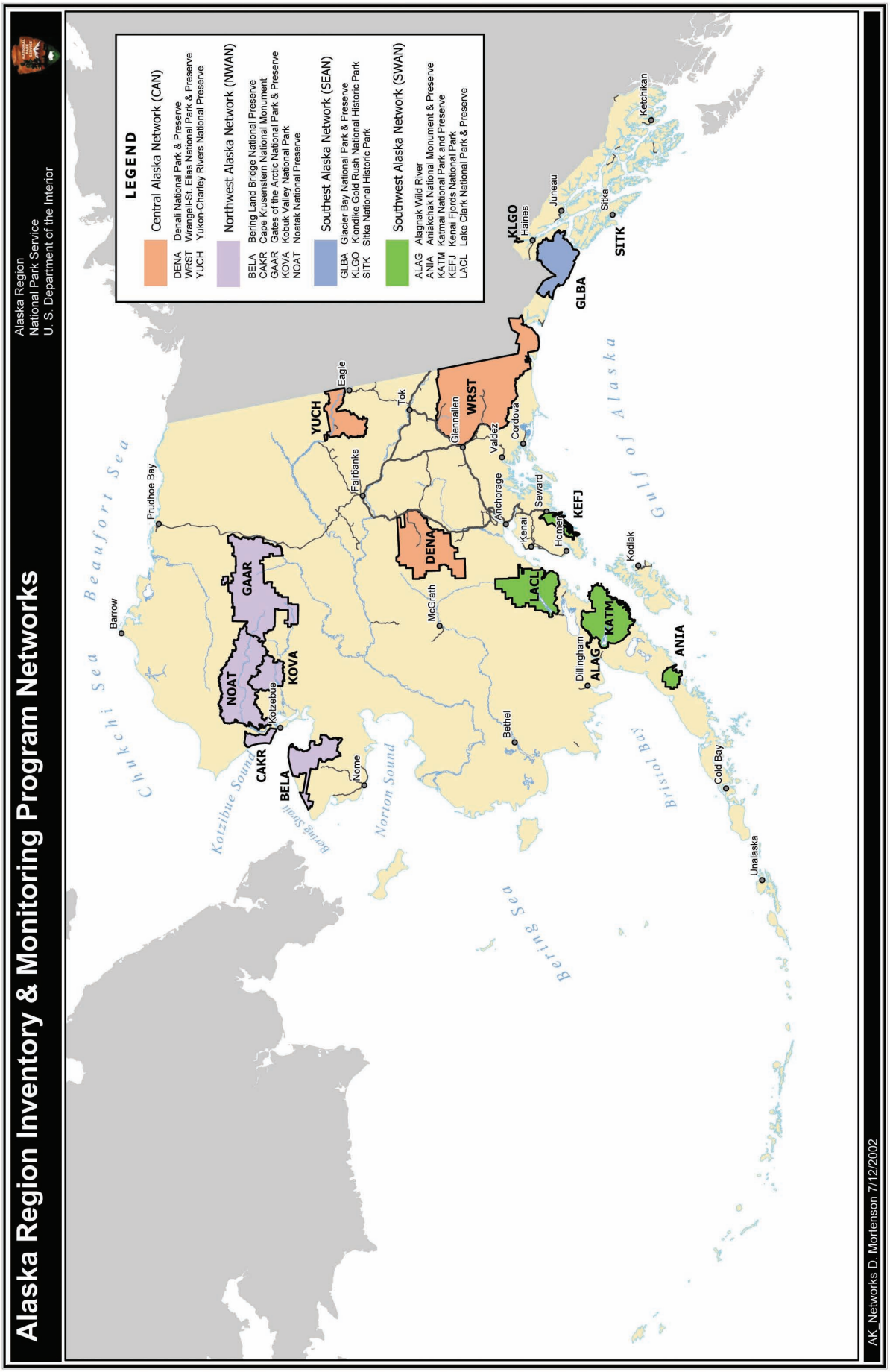

Fig. 1-1. Location of Central Alaska Network and Other Alaska networks

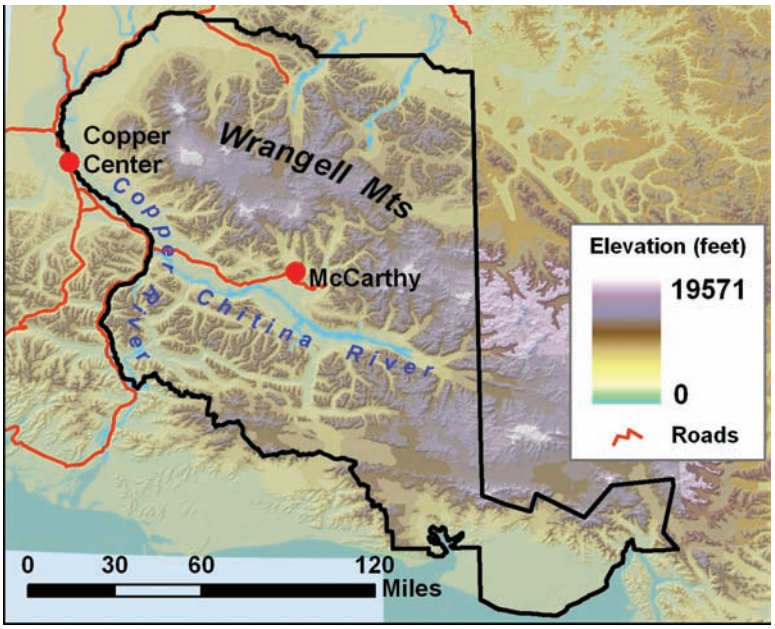

Fig. 1-2. Wrangell-St. Elias National Park and Preserve

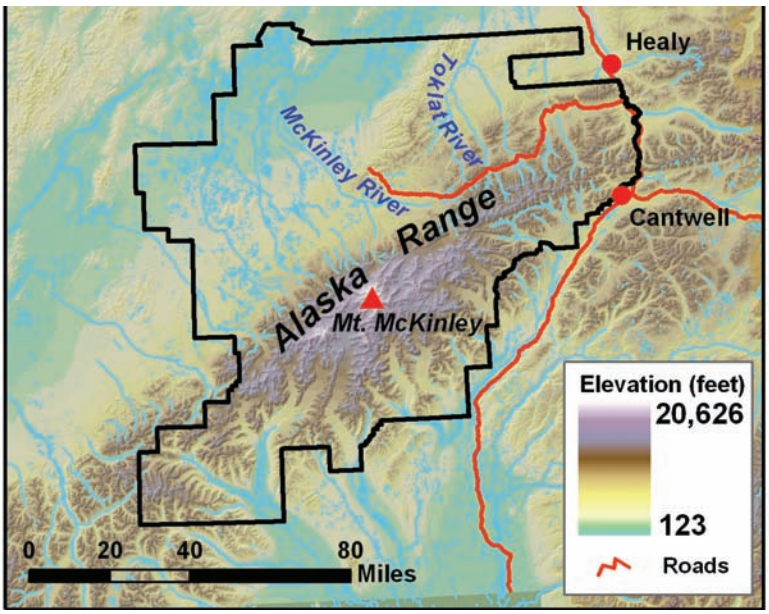

Fig. 1-3. Denali National Park and Preserve

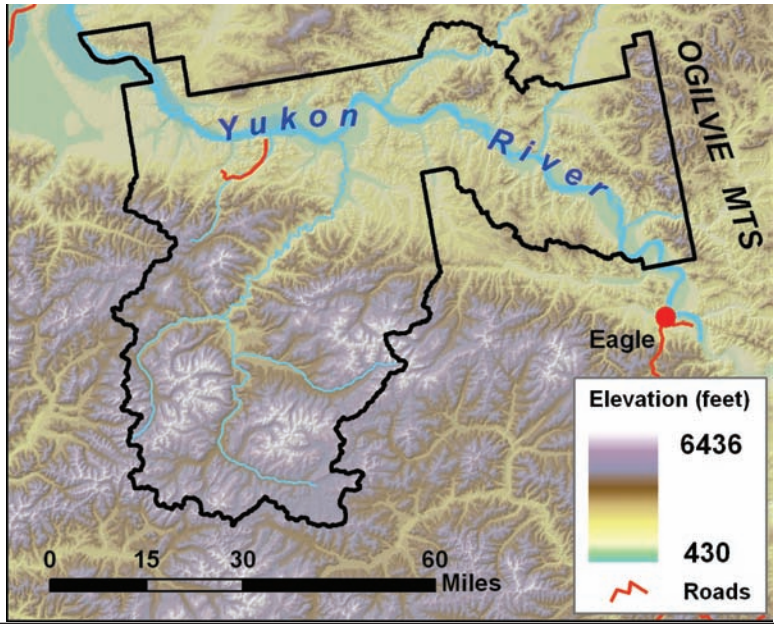

Fig. 1-4. Yukon-Charley Rivers National Preserve

a resource might be at the population, species, community, or landscape level, and in some cases may require a regional, national, or international effort to understand and manage the resource. National parks are part of larger ecosystems and must be managed in that context.

Natural resource monitoring provides site-specific information needed to understand and identify changes in complex, variable, and imperfectly understood natural systems and to determine whether observed changes are within natural levels of variability or may be indicators of unwanted human influences. Thus, monitoring provides a basis for understanding and identifying *meaningful change* in natural systems characterized by complexity, variability, and surprises. Monitoring data help to define the normal limits of natural variation in park resources and provide a basis for understanding observed changes; monitoring results may also be used to determine what constitutes impairment and to identify the need to initiate or change management practices. Understanding the dynamic nature of park ecosystems and the consequences of human activities is essential for management decision-making aimed to maintain, enhance, or restore the ecological integrity of park ecosystems and to avoid, minimize, or mitigate ecological threats to these systems (Roman and Barrett 1999).

The intent of the NPS monitoring program is to monitor a subset of park resources and processes, known as "vital signs," that are determined to be the most significant indicators of ecological condition of the specific resources that are of the greatest concern to each park. This subset of resources and processes is part 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 these resources. In situations where natural areas have been so highly altered that physical and biological processes no longer operate (e.g., control of fires and floods in developed areas), information obtained through monitoring can help managers understand how to develop the most effective approach to restoration or, in cases where restoration is impossible, ecologically sound management. The broad-based, scientifically sound information obtained through natural resource monitoring will have multiple applications for management decision-making, research, education, and promoting public understanding of park resources.

1.1.2 Federal Legislation, Policy, and Guidance

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 of conserving parks unimpaired (see

Appendix A: Summary of Legislation, National Park Service Policy and Guidance Relevant to Development and Implementation of Natural Resources Monitoring in National Parks). This specific direction on the monitoring of resources in national parks was not in the early policies of the NPS. Since 1978, legislation and guidance have evolved such that the 2001 NPS Management Policies specifically directs the service to inventory and monitor natural systems (see Appendix A: Summary of Laws, Policies, and Guidance for more detail). It is evident from even a cursory read of laws, policy, and guidance that a substantial framework is in place for the establishment of the Vital Signs Monitoring program for the CAKN as well as the other NPS networks.

1.1.3 CAKN Parks Legislation and Guidance

The three parks that comprise the Central Alaska Network were created or had lands added to them with the passage of the Alaska National Interest Land Claims Act (ANILCA) in 1980. Yukon-Charley and Wrangell-St. Elias were created by this act, while Denali had 1.6 million hectares (4 million acres) added to it. Although ANILCA was passed before the inauguration of the NPS Inventory and Monitoring program, the act contains language that describes the need for an ecological monitoring program. The passage of ANILCA had, and will continue to have, large ramifications for national parks in Alaska. It is important to understand the intent of this law and its effect on management of Alaska national parks. Title I, Section 101(b) of ANILCA states that:

- it is the intent of Congress in this Act to preserve unrivaled scenic and geological values associated with natural landscapes;
- to provide for the maintenance of sound populations of, and habitat for, wildlife species of inestimable value to the citizens of Alaska and the Nation, including those species dependent on vast relatively undeveloped areas;
- to preserve in their natural state extensive unaltered arctic tundra, boreal forest, and coastal rainforest ecosystems, to protect the resources related to subsistence needs;
- to protect and preserve historic and archeological sites, rivers, and lands, and to preserve wilderness resource values and related recreational opportunities including but not limited to hiking, canoeing, fishing, and sport hunting, within large arctic and subarctic wildlands and on freeflowing rivers;
- and to maintain opportunities for scientific research and undisturbed ecosystems.

Clearly, the information gained from an ecological monitoring program is integral to the ability of CAKN park managers to steward the land in a manner consistent with enabling legislation, primarily ANILCA. Although each CAKN park preserves unique areas, these parks share common purposes of protecting fish and wildlife habitat and populations, providing for recreation

and subsistence, preserving scenic and geologic formations, and maintaining extensive areas of undisturbed tundra, boreal forest, and temperate rainforest ecosystems. These common purposes unify the network. This unity in underlying purposes should be a great help to the network as it attempts to establish itself. Because parks have traditionally operated as independent entities, a major challenge in creation of a multipark monitoring network is overcoming these tendencies. The CAKN parks are fortunate in sharing broad goals, providing a solid foundation for "thinking like a network."

1.2 Monitoring Goals and Strategies

The first section of this chapter addressed the broad goals of monitoring in the context set by the enabling legislation for national parks generally and for CAKN parks specifically. In this section, we first discuss the importance of inventory, monitoring, and research in stewarding natural resources. We then present our current thinking about goals and objectives for CAKN monitoring, summarize our progress to date, and describe the next steps in program development. This section is intended as a status report on the development of the overall CAKN program, including network-specific goals and objectives. Because the CAKN includes a park, Denali, that has been a prototype monitoring park since 1992, we also discuss how the existing Denali program will be integrated into the CAKN program.

1.2.1 Role of Inventory, Monitoring, and Research in Resource Management

Monitoring is a central component of natural resource stewardship in the National Park Service and, in conjunction with natural

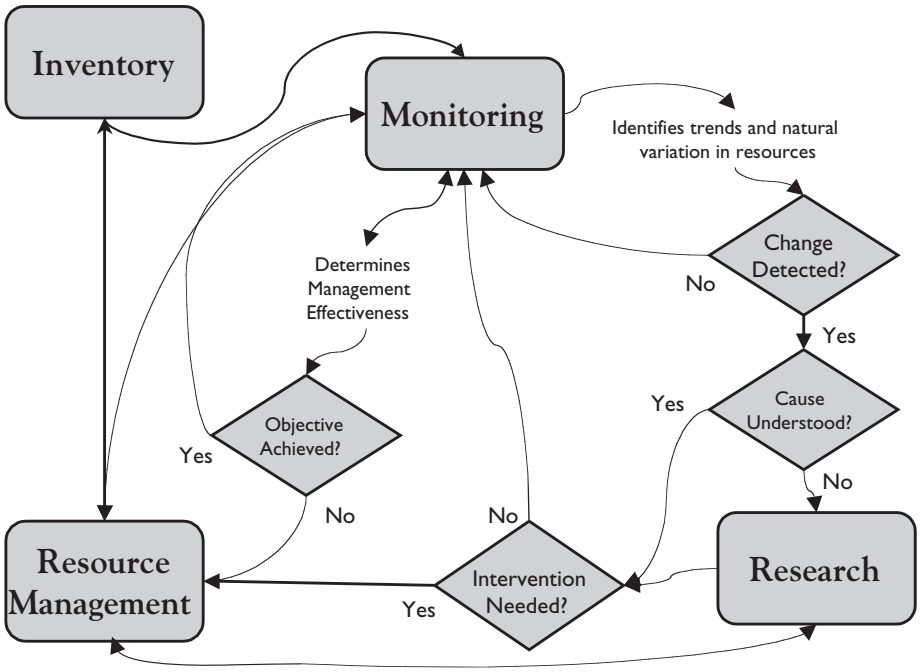

Fig. 1-5. Relationships between monitoring, inventories, research, and natural resource management activities in national parks

resource inventories and research, provides the information needed for effective, science-based managerial decision-making and resource protection (Fig. 1-5; see also Appendix B). The NPS strategy to institutionalize inventory and monitoring throughout the agency consists of a framework (see Appendix C) having three major components: (1) completion of 12 basic resource inventories upon which monitoring efforts can be based; (2) a network of 11 experimental or "prototype" long-term ecological monitoring (LTEM) programs begun in 1992 to evaluate alternative monitoring designs and strategies; and (3) implementation of operational monitoring of critical parameters (i.e., "vital signs") in approximately 270 parks with significant natural resources that have been grouped into 32 vital sign networks linked by geography and shared natural resource characteristics.

The network approach facilitates collaboration, information sharing, and economies of scale in natural resource monitoring and provides parks with a minimum infrastructure for initiating natural resource monitoring that can be built upon in the future. Nine of the 32 networks include one or two prototype long-term ecological monitoring (LTEM) programs, which were established as experiments to learn how to design scientifically credible and cost-effective monitoring programs in ecological settings of major importance to a number of NPS units. Because of higher funding and staffing levels, as well as USGS involvement and funding in program design and protocol development, the prototypes serve as "centers of excellence" that are able to do more extensive and in-depth monitoring and continue research and development work to benefit other parks. In the Central Alaska Network, Denali National Park and Preserve was the prototype for the subarctic biome (see Appendix C). With the evolution of the CAKN program, a wholly integrated program between the CAKN and the Denali Prototype Monitoring program has taken place such that the CAKN represents both aspects of the two formerly separate programs (see Section 1.2.6 for further context).

1.2.2 Goals for Vital Signs Monitoring

Servicewide goals for vital signs monitoring for the National Park Service are as follows:

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 and impairment 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 towards performance goals.

1.2.3 CAKN Program Focus

The CAKN recognizes the National Park Service Monitoring Program as a unique opportunity to advance our understanding of the ecosystems that encompass our network of parks. This understanding will come in the form of the monitoring data that are collected, analyzed, interpreted, and reported. Further, we recognize that while scientific work has been conducted in each of the network parks, this information needs to be incorporated with our monitoring efforts to improve our understanding of the holistic functioning of ecosystems within our network. An understanding of our ecosystem function is important because it will best allow us to fulfill the legislative mandate to manage parks in a manner that leaves them "unimpaired for the enjoyment of future generations." At the most basic level, we cannot evaluate appropriate ecosystem function when the bounds of natural variability are not known because we cannot identify when conditions are outside an expected range of variation. Similarly, in this situation, reliable identification of resource trends is also difficult.

We have specifically chosen to focus the CAKN monitoring program on general ecological function because our parks are relatively pristine and unstudied. In so doing, the CAKN program falls predominantly under servicewide goals #1, #3, and #4 (see preceding page). These goals concern determining status and trends of ecosystem condition, understanding the dynamics of park ecosystems, and providing data to meet legal mandates. As mentioned in the previous section, ecological vital signs may occur at any level of ecological organization, thus several of the vital signs we monitor will be of a large-scale ecological scope. While many long-term ecological monitoring programs have focused on anthropogenic causes of change, direct human effects tend to be more limited in our systems. However, scientists expect global climate changes to register first in northern climes; moreover, arctic and subarctic environments may be especially vulnerable to even slight shifts in temperature regimes (National Assessment Synthesis Team 2000). Because of their size, remote and protected status, and resultant near-pristine condition, few regions offer the environmental monitoring opportunity and promise that is possible in the arctic and subarctic parks of Alaska, even though there are zones of intensive disturbance, primarily due to mining activity. The relatively untouched nature of these vast parklands provides CAKN with important baselines to measure and evaluate

the direction and magnitude of changes brought about by human influences on regional, national, and global scales.

The focus of the Central Alaska Network is to build a holistic picture of change across the ecosystems of the network. Specifically, we desire to:

- monitor ecosystems to detect change in ecological components and to
- detect change in the relationships among those components.

Further, because we seek a holistic picture of change in our ecosystems, we primarily desire a landscape-level scope of inference from our observations. The goal in designing our program has been to minimize bias in measurements so that inference from our efforts is sound.

Our network is also highly committed to establishing the foundation of a monitoring program that will last in perpetuity. We anticipate that over time the information gained from the monitoring program will provide valuable data that will aid appropriate management decisions in the network parks. Thus management issues should be considered in design of the monitoring program, yet those issues should not limit the program because management issues change. A well-designed monitoring program will be applicable to future issues, including ones that we cannot foresee.

1.2.4 The Integration of Water Quality with Monitoring

The water resources of the CAKN are vast and span a gradient from the fifth largest river in North America, the Yukon River, to small ephemeral wetlands that provide vital habitat for shorebirds and waterfowl. This network also contains the headlands for waters that flow to bodies as far away as the Bering Sea and Bristol Bay. Moreover, within the networks' 8.8 million hectares, we have only two streams that fall under the 303(d) section of the Clean Water Act. The CAKN has recognized from the beginning that the water resources of the network, whether in the form of precipitation or in water bodies, are a primary component of all the network ecosystems (see Chapter 2 for more detail). Therefore, we have sought to fully integrate the monitoring of water into the framework of the entire Vital Signs Monitoring Program.

In keeping with our holistic view of ecosystems, we view a continuum of land to water, rather than a line of demarcation. For any ecosystem, the abundance and distribution of water is probably one of the strongest driving forces of ecological change. For purposes of approaching water monitoring in a manageable context, we categorize our water resources into moving water systems (lotic) and nonmoving water systems (lentic). In this

context, the network has decided to approach monitoring water quality by focusing not just on the chemical "health" of the water, but also on the abundance and distribution of water on the landscape. Second, we consider our monitoring of these resources from remote-sensed options and from actual *in situ* monitoring.

For lentic systems we have determined that shallow lakes will be the primary area of interest. Shallow lakes support abundant growth of lake-bottom and lake-edge plants. The high rates of primary production and the structure and nutrients provided by lake-edge plants provide habitat for macroinvertebrates and rearing areas for waterfowl, shorebirds, and fishes. The network is interested in the biota living in, near, and dependent on water-dominated parts of the landscape. We will monitor these systems remotely via RadarSat technology and will also physically visit some lakes for *in situ* measurements (see Protocol Development Summary on Water Quality/Quantity in Appendix L for complete detail).

Moving water systems represent the other large category of water resources the network would like to incorporate into the Vital Signs Monitoring program. During FY 2005, the network will be hiring a term-funded stream ecologist specifically to help develop appropriate monitoring protocols. We will also be holding scoping workshops on rivers and freshwater fish during the year to better define monitoring objectives for these areas. The network plans to have all water monitoring operational in the next five years.

The NPS Government Performance and Results Act (GPRA) goal for water resources requires that parks report on "impaired waters" as defined by section 303(d) of the Clean Water Act. The State of Alaska classifies waters in a tiered system, and the NPS is required to report on water bodies that fall under Tier 2 of the classification (for a complete description of Tiers, see Appendix D). The CAKN contains only two streams in Tier 2 (see Appendix D for description) and will report on those streams as part of the Vital Signs Monitoring Program.

1.2.5 The Integration of Air Quality with Monitoring

Under the Clean Air Act, park managers have a responsibility to protect air quality and related values from the adverse effects of air pollution. Protection of air quality in national parks requires knowledge about the origin, transport, and fate of air pollution, as well as its impacts on resources. To be effective advocates for the protection of park air resources, NPS managers need to know the air pollutants of concern, existing levels of air pollutants in parks, park resources at risk, and the potential or actual impact on these resources. Through the efforts of park personnel, support office staff, and the NPS Air Resources Division, the NPS meets its

clean air affirmative responsibilities by obtaining critical data and using the results in regulatory-related activities.

Although current air quality in CAKN parks is considered pristine by national standards, the CAKN recognizes air pollution from global and regional industrialization as a potential driver of ecosystem change in network parks (MacCluskie and Oakley 2003). Arctic haze has been documented to occur in Denali (Shaw 1995). Air quality in CAKN parks is also affected by wildland fires and volcanic eruptions. Air quality was designated a vital sign for the network because of its importance as both an anthropogenic and natural driver of change.

Within the NPS, air quality monitoring is managed nationally through participation in several established programs, each targeting a specific aspect of air quality. Denali, designated as a Class 1 park under the Clean Air Act (where the most stringent standards apply), has been the site of air quality monitoring since 1985. CAKN will use data from the Denali site to monitor air quality in the network. The network will monitor concentrations of compounds known to be generated by industrial activities and to act as pollutants (e.g., sulfate), in both wet and dry deposition. The network will also monitor composition and concentrations of particulates that affect visibility. Because Denali is part of the Interagency Monitoring of Protected Visual Environments (IMPROVE) program in the Air Resources Division, ozone concentrations will be monitored as well.

1.2.6 CAKN Approach to Program Development

The CAKN has approached developing the monitoring program in a stepwise fashion such that we will implement sections of the program one at a time as we build the program. Obviously, it is impossible to monitor all attributes of our systems at once; thus our program will evolve over time as we document change and patterns of variation in our ecosystems. This evolution will be slow and adaptive in that we will evaluate the results of our monitoring at regular intervals (annually and at 5 and 10 year intervals). Our initial focus will be on baseline information that will build the foundation of our understanding. Such an approach will allow us to build a robust knowledge of ecosystem change and the patterns of variation in system resources.

To provide a starting point for our scoping workshop in April 2002, we initiated four subject area work groups (aquatics, flora, fauna, and physical environment) that each developed a strategy of how to monitor that ecosystem component. These strategies served as for discussion during the scoping workshop as well starting points for fitting the components of the ecosystem monitoring program together. The objectives for each work group

are listed in Appendix E. The full text of each strategy appears in the CAKN Scoping Workshop Notebook (full text appears on the network webpage at http://www.nature.nps.gov/im/units/nw03/TC_login.cfm).

At the conclusion of our scoping workshop in April 2002, we had received excellent input from invited experts that helped refine subject area objectives and approaches to the program. The most important, and unanticipated, feedback from participants concerned the need to integrate the program across disciplines, if attaining a large scale picture of ecosystem function was a primary goal of the program. This input caused the Technical Committee to recognize the corresponding importance of a common, probabilistic sampling design that is applicable to the entire network. Besides the myriad statistical advantages conferred by such a sample design, it would also allow us to appropriately link spatial scales of monitoring components for extensive and intensive objectives.

Given the above, we focused our work during 2003 on developing the framework of the monitoring program. We did this by initiating an Interdisciplinary Team who worked to develop a program framework that would cut across the terrestrial/aquatic boundary and that would appropriately represent the fundamental information parks need to gain from the monitoring program. The Interdisciplinary Team began meeting in October 2002 and worked together through March 2003, with intermittent meetings with the Technical Committee for input and discussion. Chapter 2 describes in detail the evolution of thought by the Interdisciplinary Team while Fig. 1-6 illustrates the process portion of the work.

During fall 2003 and spring 2004, the Technical Committee evaluated the report of the Interdisciplinary Team and worked on constructing the "short list" of vital signs and their implementation in a three-to-five-year time frame.

Throughout 2003 another important part of developing the CAKN program was the integration of the Denali Prototype Monitoring Program with the CAKN Vital Signs Program. Due to the stage of development of the Denali Prototype Program, an assessment of that program taking place, and the staff participation in the network it was logical to fit the Denali LTEM Program with the network organization. These factors led to a convergence of thought to integrate the Denali Prototype Program fully into the CAKN for the benefit of both Denali and the network.

Further specific detail of the development of the CAKN program appears in Appendix F. The CAKN Vital Signs and their objectives appear in Table 1-1.

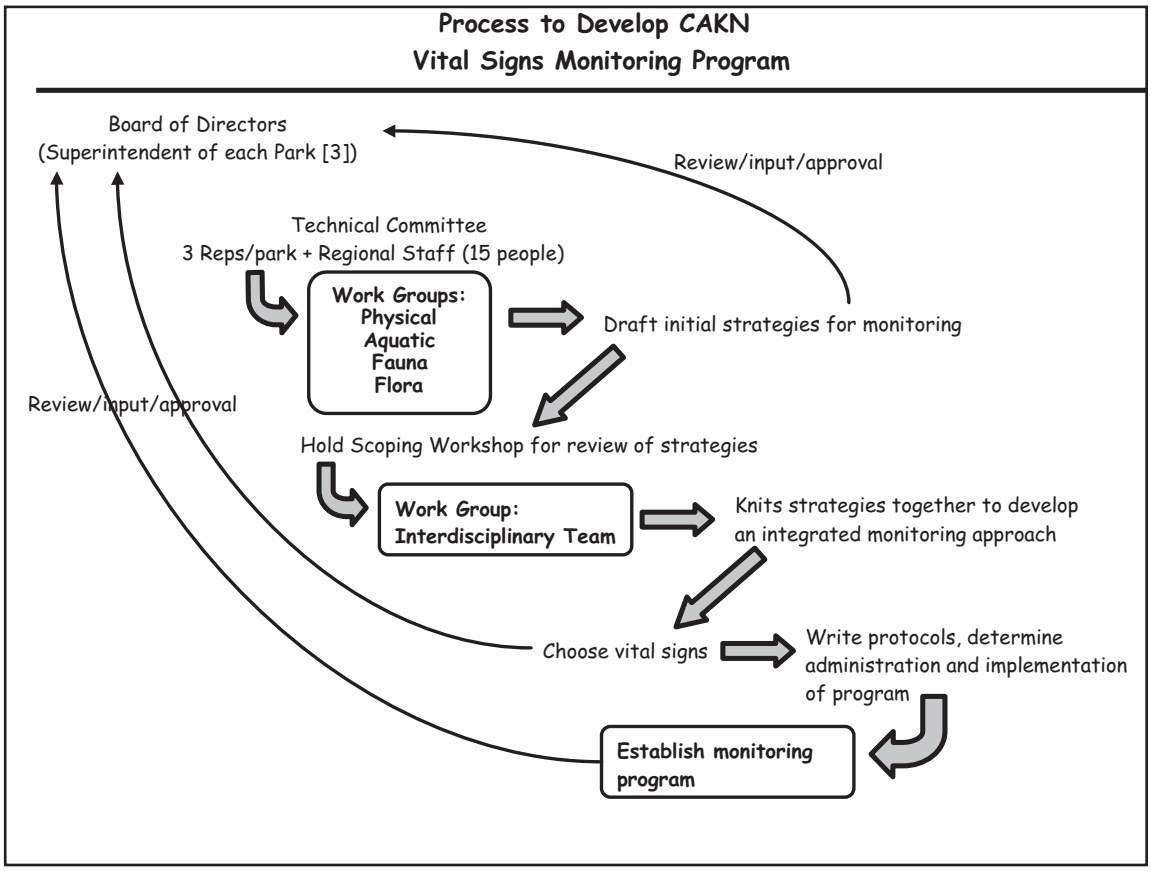

Fig. 1-6. Program development for the CAKN 2001–2004

1.3 Natural Resources of Central Alaska Network Parks: What is Important?

In an effort to emphasize the cohesive nature of our network parks, we begin this section with a synthesis of the important similarities and differences among the parks. We then present a brief overview of natural resources in each Central Alaska Network park. Appendix G discusses the natural resources of each park in more detail, including the natural resource "themes" of each. These "themes" highlight what we consider to be the most important natural resource features of each park—often the features the park was created to preserve. In summary, these parks contain resources of national and international significance. These resources include:

- mountains and opportunities to observe major geologic processes associated with mountains, including glaciation and volcanism;
- a diverse flora revealing influences from the Pleistocene;
- important resident and migratory wildlife populations;
- rivers, including major rivers with significant salmon runs; and
- recognition as international biosphere reserves.

Table 1-1. Vital signs and objectives for the Central Alaska Network under the National Park Service Monitoring framework.

Level I	Vital Sign	Objective
Air and Climate	Air quality	• Monitor the spatial and temporal trend of airborne contaminant concentrations in DENA that is a member of a nationwide array of monitoring stations.
	Climate	• Record long-term trend in temperature, precipitation and secondary climate drivers of wind speed, solar radiation and relative humidity in CAKN parks to quantify drivers of Alaska ecosystems.
	Snow pack	• Monitor snowpack in conjunction with climate in CAKN parks to quantify one of the ecological drivers of Alaska ecosystems.
Geology and Soils	Glaciers	• Monitor long-term changes in the location and extent of glaciers in DENA and WRST using aerial photography, satellite imagery, landscape profiling and field surveys. • Monitor mass balance of selected glaciers in DENA and WRST.
	Disturbance: volcanoes and tectonics	• Monitor the occurrence of major earthquakes centered in the CAKN region using data provided by the USGS-Alaska Science Center, Hazards Office, to provide an annual summary of the number and location of earthquakes for the annual Network report. • Monitor the occurrence, timing and duration of ash clouds from volcanic eruptions passing over CAKN parks using remote-sensed imagery (i.e., MODIS), and air quality data from the DENA air quality monitoring station to provide an annual summary on volcanic inputs for the annual Network report.
	Permafrost	• Detect broad-scale trends in permafrost condition across the landscape of CAKN parks by monitoring the abundance and distribution of thermokarst and other permafrost-related terrain features in index areas. • Detect broad-scale trends in permafrost condition across the landscape of CAKN parks by monitoring temperatures in existing boreholes in and near CAKN parks.
Water	Disturbance: Stream flood frequency and discharge	• Determine long term trends in flood frequency and discharge of selected rivers and streams in the network.
	River/stream flow	• Determine temporal and annual long term trends in discharge of selected rivers and streams in the network. • Determine the composition and spatial distribution of aquatic organisms within rivers/streams selected for sampling. • Detect changes in indices of stream productivity.
	Water Quality	• Detect decadal scale trends in water quantity, water quality, vegetation structure and composition and macroinvertebrates in shallow lakes.
	Macroinvertebrates	• Detect decadal scale trends in water quantity, water quality, vegetation structure and composition and macroinvertebrates in shallow lakes • Determine the composition and spatial distribution of aquatic organisms within rivers/streams selected for sampling. • Detect changes in indices of stream productivity.

Level 1	Vital Sign	Objective
Biological Integrity	Disturbance: Exotic species	• Detect the presence of exotic plant species in CAKN parks through regular surveys in areas of high human or natural disturbance or areas of known potential for supporting exotic species. • Maintain awareness of the range extensions for exotic terrestrial and aquatic animal vertebrate species to occur in CAKN parks through annual coordination with existing state and federal monitoring programs.
	Insect Damage	• Determine the annual variation and long-term trends in the extent (acreage) and frequency (return interval) of forest insect outbreaks within all three network parks.
	Freshwater fish	• Monitor changes in the distribution and abundance of anadromous (salmon) and resident fish species in network parks.
	Bald Eagles	• Determine annual levels of nesting territory occupancy, nesting success and overall population productivity in WRST. • Determine levels of contaminants in egg shells and feathers every 5 years in WRST.
	Golden Eagles	• Measure annual occupancy of nesting territories and reproductive success of Golden Eagles in the northeastern portion of DENA and a comparison study area 80 km east of DENA. • Measure annual occupancy of nesting territories and reproductive success of Gyrfalcons in the northeastern portion of DENA.
	Peregrine Falcons	• Determine annual levels of nesting territory occupancy, and reproductive success in YUCH. • Determine variation in nesting territory occupancy, nesting success, and productivity during the last decade in YUCH. • Determine levels of organochlorine pesticides, mercury, and eggshell thickness every five years in YUCH. - Measure changes in habitat on the breeding ranges for birds nesting in YUCH.
	Passerines	• Monitor population trends of common passerine species during the breeding season in each network park with methods that also allow the data to contribute to detection of statewide trends. • Detect long-term changes in the distribution and composition of breeding passerine bird communities in each network park in relation to changes in their habitats.
	Ptarmigan	• Annually determine the general population trend (high, low, declining, or increasing) of Willow Ptarmigan of Central Alaska Network parks.
	Arctic ground squirrels	• Determine the distribution and abundance of arctic ground squirrels in alpine areas in DENA and WRST. • Monitor population trends of arctic ground squirrels in conjunction with monitoring population trends of snowshoe hare and other herbivores including willow ptarmigan in DENA and WRST. • Monitor changes in vegetation composition in relation to arctic ground squirrel colonies.
	Snowshoe hare	• Determine annual trends in abundance of snowshoe hares across CAKN parks.
	Small mammals	• Monitor long-term trends in abundance and spatial distribution trends of mice and vole species in CAKN parks.
	Caribou	• Determine changes in abundance, distribution and demographics of caribou herds in the CAKN. • Estimate calf survival and recruitment for herds in CAKN.

Level I	Vital Sign	Objective
	Moose	• Determine changes in abundance, distribution and composition of moose in the CAKN every three years. • Estimate annual calf survival and recruitment success of moose and estimate annual human harvest of moose in the CAKN.
	Sheep	• Detect changes in abundance, distribution and composition of Dall's sheep in the CAKN. • Detect changes in the number and composition of harvested sheep from park lands. • Estimate sheep productivity in the CAKN parks.
	Wolves	• Determine changes in abundance, distribution and population structure of wolves annually in CAKN. • Annually estimate pup production and survival for wolves annually in CAKN. • Annually estimate mortality, including human harvest, of wolves in and around CAKN.
	Brown bear	• Determine changes in abundance, distribution and composition of bears in CAKN every 5 years. • Monitor reproductive success of bears annually in CAKN. • Estimate annual human harvest of bears in CAKN.
	Vegetation structure and composition	• Detect changes in the absolute and relative abundance and distribution of the different growth-form classes that form the vegetation cover of CAKN parks.
	Subarctic Steppe	• Determine changes in the distribution and spatial extent of this community. • Detect directional changes in the population status of selected sensitive species. • Assess whether any adverse impacts to sites supporting this vegetation are occurring.
Human use	Human populations	Use state and federal census data to monitor trends in the number of people residing in communities in and near Central Alaska Network parks.
	Consumptive uses of National Park natural resources	• Using existing data collection systems of the Alaska Department of Fish and Game and the Federal Subsistence Board, monitor the number and locations of the annual sport and subsistence take of animals in the State Game Management Units that occur within CAKN parks and preserves. • Using existing data collection systems of the Alaska Department of Fish and Game, monitor the annual number and locations of grizzly bears and black bears killed in Defense of Life and Property on CAKN park and preserve lands. • Monitor the annual use (amount and location) of house logs and firewood by local rural residents from network parks, and monitor the annual use (amount and location) of gravel mining from WRST and DENA rivers for administrative uses.
	Human Presence/ Use	• Monitor long-term trends in the spatial distribution of human presence in CAKN parks by season, level and type of activity.
	Trails	• Detect changes in the severity of impacts to all CAKN park resources from recreational use of the landscape. • Detect changes in the spatial extent and distribution of trampling damage to vegetation and soils resources in regions of the network that are subject to these problems.

Level 1	Vital Sign	Objective
Ecosystem Pattern and Processes	Disturbance: Fire occurrence and extent	• Work with the existing NPS Fire Management Program in the Alaska Region to annually monitor the location, extent, timing, and severity of wildland fires in CAKN parks to determine annual fire frequency, average fire size, average and variability of burn severity, and total area affected by fire in each CAKN park. • Work with the existing NPS Fire Management Program in the Alaska Region to monitor successional effects of fire and burn severity on: the species composition and structure of vegetation; soil temperature and moisture; active layer depth; permafrost state; and animal community composition.
	Landcover	• Monitor the long-term trends in the spatial extent and area occupied by broad landcover classes in CAKN parks using remotely-sensed imagery at 10-20 year intervals.
	Sound	• Detect and monitor change in the natural soundscapes of the ecoregions of CAKN parks, including quantification of biophony and geophony. • Provide information to managers on changes to the soundscape, both natural and human-caused, for direct management effect. • Provide objective, continuous, and season/year-round field data to affiliated and/or co-located monitoring efforts.
	Forage quantity/ quality	• Detect changes in forage quantity and quality across the entire CAKN. • Determine change in forage quality and utilization in relation to abundance and distribution of herbivores.
	Plant phenology	Using remote sensing techniques, monitor the annual dates and spatial extents of (1) snow-free, (2) onset of greenness, (3) maximum greenness, (4) senescence of greenness, and (5) snow-free for CAKN parks to allow long-term trends in landscape phenology to be detected.

1.3.1 Natural Resources of Central Alaska Network Parks: A Synthesis

The natural resources of the three parks in the Central Alaska Network are similar in many respects. The parks have very similar faunas and generally similar floras and vegetation community patterns. They have major rivers, many streams, lakes, ponds and wetlands. All three parks provide for subsistence uses by local rural residents. Two of the three parks (Wrangell-St. Elias and Denali) have extremely tall mountains and extensive glaciers that are remnants of the last glaciation. The third park (Yukon-Charley) is entirely located in the unglaciated corridor known as Beringia. The network parks are therefore linked by the Pleistocene history of the region.

The parks are also similar in having intact predator-prey systems involving wolves, multiple ungulate prey species, and grizzly bears; compared to parks in the rest of the country, this aspect of their ecosystems is unique. The parks have many notable fish and wildlife populations, including Dall's sheep in Wrangell-St. Elias, peregrine falcons in Yukon-Charley, and golden eagles in Denali. However, even attempting to describe these species and populations as "notable" or "more notable" than other species and populations in these parks gives a misleading impression, because

what is probably most significant is the integrity of the ecological systems. The designations of both Denali and Wrangell-St. Elias as recognized biosphere reserves in a worldwide context may capture the most important feature of the natural resources of the Central Alaska Network parks: The parks provide the space and time to see and hopefully understand natural processes occurring at large spatial scales and long temporal scales.

1.4 Resource Preservation Concerns

In this section, we present an overview of the resource preservation concerns of Central Alaska Network parks. For the monitoring program to be relevant, it must provide data useful to protection of park resources, now and in the future. To ensure relevancy over time, the monitoring program needs to address broad concerns and not be limited to the issues of today, because the issues will change (McDonald et al. 1998). We therefore review current issues and look ahead to identify future issues. Because Central Alaska Network parks are arguably among the most pristine of any parks, developing the monitoring program to provide information useful for addressing future issues is especially important.

We gathered material for this section in several ways. The most recent Resource Management Plans for each park were reviewed (NPS 1998, NPS 1997, NPS 1999). Resource Management Plans are long-range plans that identify the inventory, monitoring, research, mitigation, and enforcement activities needed to protect park resources. A recent analysis and model of Denali resource preservation concerns developed for the conceptual design of the Denali Long-term Ecological Monitoring Program (Oakley and Boudreau 2000:51–61) was also used. We held meetings with Yukon-Charley and Wrangell-St. Elias staff in fall 2001 to solicit additional input. We have also relied heavily on insights from past and current natural resource managers, physical scientists, and biologists working in each park.

We found the resource preservation concerns of all three parks were similar. We therefore present the broad-scale concerns affecting the network parks, including examples of how these concerns are manifested in each park. We then present park-specific concerns, which include coastal issues for Wrangell-St. Elias (the only park in the network with coastline) and military jet training activities over Yukon-Charley. Our discussion concludes with a conceptual model of the concerns and ideas about future issues.

1.4.1 Broad-Scale Concerns of All Network Parks

The resource protection concerns of Central Alaska Network parks fall into two main categories:

1. Concerns stemming from global industrialization: These include climate change, long-distance air pollution, species additions

and losses (biodiversity) and effects on migratory birds and fish when they are not present in network parks.
2. Concerns relating to human activities and development in the parks and in the regions of the parks.

We discuss each of these categories of concern in the following sections. The concerns are not independent from one another, and relationships among the concerns are discussed in Chapter 2, which includes a conceptual model of the resource preservation concerns. In this section, we provide a general overview of the concerns.

Global Industrialization

In 1997, Vitousek et al. (1997) presented a short but sobering picture of human domination of the earth's ecosystems. Human population growth, and growth in use of resources by humanity, is maintained by agriculture, industry, fishing, and international commerce. These activities change the earth's surface with two major effects: (1) changes in major biogeochemical cycles, and (2) adding or removing species. These alterations to the functioning of the earth's ecosystems are driving global climatic change and the irretrievable loss of biological diversity. This conceptual model of humanity's role in the earth's ecosystem, circa 2000, provides a broad context for considering the resource protection concerns of Central Alaska Network parks. Although remote and presumably pristine, the surrounding world is changing so quickly due to human activities that this broad perspective is needed.

The Denali Resource Management Plan (Denali National Park and Preserve 1998) raised this concern. The plan noted that the most significant potential adverse effects on Denali from industrialization resulted from activities in areas far away from Denali. Concerns stemming from global industrialization fell into four categories: climate change, air pollution, effects on biodiversity, and effects on migratory species populations. These concerns relate to all parks in the network.

Climate Change: Overall climate warming trends documented elsewhere are also being detected in much of Alaska, including Denali (Juday 2000). Dramatic melting of snow and ice in Alaska has been occurring over the last few decades due to warmer climate. Warming has caused thawing of permafrost and permanent snowfields as well as a reduction in seasonal snowfall and shorter seasons of river and lake ice. Continued warming will cause further reductions in snow cover and permafrost and a corresponding shift in landscape processes. Changes to the network park ecosystems due to climate change include decreases in useable moisture for plant growth, increases in fire occurrence

and intensity, thawing of permafrost layers reducing slope stability, and changes in glaciers.

Many of these changes could contribute to a shift in vegetative community types. Models predict community shifts from tundra to forest, black spruce to deciduous forest, and forest to grasslands, bogs, and wetlands (Starfield and Chapin 1997). Warmer temperatures will result in a longer growing season, and changes in precipitation and community types will result in changes in vertebrate distribution and habitat use. Riparian areas, wetlands, dry habitats, and areas with discontinuous permafrost are the most vulnerable to warming temperatures and will provide the best signals of change (Weller and Lange 1999).

One of the most important changes that could occur in network parks from climate change is a change in the wildfire regime. Wildfire is one of the most influential environmental processes in tundra and taiga ecosystems and is a dominant process in Central Alaska Network parks. All of Yukon-Charley, the northwestern quadrant of Denali, and parts of Wrangell-St. Elias are substantially affected by wildfire. The current vegetation mosaic and habitat diversity in these areas reflect the complex effects of fires that have occurred over the past 100 years. The frequency and intensity of wildland fires are dependent on long-term climate conditions. There has been an increase in the number of fire starts and acres burned as Alaska's interior region sees a climate warming and drying trend. This has created landscape-scale changes to vegetation, soils, and underlying permafrost, creating a dynamic mosaic within the ecosystem.

Little is known about the potential management implications of a potential increase in the burn cycles in interior Alaska. Alaska currently uses Canadian fire behavior models to determine the intensity and conditions under which fire will burn. Ecosystem-level information would be useful in developing an Alaska-based model for predicting wildland fire behavior. Understanding the role fire plays on the soils (permafrost), vegetative succession, animal movements, erosion, and tree line movement will better prepare fire managers for fire season decision making.

Long-distance Air Pollution: Long-distance transport of air pollutants is the second major concern of Central Alaska Network parks stemming from global industrialization. Air pollution monitoring at Denali since the early 1980s has documented the occurrence of low levels of arctic haze, a winter pollution phenomenon. Pollutants, most likely from Eurasian sources, become trapped in the stable winter air mass that hangs over the Arctic and extends down into North America and Eurasia,

creating arctic haze (Shaw 1995). Recent data have suggested pulses of contaminants apparently transported directly from Asia (C. Cahill, University of Alaska Fairbanks, pers. comm.). The ecological effects of these particular air pollutants in Alaska ecosystems are currently unknown. Because Yukon-Charley and Wrangell-St. Elias lack air quality monitoring stations, we do not have definitive information about the occurrence of arctic haze and Asian dust in these parks. However, both types of pollution are the result of broad atmospheric deposition patterns that likely affect much of interior Alaska, including these parks.

Effects on Biodiversity: The potential for non-native invasive species of plants and animals to become established in network parks is another concern stemming from global industrialization. Species additions and losses due to the expansion of human commerce around the globe is one of the biggest ecological problems worldwide, and even remote Alaska parks need to be aware of this potential problem. Recent surveys of Denali and Wrangell-St. Elias roads found several non-native weedy plant species becoming established, indicating the importance of this concern.

Effects on Migratory Species When They are Not in the Parks: All network parks provide habitat for migratory birds and fish. Industrialization elsewhere on the globe could adversely impact migratory birds of network parks. Most of the bird species that breed in network parks are migrants who spend most of the year elsewhere in North, Central, or South America, at sea in the North Pacific, or on South Pacific islands. One species, the arctic warbler, winters in Southeast Asia, and another, the northern wheatear, winters in central Africa. While global industrialization may not affect the breeding habitat of these species in network parks, the same may not be true of their migratory paths or wintering habitats. Adverse impacts could include reduced overwinter survivorship and increased contaminant levels.

Similarly, global industrialization could affect the anadromous fish of network parks. Salmon that spawn and rear young in the streams and rivers of network parks spend most of their lives at sea. Changes in the oceanic environment due to global industrialization could affect the number of salmon returning to network parks. Salmon are an important subsistence resource and transport marine nutrients into terrestrial ecosystems. Changes in salmon populations could affect ecosystem processes in some areas of network parks.

An important role that Central Alaska Network parks can play with respect to migratory species, besides protection of important

habitat for reproduction and overwintering, is to call attention to population changes. Providing information on status and trends of migratory species in protected habitats can help influence conservation actions elsewhere.

Human Activities and Development In and Near Network Parks

Activities in and near the parks are another source of resource protection concern for park managers. These include consumptive uses of park resources (primarily fish and wildlife), recreational uses, private land development in and near parks, and resource management.

Consumptive Uses: This category addresses consumptive uses of fish and wildlife—a major issue for all ANILCA parks due to the underlying philosophy of this key piece of legislation. ANILCA specifically allowed for consumptive use of wildlife resources (i.e., hunting, trapping, and fishing) within national preserves and for subsistence uses by local rural residents in both 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 within national preserves and "natural and healthy" populations in national parks.

Historically, the Alaska Department of Fish and Game managed both sport and subsistence harvests of wildlife within network parks. In 1990, however, the State of Alaska was ruled to be out of compliance with the subsistence sections of ANILCA, and responsibilities for managing subsistence harvest of wildlife within national parks were delegated to the parks. Under the current legal situation, the Alaska Board of Game establishes regulations for hunting and fishing seasons, harvest limits, and methods and means for nonfederally qualified subsistence users in the national preserves. The Federal Subsistence Board establishes regulations for hunting and fishing seasons and harvest for federally qualified subsistence users in parks and preserves.

The complexity of the fish and wildlife management scheme requires current, accurate information on fish and wildlife populations, their habitat needs, and prey base for effective decision-making. To ensure good stewardship and consistency with National Park purposes and management policies of fish and wildlife resources, basic population and distribution information, harvest tracking, and consistent monitoring are essential. These data allow managers to determine if management objectives for the populations are being met. With information of this type, managers can propose any necessary

changes to state and federal harvest regulations to protect resources from excessive harvest.

Most of the concerns related to fish and wildlife management in network parks have to do with large mammals subject to human harvest for subsistence and for sport. Management of consumptive uses of fish is also important in the network, primarily in Wrangell-St. Elias. Wrangell-St. Elias is responsible for the administration and in-season management of federal subsistence fisheries in the Copper River. The heart of the most difficult management issues regarding consumptive uses of fish and wildlife lies in the difference between management objectives among agencies. Alaska, like most states, manages for sustained yield of fish and wildlife species. Under the sustained yield paradigm, harvested species are more valuable than nonharvested species or predators of the harvested species. This paradigm directly contradicts NPS policy to preserve fundamental biological and physical processes, as well as individual species, features, and plant and animal communities. The NPS maintains, as parts of parks, all native plants and animals in their natural abundance (NPS management policies 2001, 4.1)

Fish and wildlife management concerns of network parks are not limited to consumptive uses. Also of concern are effects on wildlife species stemming from park visitation. These concerns include habituation of wildlife species, particularly those species that readily adapt to human presence. A related concern is bear-human interactions. These concerns require active management on the part of parks to prevent and minimize negative interactions and creation of nuisances involving wildlife. These concerns are currently most important in Denali, which has the highest visitation.

Recreational Use: Increased visitation presents two resource concerns. The visitors themselves impact resources in ways we have yet to understand and quantify. As visitation increases there is pressure to provide new trails and 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.

Private Land Development In and Near Network Parks: Private land development is a major concern for network parks. For Wrangell-St. Elias and Yukon-Charley, development on private lands within park boundaries is an especially important concern because ANILCA provided for substantial acreages of inholdings and mining claims. Denali has some issues concerning

private land development in the park, but also has more imminent concerns related to development on park boundaries because Denali borders the Parks Highway corridor where human population is expanding.

Resource Management: Resource management is a general category that includes a variety of activities in and near parks. These are activities of the NPS and other land and resource managers (e.g., the Alaska Department of Fish and Game); these activities include implementation of plans to protect, develop, or manage resources.

One of the most significant resource management activities of concern to network parks concerns management of access. Access is probably the largest underlying issue and one that is related to many of the other concerns. Transportation and access into all three parks is largely undeveloped by current standards. ANILCA requires the parks (that were established under ANILCA) to provide adequate and feasible access to inholdings within the parks. Access to inholdings and mineral development sites can be challenging to resolve in a manner consistent with other uses and values of the park.

Managing access to prevent resource degradation is a major challenge for all network parks. The challenges are somewhat different among the parks because of their histories and locations relative to Alaska settlement. Yukon-Charley and Wrangell-St. Elias have no way to count visitors as they enter the park and no way to know where they are going. This situation makes it very difficult to quantify and predict visitor impacts upon resources. In Denali, issues related to public access are among their most significant concerns. The potential for a new primary access corridor on the north side of the park, increased density of access corridors from the existing park road, and roads on the park perimeter are major concerns. Wrangell-St. Elias, which has two roads, has similar concerns.

Roads and trails can change the land physically. The presence of people and vehicles on these roads and trails can be disturbing to wildlife. Impacts from access also can include habitat loss and fragmentation, creation of edge effects, impediment to movement corridors or disturbance of normal activity patterns of wildlife, changes in hydrologic regimes, introduction of exotic plants, introduction of contaminants, air quality degradation, and phenomena such as fugitive dust.

Like other ANILCA parks, Wrangell-St. Elias is required to provide adequate and feasible access to inholders and subsistence

users. Currently, most of this access is via all-terrain vehicles and fixed-wing aircraft. Wrangell-St. Elias also permits recreational use of all-terrain vehicles on 17 established trails. The demand for recreational all-terrain vehicle use is projected to increase, mirroring the Alaska and national trends in use of these vehicles. Unlike at other parks, all-terrain vehicles are considered a customary and traditional means of transportation in Wrangell-St. Elias (Wrangell-St. Elias General Management Plan 1986). Past research and monitoring within Wrangell-St. Elias have indicated that all-terrain vehicle use has caused adverse impacts on park lands, including shifts in species composition, decreased frequency and cover of plant species, thermokarsting, erosion, and increased trail width (Cook 1990a). Of particular concern are the numerous areas where the trails traverse wetlands, permafrost soils, and steep slopes. Research in other arctic areas shows that sites will continue to degrade if the organic mat has been destroyed, even if use ceases (Rickard and Brown 1974, Sparrow et al. 1978, Walker et al. 1987). One, if not the most, significant impact caused by all-terrain vehicle use is the impairment to pristine landscapes, which was a purpose for which the park was established.

Another resource preservation concern stemming from access relates to development of major access corridors. Access to inholdings and mining operations often require the use of bulldozers and other heavy equipment and, in some cases, new roads. Within Wrangell-St. Elias, there are 110 potential RS-2477 rights of way covering 1,472 miles. Development of some of these RS 2477 rights of way would significantly change the character of the park.

1.4.2 Park-specific Concerns

Some resource preservation concerns are unique to the individual parks in the network. Currently, two such concerns are apparent and worth separate discussion. These are coastal concerns for Wrangell-St. Elias and military training overflights for Yukon-Charley. Detailed description of these concerns are in Appendix H.

1.4.3 Looking to the Future

If we have analyzed the current resource preservation concerns of network parks correctly, we will be in position to design a long-term monitoring program to provide information that will help current and future park managers preserve resources. But what if the issues change? Is there something obvious we have overlooked? For the program to be robust to future information needs, we need to put some effort into thinking about what future issues might be. By taking a long view, we can build a program that will work, despite our uncertainty about future events (Schwartz 1991).

Vitousek et al. (1997) suggested that human changes in the earth's ecosystems were of two broad types: changes in biogeochemical cycles and adding or removing species. A recent analysis by

the National Academy of Sciences reached similar conclusions (National Academy of Sciences 2001). They urged efforts to understand the relationship between biodiversity and ecosystem functioning, which they felt would be of great practical significance.

In terms of the current resource concerns of Central Alaska Network parks, the perspective provided by these strategic analyses of global issues suggests that we should also be thinking about the potential for invasive species to become established in these parks. The question of invasive species is an aspect of an overall biodiversity question and suggests that continuing to gather information about species present in the parks is important. Recent work in Denali, Wrangell-St. Elias and other parks in Alaska has demonstrated the presence of exotic plants associated with road corridors and other access sites (Densmore et al. 2001). Experts at the Central Alaska Network scoping meeting recommended that the potential for ecosystem change due to establishment of invasive species, or range changes of species such as lodgepole pine, should not be underestimated (M. Walker, University of Alaska Fairbanks, pers. comm.). The role of climate change in facilitating introduction of invasive species also needs to be kept in mind.

Currently, the major resource preservation concerns of the network parks, although related by access, seem to occupy separate spheres of influence in the network parks. Denali has many visitors, but relatively limited subsistence use, and the main areas used by visitors and by subsistence users do not overlap. In Wrangell-St. Elias, consumptive uses of fish and wildlife are relatively high; visitation is relatively low. In Yukon-Charley, visitation and subsistence are both at relatively low levels and do not generally conflict. With increasing population growth and demand for mineral resources, one can picture visitation and demand for services for park visitors conflicting with demand for private land development within the parks. Increases in either the visitation sphere or the private land development sphere could interfere with consumptive uses of fish and wildlife, especially subsistence uses. Providing future resource managers with information that could help address these converging trajectories of increasing human uses would be a valuable contribution of the monitoring program. As the selection of monitoring attributes for the Central Alaska Network program continues, we should continually ask ourselves, "How will the data help with these types of concerns?"

1.5 Past and Current Monitoring in CAKN Parks and their Neighbors

The Natural Resource Challenge (NRC) represents the first service-wide effort to fund long-term monitoring. While the Inventory and Monitoring portion of the NRC is an opportunity to establish new facets of an ecological monitoring program, it is

important to also examine past and current monitoring conducted by parks and their neighbors. Doing so will allow us to build upon those efforts and gain the maximum amount of understanding of park natural resources.

The areas that are now protected in Central Alaska Network parks have long histories of scientific exploration and environmental research. The history of monitoring (repeated data collection) is probably the longest at Denali, since it has been a park since 1917. As ANILCA parks, both Wrangell-St. Elias and Yukon-Charley have shorter histories of NPS-supported monitoring. The focus of this section is the current and historic monitoring that is occurring by both the parks and their partners and neighbors.

This section will continue to evolve over the next several years and reflects our initial efforts to gather and organize information about past and current monitoring activities in Central Alaska Network parks. Our "data mining" task also involves the entry of information into the servicewide databases for existing datasets (Dataset Catalog), literature citations (NatureBIB), and species occurrence information (NPSpecies). Our "data mining" effort is still ongoing and will continue for some time. What we present here is the current status of our ongoing efforts.

The focus of our initial search effort was on monitoring conducted by the network parks; with the close of FY 2004 we have just concluded a comprehensive search of work conducted by other agencies in or near CAKN parks, which yielded 705 new references. These references have been uploaded to NatureBib and will be evaluated over the upcoming years.

We describe in detail the monitoring efforts for the physical environment, aquatic resources, vegetation, birds, and mammals in Appendix I. We first review historic efforts, then describe current monitoring. To comprehensively show the monitoring efforts in each park, Table 1-2 illustrates by park (Yukon-Charley, Denali, and Wrangell-St. Elias, respectively) how that monitoring fits into the vital signs framework currently being used at the national level by the Vital Signs Monitoring Program. In general, the monitoring conducted by parks is issue or species specific and is not oriented to an overall systems approach.

Table 1-2. Current and historic monitoring by parks in the Central Alaska Network under the National Park Service Ecological Monitoring framework

Level 1 of National Vital Signs Framework	Level 2 of National Vital Signs Framework	Monitored Variable	DENA		WRST		YUCH	
			Current	Historic	Current	Historic	Current	Historic
Air & Climate	Air Quality	Ozone	X					
		Contaminants (persistent organic pollutants, mercury, lead, zinc, cadmium, etc.)	X					
		N & S deposition	X					
		Fine particulates	X					
		Carbon dioxide, methane, UVB	X					
	Weather and Climate	Climate	X	X	X		X	
Geology & Soils	Glacial features and Processes	Glacier movement	X	X				
	Subsurface geologic processes	Seismic activity			X			
Water	Hydrology	Stream flow		X		X		
	Water Quality	Chemistry (pH, N, DO)						
Biological Integrity (incl. spp. at risk & spp. associated with focal communities or communities at risk)	Exotic plants	Presence of exotic species in road corridor		X				
	Fish	Salmon spawning	X		X			
	Birds	Passerine dist./abund .	X	X	X	X	X	X
		Golden eagle dist./abund.		X				
		Merlin productivity	X					
		Gyrfalcon dist./abund.	X					
		Owl and wintering bird survey						X
		Waterfowl survey						X
		Seabirds			X			
		Eagle survey				X		
	Mammals	Small mammal dist./abund.	X					
		Furbearers/snowshoe hare			X		X	
		Dall sheep dist.				X		X
		Caribou dist./abund.	X		X			
		Moose dist./abund.					X	
		Wolf dist./abund.	X				X	
		Brown bear dist./abund.						
Vegetative Composition & Structure	Plants	Vegetation species composition & structure	X			X	X	

Chapter 2

Conceptual Models

2.1 Introduction

Chapter 2 of the Central Alaska Network Monitoring Plan presents and discusses the conceptual models we developed to guide design of the program. Development of conceptual models is a required step in design of the Vital Signs Monitoring Program for each network. This requirement is based on lessons learned about monitoring program design from the NPS experience with its prototype parks program as well as from many other monitoring programs. What these lessons demonstrate is that every monitoring effort is based on some underlying understanding of how the ecosystem in question works. This underlying understanding forms a mental model, often not written for others to read and discuss. To ensure a successful monitoring effort, these underlying models need to be explicit and available for discussion, evaluation, and refinement (Maddox et al. 1999).

Models are purposeful representations of reality (Starfield et al. 1994). Conceptual models provide a mental picture of how something works, with the purpose of communicating that explanation to others. Models (of all types) work best when they include only the minimum amount of information needed to meet the model's purpose (Starfield 1997).

Conceptual models play several useful roles in monitoring program design, including:

- formalizing current understanding of the context and scope of the ecological processes important in the area of interest;
- expanding our consideration across traditional discipline boundaries, fostering integration of biotic and abiotic information; and
- facilitating communication among scientists from different disciplines, between scientists and managers, and between managers and the public (Thomas 2001).

The key point about conceptual models is their role in communication among people with different points of view (Abel et al. 1998). Conceptual models can take a variety of forms—from narrative descriptions to schematic diagrams or flowcharts with boxes and arrows. Regardless of form, the success of a model depends on its ability to share viewpoints and develop a common understanding based on multiple viewpoints.

Within this program, the development of conceptual models had the specific purpose of guiding the process of selecting vital signs—the information-rich attributes that will be monitored. With this purpose, a critical role of the models was to identify the principal drivers of change, natural and anthropogenic, in network ecosystems. With the drivers of change identified, the types of ecological changes most important for park managers to detect could be evaluated. Knowing what changes it was desired to detect was the foundation for the selection of vital signs.

2.1.1 Central Alaska Network Approach to Conceptual Modeling

The Central Alaska Network is vast: 8.8 million hectares, spanning an area that is 650 km from east to west, and 650 km from north to south. Design of a monitoring program for a network of this spatial extent called for a unifying framework of some type. The initial modeling effort of the network was therefore largely focused on defining this unifying framework. The process involved considerable discussion, with twists and turns, dead-ends, and occasional breakthroughs. This large investment in problem definition early in the process will be critical to eventual success of the program (Nicholson et al. 2002).

The Central Alaska Network decided to focus on servicewide goal #3:

> Monitor park ecosystems to better understand their dynamic nature and condition and to provide reference points for comparisons with other, altered environments.

How did the goal of the network affect our general approach to modeling? The network intends to monitor ecosystems to detect change in ecological components, and in the relationships among those components. We sought to build a holistic picture of change in our ecosystems; thus, we were looking for holistic models to integrate knowledge about the ecosystems of the Central Alaska Network parks. We primarily desired a landscape level of inference from our observations. This focus of the network was appropriate because Central Alaska Network parks include vast acreages of pristine lands. Presumably, ecosystem processes here are among the least affected by direct human influences. Because human influences are currently less dominant than other influences in Central Alaska Network ecosystems, this network provided an opportunity to understand these influences as they change through time.

We were also looking for models that could help us grasp the large spatial scale of the network without losing focus on processes occurring at smaller spatial scales. Scale issues (both spatial and temporal) were among the most important that we had to grapple with (Dayton and Tegner 1984) and that our models needed to address.

We recognized that there would be some attributes we wanted to measure that could not be measured at the landscape scale due to park-specific or feasibility issues. Therefore we kept in mind a hierarchical structure to the monitoring program to accommodate both extensive and intensive levels of work. However, because of the characteristics of CAKN parks, the Technical Committee has reinforced the need to keep the big picture of our park ecosystems at the front and center of the program.

Since we were focusing on a holistic view of our ecosystems, we needed to initiate the program from a discipline-integrated view at the beginning and not later. Therefore, integration of information became an important feature of the program framework as well as in our conceptual modeling. To foster an integrated approach, an interdisciplinary committee was formed following the April 2002 scoping workshop. This interdisciplinary committee was charged with further development of conceptual models for the program.

Publication of this report constitutes the third iteration of conceptual models for the Central Alaska Network program. If the modeling process continues to work as intended, the models will generate further discussion among network program managers and scientists. These discussions, and external review of earlier drafts of this Vital Signs Monitoring Plan, including this chapter on models, will help guide our ongoing modeling process. We also continue to view the process of modeling as more important than the production of models (Starfield 1997). What we learn in the process of building and revisiting our models is key. We also do not want to become so attached to our models that we are not afraid to jettison them when new information (or a new way of looking at things) suggests that a new model is needed.

2.2 Conceptual Models

We present our models sequentially, generally following the development of our thinking through time. The four models included here represent the major waypoints reached in the modeling process.

We began with an exploration of the ecoregions of our network. This exercise helped us put the CAKN into the broadest scale framework for understanding our ecosystems. Because ecoregions were defined using the hierarchical scheme of Bailey (1996), the ecoregions analysis was helpful in identifying the natural drivers of change in network ecosystems, from regional to local scales. At the same time, we also developed a model of resource protection concerns to illuminate management needs. These models provided the foundation for the next step in the modeling process, which was to develop a unifying framework. We felt it was critical to

have such a unifying framework because of our intent to have a holistic, integrated monitoring program.

Our search for a unifying framework centered on developing ecosystem models. We finally honed in a simple model focused on habitat change. The habitat change model, combined with the resource protection concerns model, became a holistic model and the unifying framework for the program.

2.2.1 Ecological Context of Central Alaska Network Parks

When the 15 national park system units in Alaska were divided into four inventory and monitoring networks, the ecological similarity of the parks was a defining criterion. Therefore, we began our ecological modeling with an ecoregions analysis of the network (see Appendix J for full text). The ecoregion analysis allowed us to recognize that Central Alaska Network parks occur within four broad ecoregion types, defined by the driving forces of climate and landform (Fig. 2-1). These ecoregions span a gradient from maritime to continental climate regimes and include a mountainous transition zone between them. This transition zone contains extremely tall mountains with polar climate.

The major gradients within the Central Alaska Network range from boreal areas that are dry, have high seasonal temperature fluxes (i.e., continental climate), and where fire is an integral feature of landscape processes, to maritime areas that are wet, have low seasonal temperature fluxes (i.e., maritime climate), and where wind is the main disturbance factor. In between these areas that are strongly boreal and strongly maritime lie two broad, mountainous units that are aptly labeled "transitional." Within this transitional band, extreme topographic features locally affect dominant factors from both continental and maritime divisions. The resulting environments have a combination of environmental processes (e.g., boreal forest ecosystems without permafrost).

Our ecoregions analysis showed us that primary drivers to all our systems are temperature and moisture regimes, in conjunction with "fixed" factors such as latitude and altitude. We further explored whether this conceptual model provided a unified and integrated framework to the program by considering questions such as:

1. How do the major gradients of temperature and moisture affect the distribution of resources across the network?
2. How does variation in temperature and moisture affect disturbance regimes?
3. What are the effects of variation in disturbance regimes on the distribution of resources in the network?

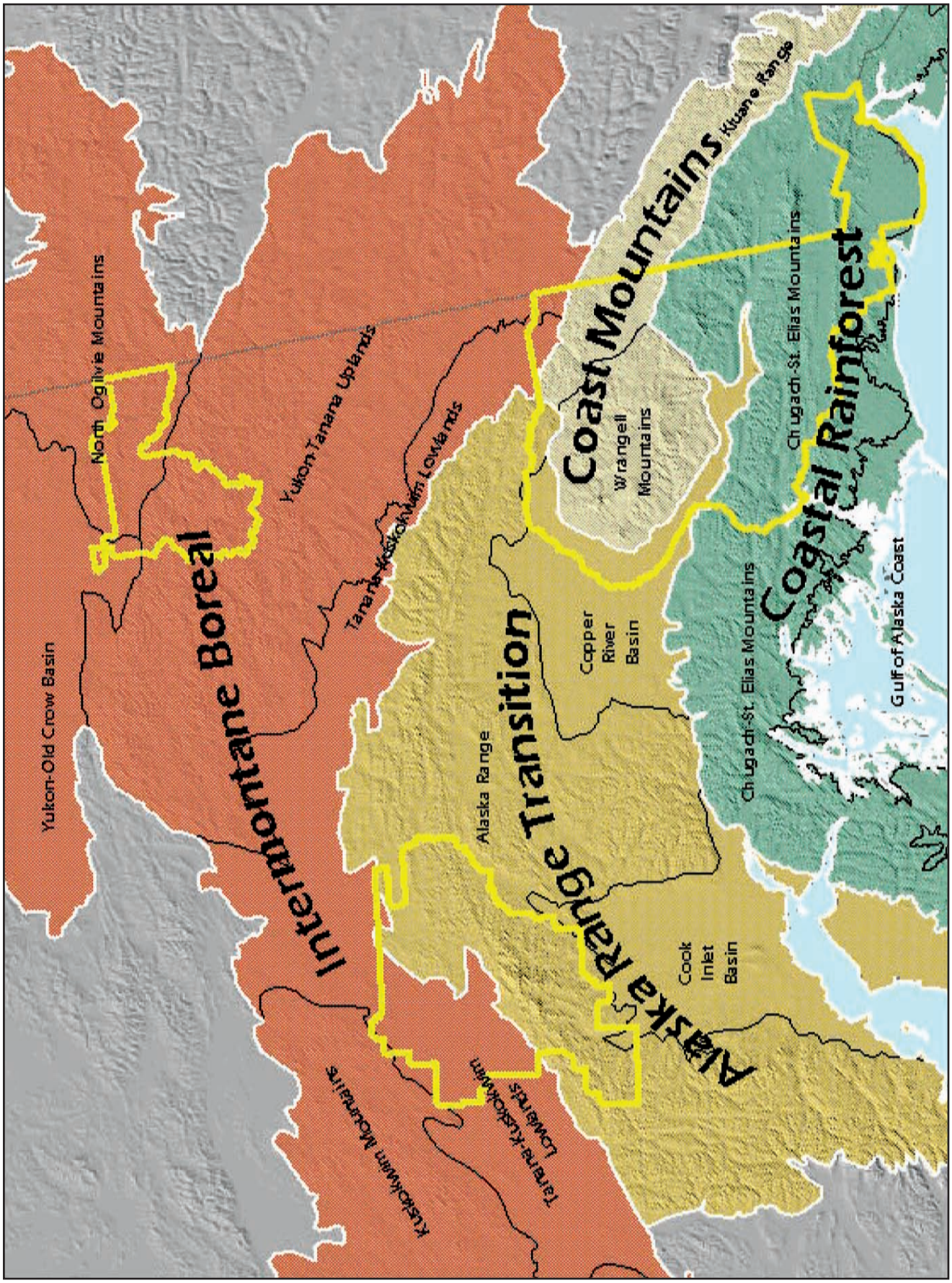

Fig. 2-1. Ecoregions. Location of Central Alaska Network parks relative to ecoregion regime boundaries, based on ecoregions mapping for Alaska by Nowacki et al. (2002).

Upon further consideration, we realized that using a conceptual model based on ecoregions as the framework for the program would focus the monitoring program on the physical drivers to our systems; it would not necessarily provide any information on how the variation in physical drivers would affect the distribution of biological organisms (terrestrial or aquatic, plant or animal). Thus, the ecoregions analysis was useful primarily for identifying drivers of change, especially natural drivers, but did not address all our modeling needs.

2.2.2 Resource Preservation Concerns Model

In this section, we pick up where we left off in Chapter 1 where we presented an overview of the most important resource preservation concerns of Central Alaska Network parks. This model is a critical part of the network conceptual framework because it defines our understanding of the management issues the monitoring should address.

The resource preservation concerns of network parks relate, ultimately, to human population growth and associated demands. These concerns are not independent of one another. In Fig. 2-2, we present a conceptual model of the concerns and how they are related. The purpose of this model is to help see what human activities are affecting the ecosystems of Central Alaska Parks and lay the foundation for creation of additional models exploring how the ecosystems could be affected. This model also helped us to identify what monitoring attributes will be most informative to preservation of the park ecosystems.

Human population growth and resulting industrialization drives all the concerns facing network parks. Global growth is the driver for climate change and the main source of long-distance air pollution and impacts to migratory birds and fish. Human population growth will increase settlement in Alaska, particularly in the Railbelt between Anchorage and Fairbanks, leading to local and regional industrialization and additional, closer sources of air pollution. Increased settlement also will increase the number of nodes of access to the parks, especially Denali. Increased human population also will increase demand for new access to the parks and for increased number of facilities (settlement) within the parks. Increased settlement along the borders also increases demand for animal harvest, which will be facilitated by increased access. Demand for increased access could result in new roads or upgrades of existing roads (in Denali and Wrangell-St. Elias), which could increase gravel mining in these parks.

Based on our analysis, humans will act as drivers of change in Central Alaska Network park ecosystems at two scales: the far-field and the near-field. The far-field issues related to global indus-

trialization—climate change, air pollution, species additions and losses, and impacts to migratory birds and fish—represent one suite of concerns. Near-field issues related to human development and activities in and near parks represent another suite of concerns. To deploy monitoring efforts strategically, a sense of the relative importance or level of concern the parks have about these issues was needed.

The concerns related to humans acting as drivers in the near-field are important because of their potential to change the undisturbed and unfragmented nature of park ecosystems. Human activities in and near Central Alaska Network parks include (1) consumptive uses, (2) uses related to park visitation and recreational activities, (3) development of non-NPS land in and near the parks, and (4) resource management actions of the NPS and neighboring entities. Park management decisions have a high probability to influence these concerns. Because of their potential to significantly impact park ecosystems, and because park decisions can reasonably

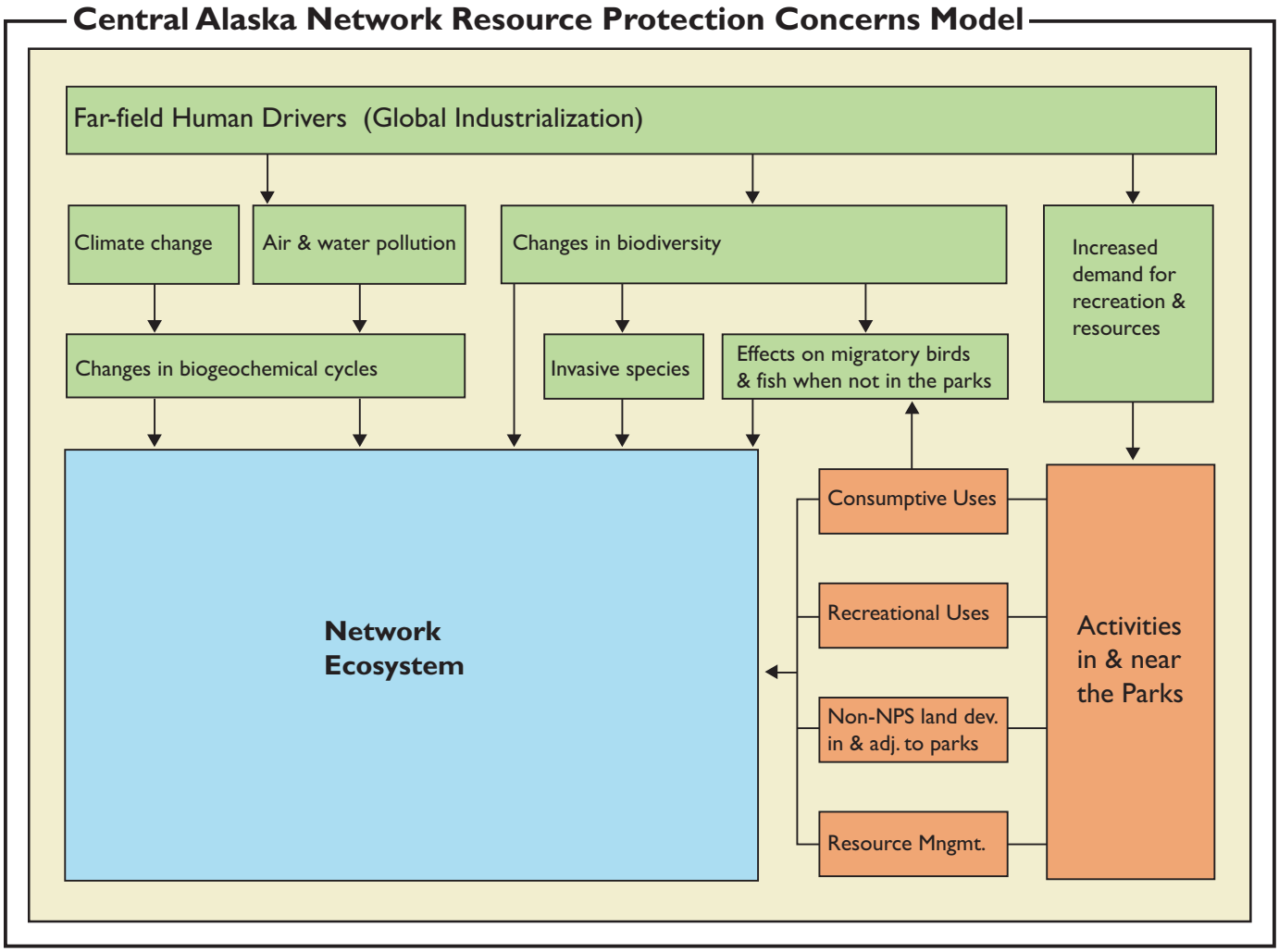

Fig. 2-2. Resource protection concerns model, showing relationships among resource protection concerns in CAKN parks. Regional scale concerns are orange. Global industrialization aspects in green.

be expected to prevent or reduce those impacts, the suite of issues related to near-field human drivers ranks highest in our listing of resource preservation concerns.

Next in importance to park management are concerns that stem from global industrialization. Pristine air quality is a key value of Denali, a Class I park under the federal Clean Air Act. The issue of air pollution is therefore important, and the documented occurrence of episodes of arctic haze and emissions from Asia indicate that network parks need to be vigilant. Climate change, also related to global industrialization, is a concern because observed and predicted warming has considerable potential to change park ecosystems. However, park management will not be in a position to take action that could change that trajectory. In this case, the main role of park monitoring will be to understand the trajectory of change related to warming and the implications for park resources.

A similar strategy applies to how the park should view protection of migratory birds and fish that may be subject to increased mortality, pollution, or habitat loss as a consequence of global industrialization when they are not at network parks. Monitoring these species within the park may provide early warning of problems that are occurring elsewhere. The potential for global industrialization to cause changes in biodiversity due to species additions and losses is also an important concern related to far-field human drivers. This concern underscores the basic need to know what species are in the parks and their general patterns of occurrence and distribution.

In summary, the resource protection concerns model recognizes current human activities acting as drivers in both the far-field and near-field. Although specific park resource preservation concerns will change over time, keeping this awareness of both far-field and near-field human activities seems like a balanced approach. This model helps the monitoring program to address concerns we are aware of now, while being robust enough to accommodate concerns we cannot predict at this time.

2.2.3 Ecosystem Model with Habitat Change as a Unifying Theme

Following publication of the Phase I report in 2002, we turned our attention to creation of a holistic, integrated framework. The Interdisciplinary Team experimented with a variety of approaches (see web site for details and intermediate steps). What we came up with is a very simple ecosystem model using habitat change as a unifying theme.

We found that "habitat change" was a unifying theme for the network because we wanted to know how the landscape was

changing. For example, was fire frequency or intensity changing? Changes in fire frequency and intensity will affect habitat and therefore where plants and animals occur on the landscape. Similarly, if glaciers were melting, this melting would change river and stream characteristics (and therefore river and stream habitats) as well as landform characteristics. These changes would alter riparian habitats and where plants and animals occur on the landscape.

The habitat change model first emerged in this simple form:

Physical Drivers → *Habitat Change* → Vegetation → *Habitat Change* → Fauna

We modified the model slightly to recognize the existence of feedbacks, to explicitly incorporate water in all its forms, and to highlight the unifying role of habitat change (Fig. 2-3).

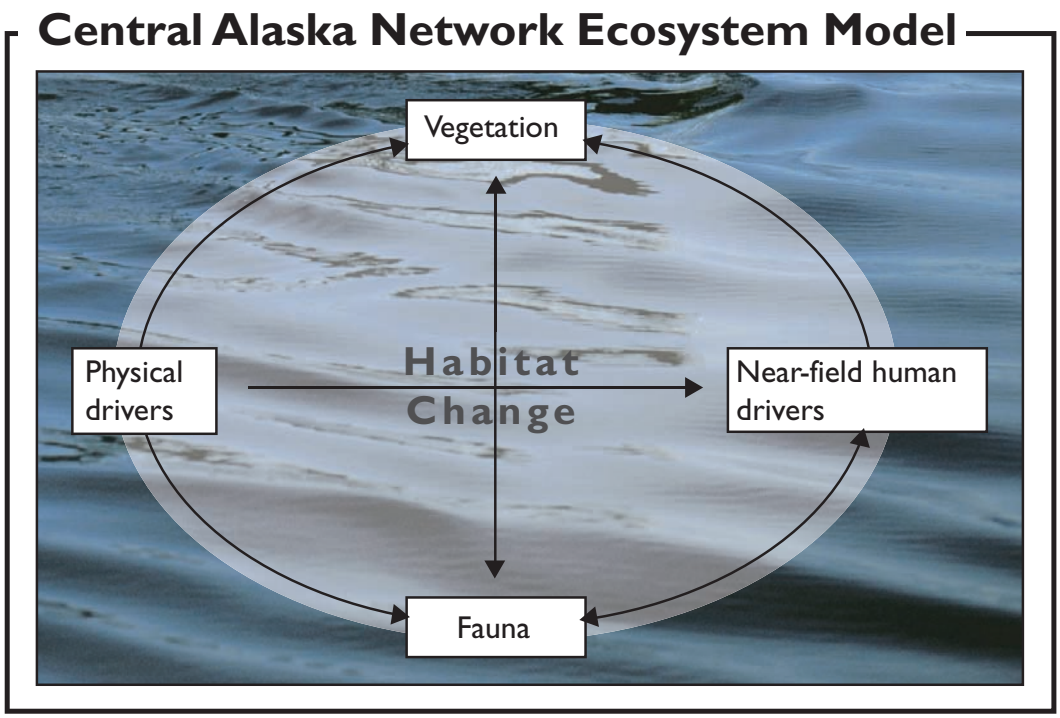

Fig. 2-3. Conceptual ecosystem model for CAKN monitoring program in which change in habitat provides a unifying theme across aquatic and terrestrial boundaries and across scales of interest. The pervasive importance of water in the model is indicated by the water background.

Below, we explore each part of this habitat change model, highlighting our discussions about each topic. Focusing on habitat change made clear what needed to be emphasized in each part of the model.

Physical Drivers

The physical drivers important in the Central Alaska Network include climate, hydrology, seasonal snow cover, glaciers, permafrost, and disturbances related to tectonics (earthquakes, volcanoes), fire, flooding, landslides, and avalanches. Many of the topics that appear in our list of physical drivers are linked by their role in the water cycle. Precipitation, seasonal snow cover, glaciers, hydrology, permafrost, and thermokarst are all part of the water cycle. Temperature is critical in the hydrological cycle because of the thermal thresholds that determine melting and evaporation. The remaining physical drivers include other aspects of weather/climate (such as wind) and physical disturbances (such as fire, landslides, and earthquakes). Thus, "the hydrological cycle and disturbance" formed the central theme for the physical drivers portion of the program.

In the CAKN Technical Committee meeting of December 2002, we focused heavily on physical drivers to our network ecosystems as potential vital signs. The potential problem of such a physical emphasis to the program was that, while those parameters were "socially" easier to discuss and decide upon (we could all easily agree that physical processes were highly important and drive our ecosystems), they would not—by themselves—provide us with information on how our ecosystems were functioning. For example, knowing that average annual temperature increased by 1° C would not tell us how that change affected park ecosystems.

The network also was aware that many entities were already collecting physical environment information that could be informative to the network at various scales. Other agencies, such as the National Oceanic and Atmospheric Administration and the Natural Resources Conservation Service are mandated to collect physical data. The network therefore decided to carefully evaluate existing physical data streams and their applicability to our network questions. The network would then judiciously augment existing physical environment monitoring, but reserve the bulk of its effort for the biological parts of the program. The biological parts of the program constitute the biggest missing piece needed to understand ecosystem change.

Vegetation

As with physical drivers, the network has always recognized vegetation as a critical component of the program. Primary producers form the energetic foundation of marine, terrestrial and aquatic ecosystems, and provide the habitat structure for other forms of life. Vegetation will change as physical drivers change.

Temperature and precipitation as they interact with landform, in addition to disturbance regimes, are the most important factors affecting vegetation. Fauna will also exert forces that result in vegetation change. Past climate and site histories also affect current vegetation.

Development of a landscape-scale vegetation monitoring program has been ongoing at Denali for several years, and the network has benefited by the conceptual models developed for that effort (Roland et al. 2003). Key concepts include the importance of environmental gradients to understanding vegetation patterns. At the broadest scales, these gradients relate to topography, edaphic conditions (e.g., soil moisture), and climate. These gradients result in "habitat" for plants. Monitoring how these gradient relationships change will be more informative than just monitoring changes in the standing crop of vegetation.

Fauna

From the beginning, deciding how to deal with "fauna" in the monitoring program presented many challenges. Clearly, information on the status and trends of faunal species, many of great interest to the visiting public and to subsistence users, was highly desirable. However, gathering the information is so costly that it could easily subsume the entire monitoring budget. Trying to choose which species or species groups are the most deserving of monitoring led to a quagmire where almost any choice could be defended, and it all depended on who was in the room.

Focusing on habitat change offered at least a partial way out of our fauna conundrum. The habitat change focus moved our faunal work in the direction of modeling their habitat relationships as an important aspect of the program. The theme of animal distributions relative to habitat is a major concern of wildlife ecologists and conservation biology (Verner et al. 1986, Scott et al. 2002). Many of the most important questions managers have today about fauna populations relate to habitat. In addition, mandates are now much broader, so that we are no longer just interested in charismatic megafauna or harvested species. We are now interested in the maintenance of biological diversity. For fauna, this has meant mean broadening our definitions of which taxa are of interest. The habitat focus pushed the network to move in the most forward-looking direction with its faunal work. This approach, focusing on habitat relationships, is different from most fauna monitoring programs, which typically focus solely on estimating animal abundance for specific species. Documenting and detecting changes in the distribution of many species of animals within a broad landscape is a population question of a different type.

Choosing which species or species groups to start with was a daunting task. Knowing that we needed to be very selective in our choices, the network decided to allocate faunal monitoring effort to achieve some balance between terrestrial and aquatic species. Recognizing the strong topographic gradients in the terrestrial portion of the network, the network also decided to allocate some faunal monitoring effort to both high and low elevation species and species groups. The network also decided to allocate effort to both keystone herbivores and top predators. From this initial allocation scheme, the specific management needs of each park were considered as final decisions on faunal species to monitor were made.

The important direction that emerged from the modeling was that for each faunal species or species groups selected for monitoring, we would endeavor to collect data to allow the creation of habitat models.

Habitat Change

Choosing to focus on habitat change requires us to define what we mean by habitat. "Habitat" is a term that is often used without being defined, leading to misuse and misunderstanding (Hall et al. 1997). We generally understand habitat to mean the place where an organism resides. Hall et al. (1997) suggest the following definition: Habitat is the resources and conditions present in an area that produces occupancy—including survival and reproduction—by any given organism.

For plants, habitat might be represented by landscape characteristics of soil type, slope, aspect, elevation and site history. For animals, habitat includes all the various facets of environment needed for survival and reproduction. Habitat is only that when it is placed in the context of the animal or plant assemblages that needs it. Thus, habitat for a macroinvertebrate could be the bottom of a rock in a stream of a certain type, while habitat for an anadromous fish would include its spawning site, migration corridor and its oceanic feeding grounds. Habitat is organism-specific; it relates to the presence of a species, population, or individual (animal or plant) to an area's physical and biological characteristics.

Habitat for animals is often equated with vegetation or vegetation type. This is a misuse of the term habitat, and the term "habitat-type" should not be used when what you really mean is "vegetation-type." Habitat is by definition suitable, so defining habitat quality can be difficult. In this regard, animal density can be a misleading indicator of habitat quality. The demographics of the animal's population will need to be looked at to understand it fully.

Perceptions of organism-habitat relationships are scale-dependent. Consistent with the network's focus on changes that occur over large areas and longer time scales, the habitat scales of interest will also be broad. We will be concerned with major changes in the distribution and character of habitat that affect plant and animal population occupancy.

Using habitat and habitat change as our central theme allows us to pursue similar lines of investigation in terrestrial and aquatic environments. This is an appealing idea because it breaks down the artificial barrier between the terrestrial and aquatic portions of the program and will help us avoid moving in completely different and independent directions with our aquatic and terrestrial work. Using the hydrological cycle as a defining theme for the physical driver portion of the program also provides a strong unifying linkage to the habitat change portion. Many of the changes we might expect to see to due to changes in the water cycle (e.g., increased thermokarst, changes in snow depth and length of cover) can be expected to have broad effects on the amount, distribution, and characteristics of both aquatic and terrestrial habitats.

2.2.4 Holistic Model

Putting the Resources Protection Concerns Model together with the Habitat Change Model provides a Holistic Model (Fig. 2-4). The Holistic Model serves as the unifying framework for the selection of network vital signs. This model shows relationships between the most important management concerns of network parks and our ecological model that will work best at the scale of the network. For simplicity, we can describe the model as having 6 footings: (1) Physical Drivers, (2) Vegetation, (3) Fauna, (4) Habitat, and (5) Near-field Human Drivers and (6) Water.

The central theme of habitat change to the monitoring program fits well with our model of resource protection concerns to the extent that we can currently anticipate them. In going through any scenario of resource protection concern, we can make clear ties to changes manifested in habitat. Additionally, this central tenet of habitat change would be robust to future, unknown concerns. Using habitat change as our focus will allow us to predict changes on the landscape and possibly model the consequences of that change. Parks could anticipate various scenarios they could encounter over the next century in their stewardship. With some idea about predicted change, managers can develop better strategies for resource protection.

Of all the themes we considered, the habitat change theme seems the most useful for management needs. Often parks need to know about specific places and the likelihood of their use by various organisms, now and in the future. Designing the monitoring program

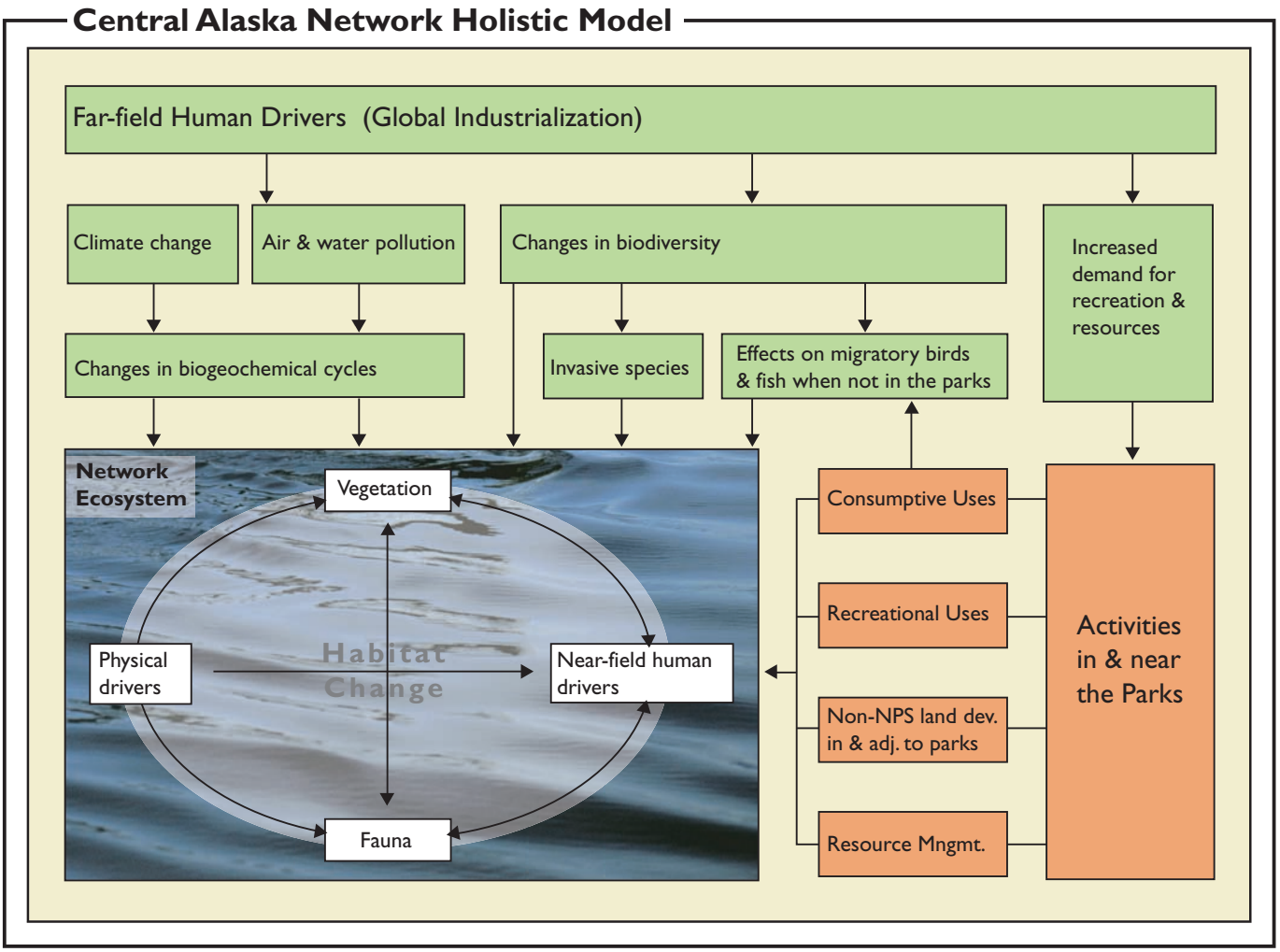

Fig. 2-4. Holistic model. Putting the resource protection concerns model and the habitat change model together creates a holistic model.

to support the development of habitat models linking flora and fauna to landscape characteristics will give managers something tangible they can use in protecting resources now and through time. Knowing about major changes in habitat is also necessary to interpreting changes in the distribution and abundance of populations.

Near-field human drivers were made a footing of the Holistic Model because of the primacy of these concerns to park managers. Recognizing these drivers, and ensuring that the monitoring program provides data useful to preventing impacts to park resources from these drivers, is critical to the ability of the monitoring program to meet park managers' needs.

Chapter 3
Vital Signs

The term vital sign is defined in this program as "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" (http://science.nature.nps.gov/im/monitor/). In this chapter, we describe the vital signs for the Central Alaska Network and the process used to select and prioritize these vital signs.

In summary, the Central Alaska Network has identified 36 vital signs that represent a systems approach to our monitoring program. Three vital signs relate to air and climate, two relate to geology and soils, four relate to water, four relate to human use, five relate to ecosystem pattern and processes, and 18 relate to biological integrity. The network developed this list through a process of meetings and ranking exercises to produce a "short-list" of vital signs we plan to implement or develop in the next three to five years.

3.1 Process for Choosing Vital Signs

The process for choosing and prioritizing vital signs has been ongoing within the Central Alaska Network since the fall of 2001 and has been a multifaceted process of scoping workshops, Technical Committee meetings, ranking via the Delphi process, and park-level meetings. Over the last three years we have focused the vital signs list and placed it within the conceptual models for the network. Table 3-1 summarizes the major steps in the CAKN process for choosing vital signs.

To initiate discussion of vital signs, we held park-level brainstorm sessions during the fall of 2001 at Wrangell-St. Elias National Park and Preserve and Yukon-Charley Rivers National Preserve. The purpose of these sessions was to present the Vital Signs program to all interested park staff and receive their input on potential vital signs for the park and network. Based on these sessions, a long list of potential vital signs was developed (Appendix K). We did not hold a session for Denali National Park and Preserve because Denali was a prototype park with an existing Long-Term Ecological Monitoring program. We added the signs that Denali was currently monitoring to this initial list of potential vital signs for the network. This park-specific list of potential vital signs was the first major milestone in the Vital Signs selection and prioritization process.

Table 3-1. Summary of the processes used in the Central Alaska Network to choose and prioritize vital signs.

Step	Event	Vital Signs Milestone	Product
October 2001	Scoping Meetings at Each Park	"Laundry lists" of potential vital signs generated by brainstorming at each park.	See Appendix K
April 2002	Central Alaska Network Scoping Workshop	Work Groups for Physical Environment, Flora, Fauna, and Aquatic Systems develop strategies for monitoring of their topic area to frame discussions with invited experts at the Scoping Workshop.	See Chapter 1 of this report, and Scoping Workshop Notebook.
Jan.-August 2003	Interdisciplinary Committee develops Framework and Initial List of Proposed Vital Signs	An initial list of vital signs is developed based on the Scoping Workshop strategies. This list is organized by the proposed program framework to ensure an integrated approach.	See Web page.
August 2003	Initial Ranking of Proposed Vital Signs by the CAKN Technical Committee	Individual members of the CAKN Technical Committee rank proposed vital signs using a web-based system.	Table 3.2 (discussed in the following section).
October 2003	Technical Committee meeting	Technical Committee reviews vital sign list and elucidates need for Near-field Human Drivers to be included in conceptual model.	Revised Holistic Model.
January 2004	Technical Committee meeting	Vital signs list is refined by specifying animal species to monitor. Second round of prioritization is undertaken for vital signs.	Current vital sign list (Table 3-2).
March 2004	Park-level meeting	Final meetings with parks to confirm vital sign list and relevance to park-level needs.	Same table as above.

The next stage of vital signs refinement was a Scoping Workshop held in April 2002. Work groups for Physical Environment, Aquatic Systems, Flora and Fauna developed subject area strategies and outlined monitoring objectives and vital signs that would be measured (see Section 1.2.6). As described in Chapter 1, at the conclusion of the Scoping Workshop the Technical Committee determined that the direction and focus of the program were appropriate for the network. The decision was based on the review from the invited experts and their concurrence that the vital signs listed in the subject area strategies were appropriate for the objectives outlined.

The next stage of vital signs refinement was to step aside from the vital signs themselves and give further thought to an overall conceptual framework for the monitoring program. The need for such a framework was a recommendation from the Scoping Workshop. The development of the framework was assigned to a subset of the Technical Committee called the "Interdisciplinary Team." Upon completion of the overall framework for the CAKN monitoring program (see Chapter 2), we revisited the subject area strategies to

embed our list of vital signs into the framework. We placed each possible vital sign into the Holistic Model under the appropriate footing (i.e., Physical Drivers, Habitat, Fauna, Vegetation). One advantage of this approach was that it allowed us to continue focusing on entire ecosystems rather than defaulting to a terrestrial/aquatic demarcation or to highly species-specific monitoring. It also helped affirm how our conceptual model serves to maintain an encompassing view of network ecosystems.

The CAKN Technical Committee met in July 2003 to discuss the framework and vital signs and how to prioritize the vital signs. Using the Holistic Model allowed us to approach our prioritization process in two ways: (1) Prioritize the list of vital signs within each of the footings in the framework, and (2) Prioritize the entire list of vital signs (ignoring the framework). We treated this initial ranking process as an experiment to see which vital signs each Technical Committee member thought were most important. We did not treat the ranking process as an "election" but rather as a way to elucidate discussion about the relative importance of each vital sign.

In this first attempt at ranking the vital signs, we asked the general question: Which vital signs should the network work on first? By "work on first", we meant "Which vital signs should we start with for further investigation of relevance and feasibility?". Knowing that we did not have enough money to do everything, but needed to start somewhere, this question seemed like a good way to get over the general reluctance people have about setting priorities (the "But It's All Important!" Syndrome). The "What To Do First?" question allowed us to approach the initial prioritization in a quick and efficient manner. This efficiency stemmed from combining prioritization criteria, including (1) relevance to conceptual models (ecological and management), (2) presumed feasibility including cost, repeatability, and variability of the vital sign, and (3) relevance to park concerns. Each Technical Committee member was asked to place their own weighting on each criteria used in their ranking.

The ranking process was conducted in a modified Delphi format using a web-based system.1 Each member of the Technical Committee was able to visit the network website, see the list of potential vital signs, and rank the lists. They could also add any comments they felt were needed to accompany their rankings. As mentioned earlier, members were asked to rank the lists within each footing (Physical Drivers, Habitat, Fauna, Vegetation). They were also asked to rank the Vital Signs in a single combined list. Once everyone on the committee had entered their ranks on the website, average ranks were calculated within each footing and

across all footings. These lists represented our initial attempt at prioritizing the network's vital signs. The comments entered by various members during the ranking process were used to highlight topics for further discussion.

This web-based ranking process worked well for avoiding "group think" because each member of the committee was asked to conduct their rankings separately. All our prior efforts to generate lists and discuss vital signs were conducted in group settings, so the web-based ranking process was a good opportunity to elucidate individual viewpoints.2 We were also able to analyze the ranks to assess biases based on each person's area of technical expertise, whether they were a "manager" or an "-ologist", and which park they came from.

As was learned in other networks, looking at the variation among responses was as informative to understanding the priorities as looking at the average response. The variation was also helpful for highlighting topics needing further definition and discussion. We learned there was generally good agreement about which vital signs should be at the top of the lists, and which vital signs should be at the bottom. The vital signs that ended up in the middle of the pack required further discussion to determine where they fit into the priorities. Of particular interest are those vital signs where the distribution of ranks was bimodal, i.e., some members ranked very high and others ranked very low. Understanding the rationale for the ranks was critical to resolving these differences.

We intuitively expected that the two prioritization approaches would have mirrored each other, but we found this was not the case. When considering vital signs within a footing area (e.g., Physical Drivers), Technical Committee members were able to reasonably discriminate among the choices and prioritize, even though the vital signs were at different levels of ecological organization (e.g., a species vs. vegetative composition). However, when considering all the vital signs together, Technical Committee members were only able to prioritize for approximately the first ten vital signs. Beyond that, they were unable to discriminate one vital sign from another in importance. The Technical Committee was uncomfortable with the list based on ranking all the Vital Signs together, and this list was set aside for now.

On October 1–2, 2003, the Technical Committee met to continue work on the list of vital signs and their prioritization. Upon further consideration of the conceptual model, the Technical Committee determined that human effects to park ecosystems needed to be more explicitly included in our models than they had been to date (see discussion in Chapter 2). As a result the Ecological Footing of

"Near-field Human Drivers" was added to our conceptual model. We determined an initial list of vital signs under this footing and potential measures. During this meeting we were also able to appropriately link some vital signs that had been listed separately. However, the Technical Committee continued to work on the list of vital signs and their measures in later meetings.

Finalization of the vital signs list occurred through two subsequent meetings of the Technical Committee early in 2004. We first met to refine and prioritize the vital sign list as a whole, irrespective of the ecological footings. In this meeting the Committee first refined the names used for some vital signs to be more specific and combined some vital signs to better reflect the information desired from the program. For example, in our Phase II Report we listed the vital sign of "animal distribution patterns" without specifying which animals would be monitored. During this meeting we specified the animal species to be monitored, and those species are specifically listed as vital signs. Coincidentally, the current vital sign list for the CAKN has the same number of vital signs as reported in the Phase II Report; the current list, however, does not include all the vital signs listed in the Phase II Report and is more specific in the vital sign list.

Our exercise in prioritizing of the vital sign list used a ranking process that considered park priorities and usefulness of each vital sign to the parks and the network in its ranking. The result of this process showed that the top ten vital signs were readily identifiable; we could not discern a clear prioritization, however, for the remaining 26 vital signs. As in earlier attempts, the committee found that giving a vital sign a rank of "19" vs. "20" meant very little and that after rank "10", the vital sign list was misleading in terms of what mattered. We were able to clearly discern our "short list" of 36 vital signs that we plan to implement and/or develop in the next three to five years. Table 3-2 lists the vital signs for the CAKN within the NPS Ecological Monitoring Framework.

3.2 Vital Signs for the Central Alaska Network

We present the list of vital signs for the Central Alaska Network in Table 3-3 with an indication of the relevance of each vital sign to each park and the network as a whole and the means by which the protocol for each vital sign will be developed. These include three vital signs related to air and climate, two related to geology and soils, four related to water, four related to human use, five related to ecosystem pattern and processes, and 18 related to biological integrity.

Table 3-2. Central Alaska Network vital signs and measures under the National Park Service Ecological Monitoring Framework.

Level 1 Category	Level 2 Category	Level 3 Category	Network Vital Sign	Measures	DENA	WRST	YUCH
Air and Climate	Air Quality	Visibility and particulate matter	Air quality	Ozone concentration, IMPROVE monitoring network for visibility and fine particles, nitrates and sulfates, pH, specific conductance, Ca, Mg, K, Na, NH_4, NO_3, Cl, SO_4, and PO4, Belfort Recording Rain Gauge, aerosol mass, elemental and organic carbon, SO_2,	X		
	Weather and Climate	Weather and Climate	Climate	Temperature, precipitation, relative humidity	X	X	X
			Snow pack	Annual deposition	X	X	X
Geology and Soils	Geomorphology	Glacial features and processes	Glaciers	Photo points of specified glaciers, benchmark measurement of glacier	X	X	
	Subsurface Geologic Processes	Seismic activity	Tectonics (disturbance)	Seismic activity	X	X	X
	Soil Quality	Soil function and dynamics	Permafrost	Distribution of thermokarst and permafrost terrain features on aerial photos; borehole temperatures	X	X	X
Water	Hydrology	Groundwater dynamics	Flooding (Disturbance)	Frequency, discharge	X	X	X
		Surface water dynamics	River/stream flow	Flow rates	X	X	X
			Water Quantity	Surface area of shallow lakes	X	X	X
	Water Quality	Water chemistry	Water Quality	Water chemistry, water level of shallow lakes, submerged vegetation, macroinvertebrates	X	X	X
		Aquatic macro-invertebrates and algae	Macro-invertebrates	Taxonomic composition	X	X	X
Biological Integrity	Invasive Species	Invasive/Exotic plants	Exotic Species (Disturbance)	Presence/absence	X	X	X
	Infestations and Disease	Insect pests	Insect Damage	Presence of insect damage on foliage	X	X	X
	Focal Species or Communities	Fishes	Freshwater fish	Presence/absence	X	X	X
		Birds	Passerines	Population trends of common species		X	
			Bald Eagles	Nesting territory occupancy, nesting success, mean brood size, overall population productivity, eggshell thickness, levels of contaminants	X		
			Golden Eagles	Nesting territory occupancy, nesting success, mean brood size, overall population productivity, nesting territory fidelity, survival rates	X	X	X

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Table 3-2. (continued)

Level 1 Category	Level 2 Category	Level 3 Category	Network Vital Sign	Measures	DENA	WRST	YUCH
			Peregrine Falcon	Nesting territory occupancy, nesting success, mean brood size, overall population productivity, loads of organochlorine pesticides, mercury, eggshell thickness, breeding range habitat change			X
			Ptarmigan	Distribution, abundance	X	X	X
		Mammals	Arctic ground squirrel	Distribution, abundance	X	X	X
			Brown bears	Density estimate of brown bears, geographic extent	X	X	X
			Caribou	Population estimate of herd size, geographic extent	X	X	X
			Moose	Population estimate, geographic extent	X	X	X
			Sheep	Population estimate, geographic extent	X	X	X
			Small mammals	Density estimates of small mammals, geographic extent	X		
			Snowshoe hare	Distribution, abundance	X	X	X
			Wolves	Population estimate, geographic extent	X	X	X
		Vegetation communities	Forage quantity/ quality	N content of Salix sp.	X	X	X
			Subarctic steppe	Areal extent			X
			Vegetation structure and composition	Absolute and relative abundance of growth-form classes, abundance and composition of dominant species, distribution and abundance of discrete vegetation types, species richness, species composition, basal area of tree species, depth of active layer	X	X	X
Human use	Non-point Source Human Effects	Non-point source human effects	Human population	Population census	X	X	X
	Consumptive Use	Consumptive use	Consumptive uses of National Park natural resources	Fish and wildlife harvest (numbers and locations), marine derived nutrients, number of trees harvested for fire and house logs	X	X	X
	Visitor and Recreation Use	Visitor usage	Human presence	Presence/absence	X	X	X
			Trails	Miles of trail	X	X	X
Ecosystem Pattern and Processes	Fire	Fire and fuel dynamics	Fire	Long-term trend of fire frequency, average fire size, average burn severity, total area affected by fire	X	X	X
	Land Cover and Use	Land cover and use	Landcover	Changes in area of each land cover type	X	X	X
	Soundscape	Soundscape	Soundscape	Decibel levels	X	X	X
	Productivity	Productivity	Plant phenology	Snow-free data, date of onset of greenness, date of maximum greeness, date of senescence of greenness, snow-cover date	X	X	X

3.3 Relationship of the Proposed Vital Signs to Conceptual Models and Justifications

Each Vital Sign is linked to our Holistic Model, which encompasses our conceptual model for the ecology of our systems as well as our concerns for resource protection (Figure 3-1).

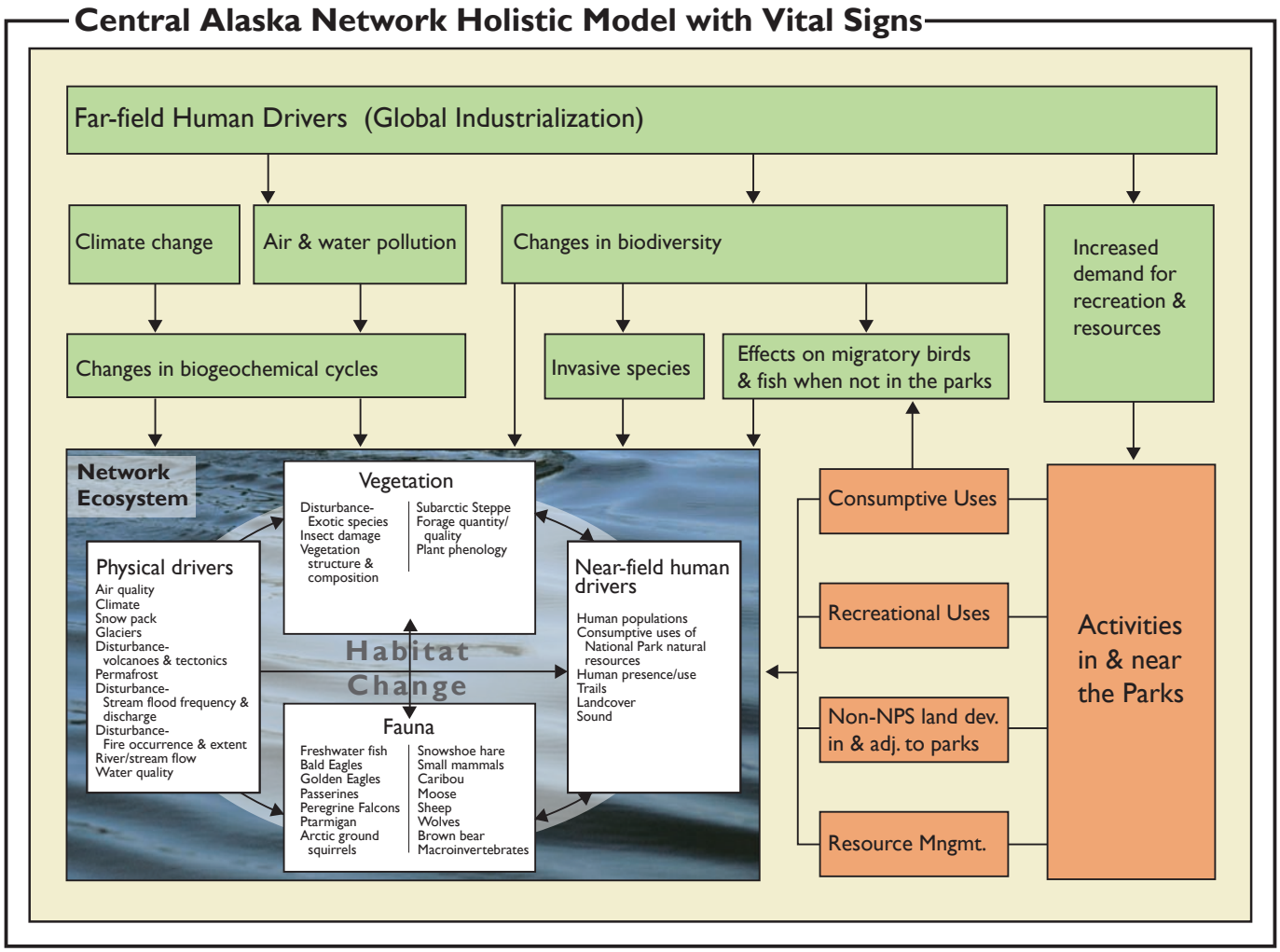

Fig. 3-1. Vital signs of the Central Alaska Network in relation to the holistic model that serves as the overall conceptual framework for the monitoring program.

Table 3-3. Vital signs for the Central Alaska Network under the Vital Signs Framework, as developed for the National Park Service Vital Signs Monitoring program. Monitoring currently conducted by Parks and other in the Parks is also indicated.

National Vital Signs Framework	National Vital Signs Framework		Park/Network Relevance XXX = High XX = Medium X = Lower				Protocol Development of Vital Signs		
Level 1	Level 2	Vital Sign Name	DENA	WRST	YUCH	CAKN	DENA	WRST	YUCH
Air and Climate	Air contaminants	Air quality	X				•	–	–
	Weather and Climate	Climate	XXX	XXX	XXX	XXX	+	+	+
		Snow pack	XXX	XX	XX	XXX	+	+	+
Geology and Soils	Glacial features and processes	Glaciers	XX	XX		X	+	+	–
	Volcanic features and processes	Disturbance: volcanoes and tectonics		XX		X	•	•	•
		Permafrost				X	+	+	+
Water	Surface water dynamics	Disturbance: Stream flood frequency and discharge	X	XX	XXX	X	+	+	+
		River/stream flow	X	XX	XXX	X	+	+	+
	Water chemistry	Water Quality		XX	XXX	XXX	+	+	+
	Aquatic macro-invertebrates and algae	Macroinvertebrates			XXX	X	+	+	+
Biological Integrity	Invasive/Exotic plants	Disturbance: Exotic species		XX		X	•	•	•
	Insect pests	Insect Damage				X	•	•	•
	Fishes	Freshwater fish	XX	XXX	X	XX	+	+	+
	Birds	Passerines	XXX	X	X	XXX	+	+	+
		Bald Eagles				XX	–	+	–
		Golden Eagles	XXX			XX	+	–	–
		Peregrine Falcons			XXX	XX	–	–	+
		Ptarmigan	X			X	+	+	+
	Mammals	Arctic ground squirrels	X			XX	+	+	+
		Snowshoe hare	X	XXX	XXX	XX	+	+	+
		Small mammals	X			XX	+	+	+
		Caribou	XX	XXX	XXX	XX	•	•	•
		Moose	XXX		XXX	XX	•	♦	•

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Table 3-3. (continued)

National Vital Signs Framework	National Vital Signs Framework		Park/Network Relevance XXX = High XX = Medium X = Lower				Protocol Development of Vital Signs		
Level 1	**Level 2**	**Vital Sign Name**	**DENA**	**WRST**	**YUCH**	**CAKN**	**DENA**	**WRST**	**YUCH**
		Sheep	XX	XXX	XXX	XX	♦	♦	♦
		Wolves	XXX		XXX	XXX	•	♦	•
		Brown bear	XXX		X		♦	♦	♦
	Vegetation communities	Vegetation structure and composition	XXX	X	XXX	XXX	+	+	+
	Terrestrial communities	Subarctic Steppe			X	X	–	–	+
Human use	Point-source human effects	Human populations		X		X	•	•	•
	Consumptive use	Consumptive uses of National Park natural resources	XXX	XXX	XXX	XXX	•	•	•
	Visitor usage	Human Presence/ Use	X	X	X	XX	•	•	•
		Trails	XX	XX		X	•	•	•
Ecosystem Pattern and Processes	Fire and fuel dynamics	Disturbance: Fire occurrence and extent	X		XXX	XX	•	•	•
	Land cover / Land use	Landcover	XXX	XX	XXX	XXX	+	+	+
	Soundscapes	Sound	X	X	X	X	•	+	+
	Productivity	Forage quantity/ quality			XXX	X	+	+	+
		Plant phenology	X	X	X	XX	+	+	+

+ Indicates vital signs that CAKN is developing protocol for implementation in parks. Shading denotes 10 vital signs that have full protocols written completed and/or are under peer review.

• Vital signs that are monitored by a network park, another NPS program, or by another federal or state agency using other funding. The network will collaborate with these other monitoring efforts.

♦ High-priority vital signs for which monitoring will likely be done in the future, but which cannot currently be implemented because of limited staff and funding.

– Indicates vital signs that do not apply to park or for which there are no foreseeable plans to conduct monitoring.

Chapter 4
Sampling Design

4.1 Introduction

This chapter outlines the overall statistical sampling design for all vital signs in the CAKN parks. The statistical sampling design describes how spatial locations are chosen for sampling and how sampling effort will be rotated among those spatial locations. Certain details of the sampling designs will not be included here. For example, detailed maps showing realized sample locations are included in each vital sign protocol. Analysis plans are described generally in Chapter 7 and specifically in the protocols. Here, we focus on the overall sampling designs that will permit statistical inferences to large areas.

This chapter is organized as follows. In 4.2. Sampling Concepts and Definitions, several statistical concepts and terms are defined for use later in the chapter. In section 4.3, an overview of the proposed sampling approaches introduces and explains the sampling plans that follow. Later discussions are grouped into sections by the general type of sampling proposed. These sections are 4.4 Grid-based Sampling, 4.5 List-based Sampling, and 4.6 Index Sites. In these sections, the overall statistical design for vital signs to be monitored at the outset of the program will be described. The areas of inference and general considerations for each vital sign will also be given.

4.2 Sampling Concepts and Definitions

Subsequent sections of this chapter describe various sampling plans proposed for parks in the CAKN. These sampling plans rely on a few underlying concepts and use specific statistical terms. This section describes some of the background concepts behind the recommended designs and defines sample unit, panel, rotation design, and membership design.

During development of the sample designs, our working definition of "monitoring" was the collection and analysis of repeated observations or measurements over a long period of time to document the status and trend in ecological parameters. Monitoring is usually designed to provide unbiased statistical estimates of status and trends in large areas or entire study units. Monitoring programs, in our minds, do not set out to investigate a single question or test a specific hypothesis; rather they attempt to collect objective and scientifically defensible data to answer wide-ranging broad hypotheses, some of which may not be finalized at the outset. Using data collected by monitoring programs, long-term correlations between management or natural changes and ecological parameters can occasionally be documented and can provide the most compelling

and complete picture of ecosystems and ecosystem changes. Monitoring, however, will not establish statistical cause and effect relationships between external changes and the status of ecological parameters. Because of its long-term nature, monitoring usually collects relatively quick and easy-to-measure field data that are repeatable in the sense that different people taking the same measurement will likely produce the same value. Successful monitoring programs produce compelling evidence of ecological status and change because they collect long-term data and their inferences apply to large areas, but successful monitoring programs are difficult to implement because they require data to be collected for many years, and this requires consistent motivational and financial support.

The monitoring plans proposed for CAKN rely on concepts in finite population sampling. In finite population sampling, the area for which inferences are desired (e.g., a park or ecoregion) is generally viewed as a finite collection of *sample units* (or just *units*). In general, sample units are the smallest entities upon which measurements are taken. The total collection of sample units is called the *population*. In some studies, sample units will be discrete entities such as stream segments, ponds, lakes, etc. In other studies, sample units will be small areas or pixels. In still other studies, sample units will be aerial survey routes or individual animals. *Responses* are defined to be measurements taken on the sample units. The subset of units from the population for which we collect responses is called the *sample*. If the sample is chosen using some type of random draw, the sample is said to be a *probability sample*. Whenever possible we have opted for a probability sample to monitor vital signs of the CAKN.

Most sample designs proposed for CAKN rotate field sampling efforts through various sets of sample units over time. In this situation, it is useful to define a *panel* of sample units to be a group of units that are always all sampled during the same sampling occasion or time period (McDonald 2003). Note that this definition does not preclude a sample unit from being a member of two different panels.

The way in which units in the population become members of a panel will be called the *membership design* (McDonald 2003). For populations such as the CAKN, the membership design specifies the spatial sampling schedule. For example, if two panels are to be constructed, the membership design might specify that members of panel 1 be selected at random from the population. For panel 2, the membership design might dictate that the members of panel 1 be placed back into the population and another random sample be taken to comprise the units of panel 2. Under this plan, it is possible to select the same unit for membership in both panels.

Another membership design might specify a systematic sample of units be drawn and then placement of every other unit into panel 1, starting with the first. Every other unit starting with the second would could be placed in panel 2. Under this design, it is not possible to get the same unit in both panels. Note that the membership design does not specify when each panel is visited.

The pattern of visits through time to all panels is the *revisit design* (McDonald 2003). For the CAKN, revisit designs specify the temporal sampling schedule. For example, if two panels are defined and 10 sampling occasions will occur, the revisit design might specify that units in panel 1 be visited during occasions 1, 3, 5, …, 9, and the units in panel 2 be visited during occasions 2, 4, 6, …, 10. An alternative revisit design might specify that units in panel 1 be visited every occasion, while those in panel 2 are to be visited every third occasion.

McDonald (2003) proposed notation for revisit designs that may help with description. Under this notation, the revisit plan is represented by a pair of digits, the first of which is the number of consecutive occasions that a panel will be sampled, the second of which is the number of consecutive occasions that a panel is not sampled before repeating the sequence. The total number of panels in the rotation design is normally the sum of digits in the notation. For example, using this notation the digit pair [1-2] means that members of three panels will be visited for one occasion, not visited for two occasions, then visited again for one occasion, not visited for two occasions, and so on. If a single panel is to be visited every sample occasion, its revisit design would be [1-0]. The notation [1-1] means a panel is to be sampled every other sampling occasion. The notation [1-n] means a panel is to be visited once and never again. The notation [1-0,1-5] means that units in one panel will be visited every occasion, while units in 6 other panels will be visited once every 6 years. The schematic representation and notation for five example revisit designs appears in Table 4-1.

4.3 Overview of Sampling Approaches

Historically, monitoring efforts in CAKN consisted of

- climate and air quality data collected near Denali headquarters,
- vegetation structure and composition data collection in the Rock Creek watershed of Denali,
- peregrine falcon surveys in Yukon-Charley,
- golden eagle nest surveys in Denali,
- wolf pack monitoring in Denali and Yukon-Charley, and
- sporadic moose surveys in all three parks.

At the beginning, the CAKN monitoring program attempted to integrate all these plus additional studies under a single overarching survey design. We quickly realized, however, that a single

Table 4-1. Notational representation of five example revisit designs. 'X' in a cell indicates that all members of the panel are visited that occasion.

	Sample Occasion									
Panel	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
					Design [1-0]					
1	X	X	X	X	X	X	X	X	X	X
					Design [1-n]					
1	X									
2		X								
3			X							
4				X						
5					X					
6						X				
7							X			
8								X		
9									X	
10										X
					Design [2-n]					
1	X									
2	X	X								
3		X	X							
4			X	X						
5				X	X					
6					X	X				
7						X	X			
8							X	X		
9								X	X	
10									X	X
					Design [2-3]					
1	X	X				X	X			
2		X	X				X	X		
3			X	X				X	X	
4				X	X				X	X
5	X				X	X				X
					Design [1-0,2-3]					
1	X	X	X	X	X	X	X	X	X	X
2	X	X				X	X			
3		X	X				X	X		
4			X	X				X	X	
5				X	X				X	X
6	X				X	X				X

overarching sample design was impossible given the different fundamental types of sampling required by each study. Certain ecological parameters, such as vegetation composition or passerine bird abundance, were specific to two-dimensional locations and required a sample of two-dimensional landscapes. Certain other parameters, such as those measured in shallow ponds or on wolf packs, were specific to an entity that existed only as an identity, and those identities were amenable to placement in a one-dimensional list. Still other parameters, such as climactic measurements, were more-or-less constant at the scale of a single park and could be adequately monitored by collecting data at one or two sites. In the end, we relaxed our requirement that all monitoring utilize a single sampling scheme in favor of separate survey designs that shared a common sample design when at all possible.

During development of the sampling plans for CAKN, many milestones were passed and decisions made that influenced the ultimate plan. A few of the key milestones are worth mentioning to clarify the plans. First, an aversion to judgment sampling (judgment sampling = non-probability sampling) developed among nearly all lead investigators and staff involved in study design as a result of consultations with a number of statisticians who uniformly recommended against it if possible. We found, however, that probability sampling was not economically realistic in some cases, and eventually adopted judgment sampling for a few studies. In these cases, judgment samples were justified either because the vast majority of the entities under study will be sampled, or because the spatial variation in responses at the scale of a park were inconsequential to long-term monitoring. The second milestone was based with the advent of the "mini-grid" approach. This was a milestone because it was the first feasible sample design under which it was possible to realize fully the utility of probability samples for making inferences to large expanses of a park. Finally, the concepts of rotation design and membership design were introduced and discussed. Prior to these discussions, it was unclear when and how field efforts were to be employed.

In the end, three fundamentally different schemes for collecting measurements in the field were adopted for the CAKN monitoring studies. The first scheme (grid-based sampling) constructs a grid of either points or cells to use as sample units and draws a probability sample. The second scheme (list-based sampling) constructs a list of sample units and either draws a probability sample or attempts to census all units. The third scheme collects information on areas or at points (index sites) that were hand-picked by lead investigators to yield adequate data on a particular vital sign. The remainder of this chapter contains one main section for each of the three types of sample schemes.

4.4 Grid-based Sampling

Grid-based sampling will be the primary spatial sampling method for the vegetation, passerine bird, snow depth, and moose population vital sign monitoring programs in CAKN. Two grids will be constructed to accommodate these studies.

The first grid is constructed by randomly placing a two-stage systematic grid of sample locations across all areas of all parks. Spacing of points for stage 1 of this two-stage grid is 20 km × 20 km. For stage 2 of the sample, a 5 point × 5 point "mini-grid" with 500 m spacing is centered on each stage 1 point. The vegetation, passerine bird, and snow depth studies all utilize the "mini-grid" concept to some extent to locate their sample points in the field. The "mini-grid" approach was adopted for these studies due to the reduced travel costs it affords. Travel costs are reduced because crews can walk, boat, or fly into mini-grid locations, and field sampling can occur over a number of days without having to employ expensive helicopters for transportation between points.

The second grid, constructed for use by the moose study, consists of approximately 5.5 square mile cells laid out over all areas of all three parks in the CAKN. The boundaries of these grid cells coincide with every 2 minutes of latitude and every 5 minutes of longitude in order to facilitate easy navigation by aircraft.

The specific details of the grid-based sampling for the vegetation, passerine, snow depth, and moose vital signs are given in separate sub-sections below.

4.4.1 Vegetation Structure and Composition

Vegetation sampling in Denali will be restricted to mini-grids located in the northern part of the park. The northern part of Denali is currently under heightened development pressures, and to sample a useful density of mini-grids in that area in a reasonable amount of time, the area of inference in Denali was restricted. This area of inference in the northern part of Denali will be called the vegetation "sampling window" in later discussions. Statistical inferences from data collected by the vegetation study will be restricted to the sampling window. Sampling windows for Yukon-Charley and Wrangell have yet to be described.

In Denali, the sampling window includes the northeastern half of the park. This road extends from park headquarters (on the eastern edge of Denali) to Wonder Lake in the middle of the park. Because of heightened interest in the road corridor by park management, and because foot access to mini-grids near the road is relatively easy, a 6 km buffer was placed around the road to define a separate sampling strata. Sampling in the "road corridor" strata will be intensified relative to that which is occurring in the rest of the park. The road corridor will be sampled by a 10 km × 10 km

grid of mini-grids. Approximately one half (4/9) of the mini-girds in the road corridor coincide with the stage 1 grid of 20 km × 20 km points. The remaining mini-grids in the road corridor were located by intensifying the 20 km grid to 10 km. No strata are anticipated in Wrangell and Yukon-Charley.

The basic sampling unit of the vegetation study, mini-grids were assigned to panels systematically after sorting by phenology and access. The location of each mini-grid was inspected by lead investigators, who in turn assigned each mini-grid to a phenology class (early, middle, late). Distance of mini-grids from the park road was also calculated. Mini-grids in the road corridor stratum were assigned 0 distances to the park road. The resulting list of mini-grids were sorted by phenology class, then distance to the park road within phenology class. The membership design then assigned mini-grids to panels systematically until all were assigned; i.e., first in the list was assigned to panel 1, second to panel 2, and so on, repeating as necessary. The number of mini-grids in each panel was a function of the total annual sampling effort and the proposed rotation design (next paragraph).

The rotation design proposed for the vegetation study will be [1-5]. This revisit plan visits mini-grids in 6 panels once every 6 years. Members of panel 1 will be visited the first year. Members of panel 2 will be visited the second year, and so on. This revisit plan balances the need for revisits to the same site to collect information on trends with the trampling effects caused by crews during field measurements.

4.4.2 Passerine Birds

The passerine bird study utilizes a subset of the vegetation mini-grids to shorten the return interval for sampling. The passerine study also more intensively samples the road corridor strata on the same mini-grids sampled by the vegetation study. Annually, the passerine study will sample a different number of mini-grids than the vegetation study and will therefore be on a different visitation schedule. However, all mini-grids visited by the vegetation study will eventually be sampled by the passerine bird study.

The total annual sample of mini-grids sampled for passerine birds was split between 20 panels of sample units. The first panel consists of a small number of mini-grids hand-chosen from those in the road corridor that will be visited every year. The purpose of this first panel is to measure interannual variability accurately and thereby inform overall trend detection. Because sites in the first panel are also accessible on foot, this panel ensures that the program will collect data from a few sites regardless of future budgetary constraints. The next six panels were filled with mini-grids from a list of mini-grid locations that had been ordered on

a spatial hierarchy. This ordering ensured that mini-grids in each panel were spread out as much as possible over the sampling window and road corridor. The members of these six panels will be visited once in two consecutive summers, followed by four years during which they are not sampled, and then they will be sampled for two consecutive summers in another rotation cycle. These panels will give the design statistical connectivity across sampling occasions and space. The remaining 13 panels, which were also populated with mini-grids from the spatially hierarchically ordered list, will be visited once every 12 years to give the program broad spatial coverage. The membership design for passerine monitoring will thus be a mixture of judgment sampling (the first panel) and spatially balanced assignment. The rotation design will be [1-0,2-4,1-12].

Mini-grids in panels receiving the [2-4] rotation schedule were, as much as possible, assigned to be the same as those visited by the vegetation study during the same year. Because the vegetation and passerine study sample a different number of mini-grids annually, it was possible to co-locate and co-visit approximately half of the passerine mini-grids with the vegetation study. The remaining passerine mini-grids will be sampled by the vegetation study in a different year.

At each of the 25 points in a mini-grid, the passerine study will conduct 10-minute point counts. During this time, bird calls will be identified and, to the extent possible, located. Laser rangefinders will then be used to measure distance from the observer to the presumed location of the call. The histogram of these detection distances will allow a function to be estimated which will adjust overall counts for decreased probability of detection at large distances. Estimation of the detection function will employ the point-based distance methods available in program Distance (Buckland et al. 2001).

4.4.3 Snow Depth

The snow depth study will utilize the same mini-grids as the vegetation and passerine study. Inferences from the snow depth study will be to lower-elevation areas of all three CAKN parks, and in Denali, to mini-grids in the sampling window. As with the vegetation and passerine study, the road corridor will be sampled with higher intensity. An aerial snow depth marker will be placed at one point in each mini-grid where it can be viewed adequately from the air. Aerial snow depth markers are metal poles with bright horizontal demarcations at one foot intervals. Snow depth can be measured from an aircraft using these poles by recording the demarcation above the snow. Placement of the pole will ensure that an adequate aerial approach and departure path is

available for fixed-wing aircraft, as well as adequate visual contrast from the air.

Every snow depth marker will be measured at least once during the winter months. For the purposes of the long-term monitoring project, snow depth will be measured every sampling occasion (i.e, every year). Rotation design for the snow depth study will be [1-0]. The snow depth study's sample units will be a mini-grid, and its membership design will be a stratified systematic design.

4.4.4 Moose Surveys

Monitoring of moose populations in CAKN will employ the modified Gasaway technique, currently being used by the Alaska Department of Fish and Game in other parts of the state. The original Gasaway method was developed by Gasaway et al. (1986), and the modified Gasaway technique was proposed by Ver Hoef (2001, 2002). Under the modified method, a large grid of square aerial survey cells will be defined to cover the entirety of all three parks in CAKN. Each aerial grid cell will be 2 minutes of latitude by 5 minutes of longitude, which equates to approximately 5.5 square miles in central Alaska. Once defined, the list of grid cells will become a sampling frame, and consequently the modified Gasaway method draws a frame-based sample.

Prior to initiation of surveys during the winter months of a particular year, all grid cells will be flown rapidly using Cessna 185 or 206 aircraft. The number of moose seen during these initial flights will be used to categorize every grid cell into a "high density," "low density," or "non-sampled" stratum. The non-sampled strata will consist of areas that are too steep to contain moose (e.g., high alpine rock and ice, large lakes). Following stratification, an equi-probable general randomized tessellation stratified (GRTS) sample of aerial survey cells will be drawn separately from the low and high density strata (Stevens and Olsen 2004). Cells in this sample will receive more intensive surveys using Super Cub aircraft.

During the Super Cub surveys, the entire aerial survey grid will be flown. Moose groups will be classified and locations recorded using the aircraft GPS when moose are sighted. Recording moose locations will allow estimation of the sightability function. All moose in a particular cell are assumed to be equally sightable from the air; however, at least initially, sightability of moose groups at large distances off the aerial flight path will be estimated and (potentially) accounted for using standard distance sampling methods (Buckland et al. 2001).

Aerial survey effort will rotate annually among Denali, Wrangell, and Yukon-Charley. Denali will be surveyed during year 1, Wrangell will be surveyed during year 2, Yukon-Charley will be

surveyed during year 3, and the cycle will repeat indefinitely. Technically, the rotation scheme at a particular park will be [1-n] because different grid cells will be sampled every occasion. The membership design will be GRTS sampling for the members of the panel sampled that year. The GRTS sample will be independently selected each year.

Moose population parameters (e.g., density) will be applicable to areas included in the high and low strata of each park. If the total extent of the non-sampled strata changes in a particular year, the moose study's area of inference will also change. In other parts of Alaska, moose surveys have been conducted only when snow conditions were optimum for sighting moose on the ground. If favorable snow conditions fail to develop in a particular year at the park scheduled for moose surveys that year, the surveys will rotate to the next park on the schedule. This may result in a haphazard pattern of surveys at a particular park that will not bias estimates of moose abundance or trends.

4.5 List-based Sampling

List-based sampling will be the primary sampling method for monitoring water quality in ponds and lakes and populations of wolves and golden eagles. The pond and lake component of the CAKN water quality vital sign program will select sampling units from a list of lakes and ponds in the three CAKN parks. This list, or *sample frame*, will be constructed from recent satellite imagery and will contain identifiers, sizes, and positions of all lakes that can be seen in the satellite imagery. The wolf population monitoring study will maintain a list of wolf packs residing at least partially in Denali and Yukon-Charley, and will attempt to sample (count) all packs every year. The golden eagle study will sample watersheds from a short list of watersheds in the northern parts of Denali. The following sections describe the designs for these studies in detail.

4.5.1 Pond and Lake Sampling

The CAKN approach to water quality monitoring focuses on parameters in shallow lakes and ponds and flowing waters. The water quality vital sign will employ a list or frame-based sampling design, much like the Environmental Protection Agency (EPA) Environmental Monitoring and Assessment Program (EMAP). The following discussion focuses on the design used to monitor shallow lakes and ponds, as the flowing waters protocol is still under development.

Satellite radar imagery (RadarSat 2) will be obtained for all parts of all parks in the CAKN with assistance from scientists via a Cooperative Ecosystem Studies Unit (CESU) Agreement with the University of Alaska, Fairbanks. The basic imagery is freely available from the National Aeronautics and Space Administration

(NASA) but will require processing and storage costs. Imagery of any particular location in a park is available twice weekly when the satellites involved make their overpasses.

Prior to the first field season, applicable radar images will be compiled into a complete coverage of all parks and processed to identify individual water bodies, their sizes, and their location. The minimum water body size detectable on satellite imagery is 25 m^2. This processing will be automated and easily repeatable in future years if necessary. Following identification of water bodies in the satellite imagery, primary investigators will identify all navigable waters in the list. Navigable waters will include rivers and streams navigable by motorized boats and rafts, as well as ponds and lakes that are large enough to permit float plane landings and take offs. Following identification of navigable waters, all other water bodies will be attributed by distance to nearest navigable body.

Bi-weekly satellite imagery will also be used to identify spring break up in the parks. Break-up, in addition to being of interest itself, will define the time of year that lakes and ponds are sampled in the field.

The overall sample design for the pond and lake monitoring study will select an unequal probability sample of ponds and lakes based on distance from navigable water. The probability of including a pond or lake in the overall sample will be inversely proportional to its distance from the nearest navigable water. This design was chosen because of the high costs of traveling to a particular water body on foot after arrival at the closest navigable water body. Because of the time and effort required to haul personnel and equipment into sample units by foot, overall expenses will be reduced if more lakes and ponds are sampled near navigable waters than farther away. Properly weighted estimates based on data from the unequal probability sample will apply to all water bodies in the sample frame.

The unequal probability sample will be drawn in a way that assures a high degree of spatial balance. Spatial balance means that sampled ponds and lakes will be spread out approximately uniformly across all navigable waters. Spatial balance will be achieved by drawing an unequal probability general randomized tessellation stratified (GRTS) sample (Stevens and Olsen 2004). GRTS samples assure spatial balance by recursively subdividing the parks, drawing the sample, and then reversing the ordering. The final result is a list of ponds and lakes such that any contiguous set of units achieves a high degree of spatial balance.

Prior to selection of the GRTS scheme, a few (< ~6) ponds will be selected by principal investigators for sampling every summer. These ponds will be located close to easily navigable waters and will serve as index sites for the broader GRTS sample. These ponds will be placed in panel 1 of the pond and lake sampling study and will not be available for selection in the GRTS sample.

Once the index sites are determined and the unequal probability GRTS sample is drawn, the pond and lakes membership design will allocate units to panels in groups from the ordered GRTS sample. If n_2 units are required in panel 2, the first n_2 units in the ordered GRTS sample will be assigned to panel 2. If n_3 units are required in panel 3, units from the $(n_2 + 1)$-th to the $(n_2 + n_3)$-th in the ordered GRTS sample will be allocated to panel 3. If n_4 units are required in panel 4, units from the $(n_2 + n_3 + 1)$-th to the $(n_2 + n_3 + n_4)$-th will be allocated to panel 4, and so on. This membership design will assure a high degree of spatial balance in each panel.

The rotation design proposed for the pond and lake study will be [1-0,2-8]. Under this rotation design, ponds and lakes in panel 1 will be sampled every year. Ponds and lakes in panels 2 through 11 will be sampled for two consecutive years, then not visited for 8 years, before being sampled again for 2 consecutive years, and so on. Rotation of field sampling effort among ponds in panels 2 through 11 will continue indefinitely, or until the frame is reconstructed from new satellite imagery in the distant future.

4.5.2 Wolf Pack Surveys

Wolf populations in or overlapping parts of the CAKN will be monitored using the total-count radio-telemetry method. Using this method, dominant breeding wolves from every pack residing within park boundaries will be targeted for radio collaring. In addition, dominant breeding wolves will be targeted for capture in "gaps" between known pack ranges and in known ranges that do not contain at least one functioning radio collar. Standard animal-capture measurements, such as tissue samples and reproductive status, will be collected on all captured wolves.

During early and late winter, aerial surveys will be flown to locate all known packs with functioning radio collars, and a total count of wolves seen will be recorded. Sampling units for the wolf study will be a wolf pack, and a census of all wolf packs will be attempted every sample occasion. Sightability of non-collared wolves from the air will be estimated and accounted for.

Aerial surveys for wolves will be conducted annually between Denali and Yukon-Charley. Technically, the list of packs constitute the sampling frame, and the rotation design for wolf monitor-

ing at a particular park will be [1-n] because different sample units (packs) will potentially be sampled each year. The membership design for wolf monitoring is difficult to quantify. While the wolf membership design will not involve a probability sample of packs, the membership design is relatively unimportant because project biologists are confident that a near-census of packs will be attained each year.

4.5.3 Golden Eagle Surveys

At present, golden eagle monitoring will only occur in Denali. The golden eagle study area in Denali will encompass approximately one-quarter of the entire park near the eastern border of the park, including the park headquarters and road. While golden eagles exist in other parts of the park, this portion contains the highest densities and is the largest area that could be feasibly sampled. The golden eagle study area has been partitioned into approximate watersheds.

Helicopter surveys for golden eagles will consist of two types of flights each year. The first type will be reproductive surveys in all watersheds of the study area. The second type will be sightability flights in approximately two watersheds of the study area. Reproductive surveys have been conducted in Denali for many years and consist of two separate flights, one in April and another in July. During the April reproductive flights, previously known nesting sites are checked for occupancy and presence of eggs. New or previously unknown nest sites are included when encountered during the April flight. In July, nests containing eagle pairs that were incubating eggs during the April flight will be re-checked to assess success. The April and July surveys of the entire study area each require approximately six days.

Following the April reproductive survey flight, from one to three sightability flights will be conducted in a rotating sample of approximately 2 watersheds within the study area. These flights will allow the study to estimate the number of occupied territories missed during the April reproductive survey and thereby adjust the number of occupied territories for the sightability of golden eagles and their nests. This will be accomplished by applying the proportion area occupied models of MacKenzie et al. (2003). If possible, habitat covariates will be incorporated into the proportion area occupied models that will allow adjustments to be made to study-area wide estimates of the number of occupied territories. If sightability of occupied territories appears to be constant after a number of years of monitoring, the sightability flights may be scaled back in favor of additional surveys outside the study area.

To determine which watersheds receive sightability surveys in which years, the watersheds will be randomly ordered and system-

atically assigned to years. For example, the first and third watersheds in the randomly ordered list will be surveyed for sightability during year 1. The second and fourth watersheds will be surveyed during year 2, and so on. Sampling units for the golden eagle study are watersheds, and a membership design does not exist for the reproductive surveys because a census of watersheds will be attempted every year. The rotation scheme for sightability surveys will be [1-2]. The membership design for sightability surveys will be simple random allocation of watersheds to the three panels of the rotation design.

4.6 Index Sites

The peregrine falcon, climate, snowpack, and air quality monitoring components in CAKN will collect data at a small number of representative sites located in the three parks. This focus on index areas or sites is justified due to the high costs of the surveys or equipment involved in the measurements. Technically, statistical inference to a larger area, such as a park or a portion of a park, is not possible using data collected in areas or at sites that were not chosen by a probability sample. However, monitoring of parameters in specific areas or at specific sites is adequate for these studies because either the index area contains the vast majority of the population of monitored subjects, or the spatial fluctuation in measurements across a park is inconsequential for long-term monitoring purposes. This section describes details of the peregrine falcon, climate, snowpack, and air quality monitoring programs.

4.6.1 Peregrine Falcon Surveys

Peregrine falcon surveys will only be conducted in Yukon-Charley. The basic approach for monitoring peregrine falcons will maintain historic surveys that closely mimic the protocol established by the U.S. Fish and Wildlife Service's Monitoring Plan for the American Peregrine Falcon (USFWS 2003). The peregrine falcon surveys will be similar to golden eagle surveys in Denali, with the main difference being that the falcon study will utilize boats to sample the Yukon river riparian corridor every year. Similar to the golden eagle study, the peregrine falcon study will conduct two annual surveys during which territory occupancy, nesting success, and productivity will be ascertained. Until a stable sightability function is established, one or more surveys designed to collect data on sightability in the river corridor will be conducted annually. Sightability surveys will be conducted soon after initial occupancy surveys by the same or independent crews to assess which nests were missed.

Technically, the peregrine falcon survey contains a single index site consisting of all surveyable areas along the Yukon river. Statistical inferences about peregrine falcon parameters are not possible to areas outside the surveyed area of Yukon-Charley;

however, the vast majority of peregrine falcons in Yukon-Charley reside in the river corridor. The rotation design for both the reproductive and sightability surveys will be [1-0]. No membership design exists for the falcon study because the single index site will be surveyed every year.

4.6.2 Climate and Snowpack Monitoring

The climate and snowpack monitoring study in CAKN will maintain or establish several different types of climate and precipitation monitoring stations. One component of the climate monitoring study will maintain data collected at existing National Weather Service (NWS) and Natural Resources Conservation Service (NRCS) sites where data have been collected for a number of years. These sites include cooperatively operated climate monitoring stations, ground-based snow courses, and aerial snow markers that are not located on mini-grids. Another component of this monitoring plan will add several ground-based snow courses to each of the three CAKN parks to improve the spatial coverage of existing snowpack monitoring data. Several SNOTEL stations will be established within the network to record accurate measurements of snow depth and precipitation autonomously. In addition, fully instrumented climate stations will be added at selected sites within the three parks to capture a broad range of the climatic gradients.

4.6.3 Air Quality Monitoring

At present, air quality monitoring is only occuring at Denali. At Denali, air quality monitoring will maintain data collection from the existing airborne contaminant monitoring program. This entails continuing to maintain the NPS air quality monitoring station near park headquarters on the eastern boundary.

Chapter 5

Sampling Protocols

In this chapter we present a schedule for development of sampling protocols for the 36 vital signs of the Central Alaska Network. At present the network intends to complete, at minimum, development of each protocol by FY 2008 and implement each protocol by FY 2010. Appendix L includes the Protocol Development Summary (PDS) for each vital sign and outlines a justification for the monitoring, the objectives for monitoring, and a schedule of development for each protocol. Table 5-1 shows the timeline for development and implementation of all the protocols. Table 5-2 contains the title for each protocol, the vital sign it is associated with, and where the monitoring will be implemented.

The network is producing ten protocols that will be submitted for peer review during FY 2005. These are indicated in Table 5-2 by an asterisk and in Table 5-1 as "completed" in FY 2005 and "implemented" in FY 2006.

Table 5-1. Implementation schedule for Central Alaska Network Vital Signs monitoring program.

Vital Sign	Protocol Status			
	FY 2005	FY 2006	FY 2007	FY 2008
Air quality	Completed	Implement		
Climate	Completed	Implement		
Snow pack	Completed	Implement		
Glaciers	Completed			
Disturbance: volcanoes and tectonics			Begin development	Completed
Permafrost	Develop protocol	Develop protocol	Implement	
Disturbance - stream flood frequency and discharge	Begin development	Develop protocol	Develop protocol	Completed
River/stream flow	Begin development	Develop protocol	Develop protocol	Completed
Water quality	Completed	Implement		
Macroinvertebrates	Completed	Implement		
Disturbance: exotic species			Begin development	Completed
Insect damage				
Freshwater fish	Begin development	Develop protocol	Develop protocol	Completed
Bald eagles	Begin development	Completed	Implement	
Golden eagles	Completed	Implement		
Passerines	Completed	Implement		
Peregrine falcons	Completed	Implement		
Ptarmigan			Begin development	Develop protocol (finalize in 2010)
Arctic ground squirrels			Begin development	Develop protocol (finalize in 2010)
Snowshoe hare	Begin development	Develop protocol	Develop protocol	Completed
Small mammals	Completed	Implement		
Caribou	Begin development	Completed	Implement	
Moose	Completed	Implement		
Sheep	Begin development	Completed	Implement	
Wolves	Completed	Implement		
Brown bear		Begin development	Completed	Implement
Vegetation structure and composition	Completed	Implement		
Subarctic steppe			Begin development	Develop protocol (finalize in 2009)
Human populations	Begin development	Completed	Implement	
Consumptive uses of National Park natural resources		Begin development	Develop protocol	Completed
Human presence/use		Begin development	Develop protocol	Completed
Trails		Begin development	Develop protocol	Completed
Disturbance: fire occurrence and extent	Begin development	Develop protocol	Completed	Implement
Landcover	Begin development	Develop protocol	Completed	Implement
Sound	Begin development	Develop protocol	Completed	Implement
Forage quantity/quality		Begin development	Develop protocol	Develop protocol
Plant phenology		Begin development	Develop protocol	Develop protocol

Table 5-2. Vital signs and their protocol titles for the Central Alaska Network. Vital signs with an "" are slated for implementation in 2006.*

Vital Sign Name	Protocol Name	Parks Where Implemented		
		DENA	WRST	YUCH
Air quality*	Air quality monitoring at Denali National Park and Preserve: monitor ozone, pollutant compounds in wet and dry deposition (fallout), and particulates affecting visibility	X		
Climate*	Monitoring climate and snowpack change in Central Alaska parks	X	X	X
Snow pack*	Monitoring climate and snowpack change in Central Alaska parks	X	X	X
Glaciers	Monitoring changes in glacial extent and mass balance in Central Alaska parks	X	X	
Disturbance: volcanoes and tectonics	Monitoring volcanic and tectonic disturbance in Central Alaska Network parks	X	X	
Permafrost	Monitoring permafrost and thermokarst changes in Central Alaska parks	X	X	X
Disturbance: stream flood frequency and discharge	Trends in flow and flood dynamics of CAKN streams	X	X	X
River/stream flow	Trends in flow and flood dynamics of CAKN streams	X	X	X
Water quality*	Detecting trends in the abundance, size, distribution, water quality, and biological communities of shallow lake and pond systems in the Central Alaska Network	X	X	X
Macroinvertebrates*	Detecting trends in the abundance, size, distribution, water quality, and biological communities of shallow lake and pond systems in the Central Alaska Network	X	X	X
Disturbance: exotic species	Monitoring spatial extent of exotic species in the Central Alaska Network			
Insect damage	Monitoring insect damage in the Central Alaska Network			
Freshwater fish	Consumptive use of fish in CAKN parks	X	X	X
Bald eagles	Monitoring the spatial and temporal trends of the breeding population of bald eagles (Haliaeetus leucocephalus) in Wrangell-St. Elias National Park and Preserve, Alaska		X	
Golden eagles*	Monitoring the spatial and temporal trends of the breeding golden eagle (Aquila chrysaetos) and in Denali National Park and Preserve, Alaska.	X		
Passerines*	Monitoring landbirds in CAKN: population trends of common species, community structure and distribution, and ecology of species of conservation concern	X	X	X
Peregrine falcons*	Population trends of nesting peregrine falcons (Falco peregrinus anatum) in Yukon-Charley Rivers National Preserve, Alaska			X
Ptarmigan	Ptarmigan population trends	X	X	X

(continued on next page)

Table 5-2 continued

Vital Sign Name	Protocol Name	Parks Where Implemented		
		DENA	WRST	YUCH
Arctic ground squirrels	Monitoring the population trends of arctic ground squirrels (*Spermophilus parryii*) in Denali National Park and Preserve and Wrangel-St. Elias National Park and Preserve, Alaska	X	X	
Snowshoe hare	Snowshoe hare population trends	X	X	X
Small mammals	Distribution and abundance of small mammals	X		X
Caribou	Caribou—abundance, distribution, and demography	X	X	X
Moose*	Moose—abundance, distribution, and composition	X	X	X
Sheep	Dall's sheep monitoring		X	
Wolves*	Wolves—abundance, distribution, and demographics	X		X
Brown bear	Brown Bears—abundance, distribution, and composition	X	X	X
Vegetation structure and composition*	Monitoring structure and composition of vegetation in CAKN Parks at the landscape scale	X	X	X
Subarctic steppe	Monitoring subarctic steppe vegetation – community of special concern	X	X	X
Human populations	Human populations in the Central Alaska Network region	X	X	X
Consumptive uses of National Park natural resources	Monitoring consumptive uses of natural resources in CAKN parks	X	X	X
Human presence/use	Monitoring human presence in CAKN parks	X	X	X
Trails	Monitoring impacts to vegetation and soil resources from social trails and trampling	X	X	X
Disturbance: fire occurrence and extent	Disturbance monitoring: monitor trends in extent, severity and effects of wildland fire in Central Alaska Network parks	X	X	X
Landcover	Landcover change in the Central Alaska Network	X	X	X
Sound	Monitoring changes in the natural soundscape in Central Alaska Network parks	X		
Forage quantity/quality	Monitoring changes in forage quantity/quality of CAKN parks	X	X	X
Plant phenology	Monitor timing of seasonal snow cover and vegetation green-up, maximum greenness and senescence in the CAKN landscape	X	X	X

Chapter 6

Data Management

6.1 Introduction

Collecting data on specific natural resource parameters is our first step toward understanding the ecosystems within our national parks. These ecosystems are evolving, as is our knowledge of them and how they work. We use these "raw" data to analyze, synthesize, and model aspects of ecosystems. In turn, we use our results and interpretations to make decisions about the Park's vital natural resources. Thus, *data* collected by researchers and maintained through sound data management practices will become *information* through analyses, syntheses, and modeling.

This can only be achieved through the development of a modern information management infrastructure (e.g., staffing, hardware, software) and procedures to ensure that relevant natural resource data collected by NPS staff, cooperators, researchers, and others are entered, quality-checked, analyzed, reported, archived, documented, cataloged, and made available to others for management decision making, research, and education.

This chapter summarizes the CAKN data management strategy, which is more fully presented in the CAKN Data Management Plan (DMP, www.nature.nps.gov/im/units/cakn/DataMgt.htm *effective Jan. 2005*). The CAKN DMP serves as the overarching strategy for achieving the goals noted above. The plan supports I&M program goals and objectives by ensuring that program data are documented, secure, and remain accessible and useful indefinitely.

6.1.1 CAKN Data Management Strategy

The CAKN data management strategy holds that all data and derived information generated or otherwise used by the program will meet a high level of quality standards. Further, all data and information the CAKN program deems necessary to meet objectives, and that are not otherwise maintained, will be archived, documented, and made easily available and accessible. Data and information will be managed in a transparent manner such that all components may be easily compared by location, time and subject. Data and information will be accompanied by supporting documentation (metadata) that provide context, value, utility, and longevity, thereby facilitating broad understanding of CAKN program output to current and future end users.

Data management within the CAKN I&M program aims to ensure that:

- Data are easily discoverable and obtainable

- Uncertified data are not released
- Distributed data are accompanied by complete metadata that clearly establish the data as a product of the NPS I&M program
- Sensitive data are identified and protected from unauthorized access and inappropriate use
- A complete record of data distribution/dissemination is maintained

The following objectives of the CAKN Data Management Plan help frame our strategy:

Overall objectives:
- Outline the long-term goals of a comprehensive data management strategy for the CAKN I&M program
- Associate data management goals with the long-term goals of the network and service-wide I&M program
- Outline the procedures and work practices that support effective data management
- Guide current and future staff of the CAKN to ensure that sound data management practices are followed
- Guide the enhancement of legacy data to match formats and standards put forth in this plan
- Encourage effective data management practices as an integral part of project management so all data are available and usable for park management decisions now and into the future
- Optimize and promote interagency sharing and development of data, software applications, and analyses

Specific objectives:
- Establish roles and responsibilities of CAKN program staff for managing data
- Identify necessary elements for a functional data management program and describe any anticipated changes to those elements
- Establish an organizational schema for CAKN program data and information so that they are retrievable by staff, cooperators, and the public
- Establish basic quality control standards
- Establish standards for data, data distribution, and data archiving to ensure the long-term integrity of data, associated metadata, and any supporting information

6.1.2 Types of Information Managed by the CAKN

The term "data" is frequently used in a way that also encompasses other products generated alongside the tabular and spatial data that are the primary targets of our data management efforts. These products fall into five general categories: raw data, derived data, documentation, reports, and administrative records (Table 6.1).

Table 6-1. Categories of data products and project deliverables.

Category	Examples
Raw data	GPS rover files, raw field forms and notebooks, photographs and sound/video recordings, telemetry or remote-sensed data files, biological voucher specimens
Compiled/derived data	Relational databases, tabular data files, GIS layers, maps, species checklists, analyzed data
Documentation	Data collection protocols, data processing/analysis protocols, record of protocol changes, data dictionary, FGDC/NBII metadata, data design documentation, quality assurance report, catalog of specimens/photographs
Reports	Annual progress report, final report (technical or general audience), periodic trend analysis report, publication
Administrative records	Contracts and agreements, study plan, research permit/application, other critical administrative correspondence

Specific data and information the CAKN program deems necessary to meet objectives includes:

- Core variable data measured in the field
- Data derived via vital sign protocols from core variable data
- Spatial data files
- Photographs (field and aerial)
- Laboratory data
- "Data" or "Technical" reports, including protocols
- Administrative reports
- Field data sheets, books
- Selected external and legacy data and datasets

6.2 Data /Information Management Overview and Infrastructure

The information system architecture necessary to fulfill the role of program data management will include both existing and planned components. National-level I&M data management infrastructure and strategy is used as a basis for data management in the CAKN. Existing regional-, network- and park-level infrastructure will be augmented as needed by additional components required in this plan to meet CAKN program data management objectives.

6.2.1 National-level I&M Data Management Infrastructure

Data management guidance from the Washington office includes several databases for summarizing park data at the national level. These include NatureBib, NPSpecies, and NR-GIS. Figure 6.1 depicts the general implementation of these applications.

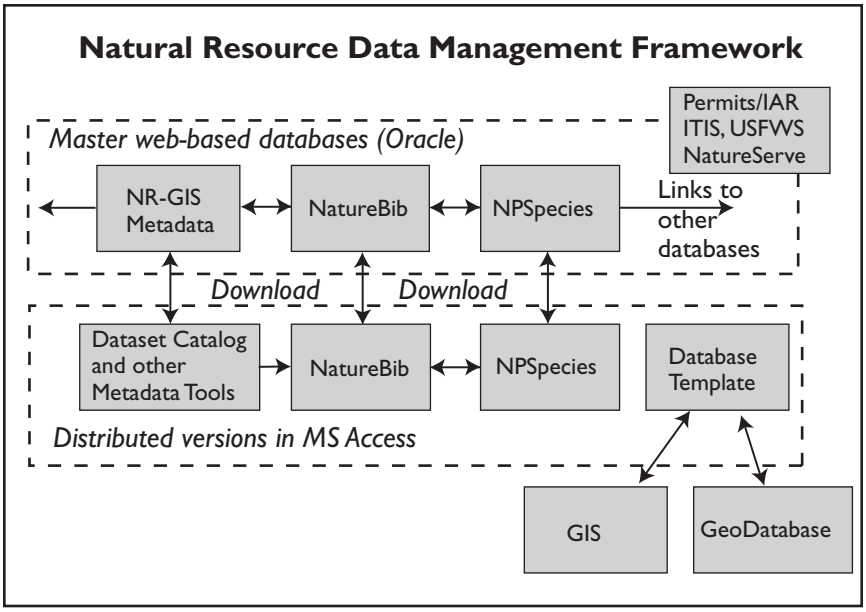

Fig. 6-1. Model of the national-level application architecture.

These online datasets serve to store and make accessible the basic natural source information and data in the parks. Over three years (2000–2003), the CAKN, through both contracts and staff time, conducted park-level data mining to populate these databases. The primary goal of data mining was to discover and document datasets and documents such that they could easily be reviewed for purposes of developing the monitoring program. NPSpecies was populated largely through a national-level effort to accumulate all information pertaining to observed species in the parks. This body of data is greatly enhanced by the CAKN biological inventories completed in 2004.

6.2.2 Alaska Region (AKRO)-level Data Management Infrastructure

Regional network connections will serve to transfer working databases for upload to server-based data stores in Fairbanks and subsequently Anchorage for offsite storage. These server-based databases will serve CAKN I&M data and information to the NPS Alaska region and act as a staging ground for data upload to the national databases.

The AKRO provides the following that the CAKN will utilize to meet its goals:

- The Wide Area Network file server for general file exchange and storage
- GIS and related tabular data accessible via custom applications distributed to the parks as well as the Alaska GIS Data Clearing House (www.nps.gov/akso/gis).
- Client-server database architecture featuring MS SQL Server
- File server to provide offsite storage for all CAKN data

6.2.3 Network-level Data Management Infrastructure

Primary data and information management infrastructure for the CAKN:

- The CAKN will manage a primary repository located in the Yukon-Charley/Gates of the Arctic (YUGA) office in Fairbanks for data and information generated by the network. These data will be accessible via custom applications as well as the CAKN website and open to authorized NPS personnel.
- The primary CAKN repository will be backed up to an offsite server in the AKRO.
- Finalized CAKN monitoring data and information, fit for public distribution, will be uploaded to the online national databases (NPSpecies, NatureBib and NR-GIS).
- Certain CAKN datasets will be maintained by outside organizations; metadata for these, however, will be maintained in the primary CAKN repository. An example of this category is the climate data, which will be handled by the Western Regional Climate Center under formal agreement with the CAKN.

To facilitate file management, the CAKN Data Management Plan specifies a common directory structure to be used by each vital sign component. This "corporate" directory structure will be maintained on the primary CAKN repository in the YUGA office. Duplicate structures will be established on local drives at each park.

6.2.4 Park-level Data Management Infrastructure

Park-based local area networks will serve as connections to local file servers housing working databases for initial archiving of raw data, data entry, and data cleansing. Network operations are designed to function within and augment park operations. Figure 6.2 illustrates CAKN information technology (IT) operations within a typical park IT framework.

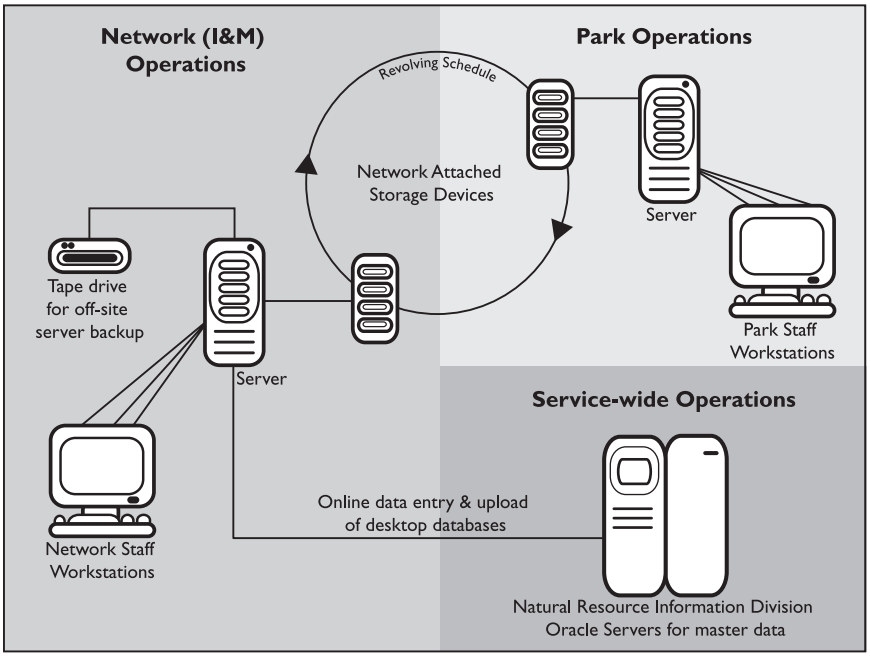

Fig. 6-2. Information Technology Connectivity Diagram

Figure 6-3 presents a generalized schematic of the CAKN data management infrastructure as well as a life cycle for CAKN data. While variations to the cycle will occur based on project specifics,

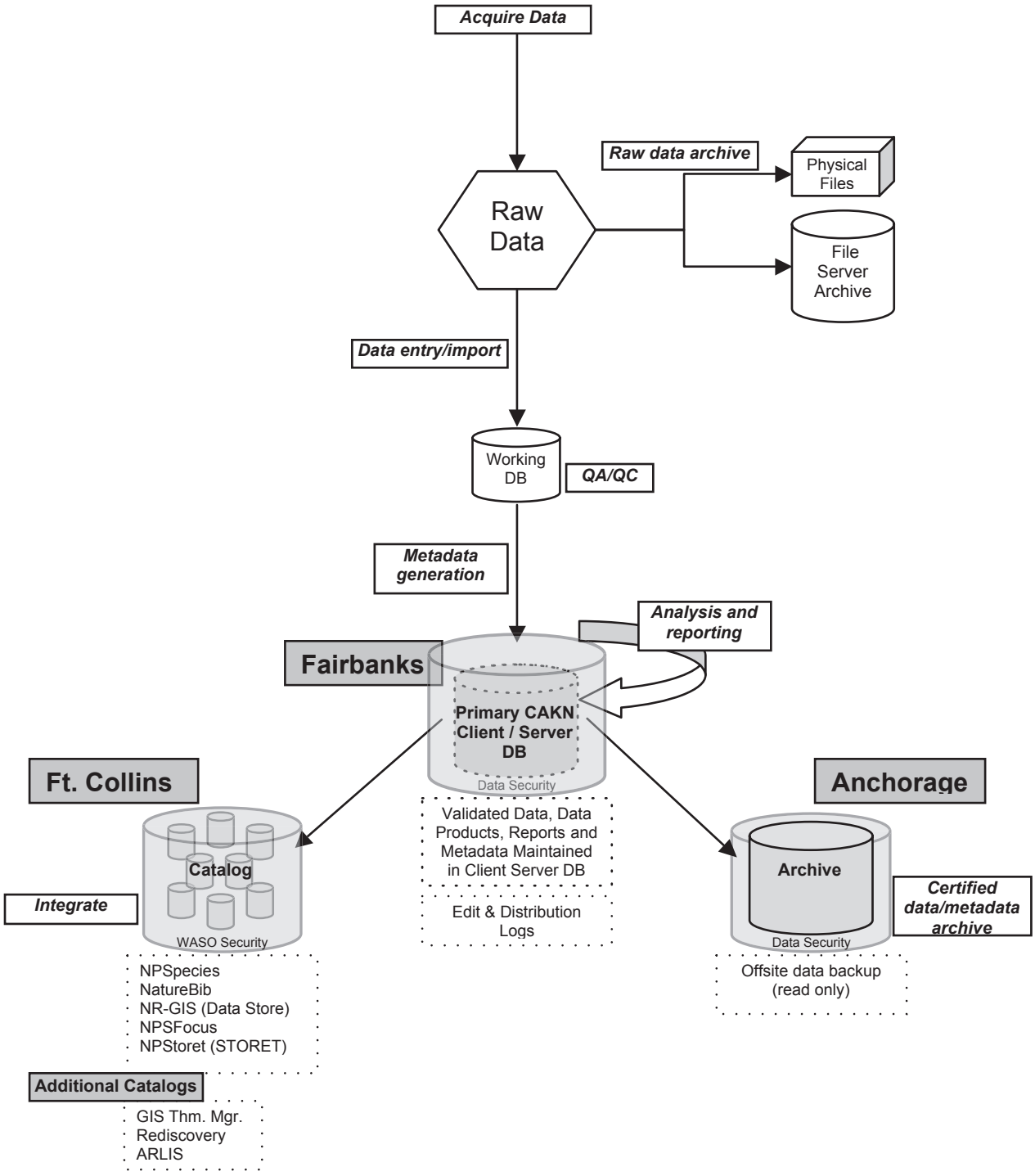

Fig. 6-3. Generalized path of data within the CAKN. The primary data server is accessed via desktop and web-based applications. Analyzed or derived data products are stored on the primary server, archived and catalogued (integrated) along with certified data.

the majority of data handled by the CAKN will follow this general course.

6.3 Data Management Roles and Responsibilities

For the CAKN Inventory and Monitoring program to work effectively, everyone within the network will have stewardship responsibilities in the production, analysis, management, and/or end use of data and information. The CAKN Data Management Plan specifies basic roles and responsibilities spanning the spectrum of data handling from collection to archiving. This spectrum includes field workers, natural resource specialists, GIS specialists, and other data specialists such as statistician and biometricians. More detailed roles and responsibilities are given in the protocol for each vital sign. Table 6-2 lists these basic roles and principal responsibilities.

Table 6-2 Programmatic Roles and Responsibilities for Data Stewardship

Role	Programmatic Data Stewardship Responsibilities
Project Crew Member	Collect, record, and verify data
Project Crew Leader	Supervise crew and organize data
Data/GIS Specialist or Technician	Process and manage data
Information Technology Specialist	Provide IT/IS support
Project Leader	Oversee and direct project operations, including data management
Resource Specialist	Validate and make decisions about data
GIS Manager	Support park management objectives with GIS and resource information management
Network Data Manager	Ensure inventory and monitoring data are organized, useful, compliant, safe, and available
Database Manager	Know and use database software and database applications
Curator	Oversee all aspects of the acquisition, documentation, preservation, and use of park collections
Statistician or Biometrician	Analyze data and present information
Network Ecologist	Integrate science in network activities
Network Coordinator	Coordinate and oversee all network activities
I&M Data Manager (National Level)	Provide Service-wide database availability and support
End Users (managers, scientists, publics)	Inform the scope and direction of science information needs and activities. Apply data and information services and products

Chief personnel involved with data management include the vital sign *project leader* and the network *data manager*. The network *coordinator* interfaces with project leaders to ensure that timelines for data entry, validation, verification, summarization/analysis and reporting are met.

Figure 6.4 illustrates the core data management duties of the *project leader* and *data manager* and where those duties overlap.

6.3.1 Project Leader

As chief steward of a CAKN vital sign monitoring component, the project leader plays a primary role in ensuring the proper handling of data and information. The project leader works with

the network data manager to satisfy network standards and meet broader I&M program goals. Project leaders are responsible for designating an alternate leader who is capable of maintaining project operations in his or her absence.

6.3.2 Data Manager

The fundamental role of the network data manager is to understand and determine program and project requirements, to create and maintain data management infrastructure and standards, and to communicate and work with all responsible individuals. In this capacity, the data manager works closely with project leaders to ensure the overall integrity of CAKN monitoring program data and information.

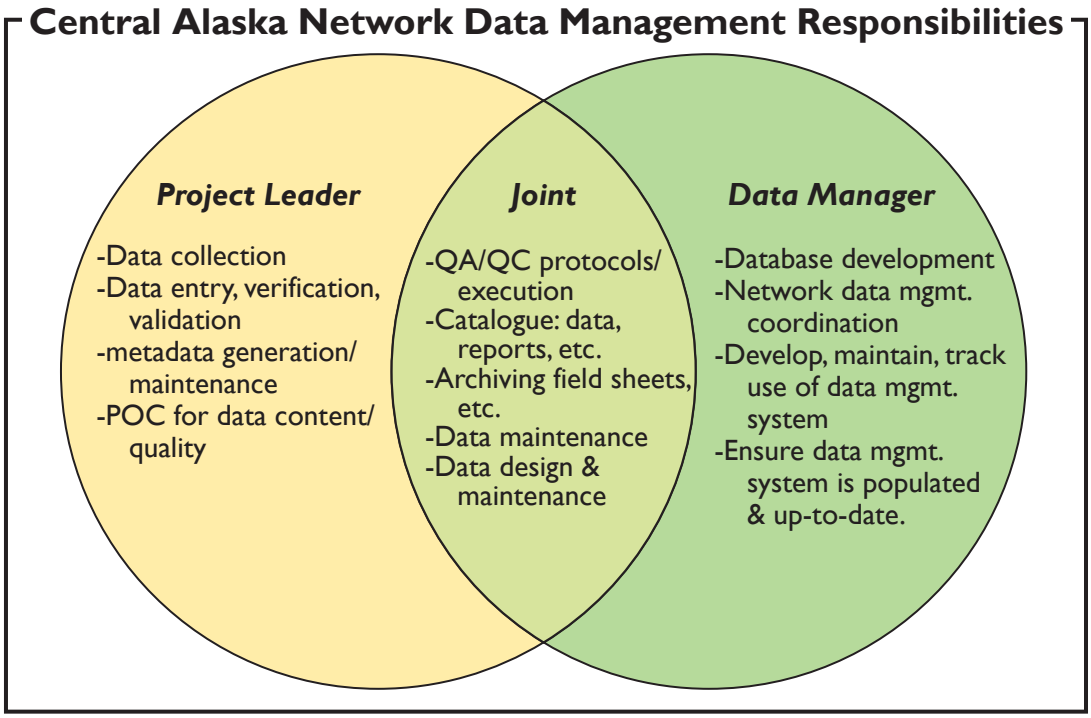

Fig. 6-4. Core responsibilities and how they overlap between the project leader and the network data manager.

6.4 Data Management Standards

The CAKN will conform to National Park Service standards and policy in all aspects of program data management operations. Further, the CAKN will conform to national I&M program standards and mandates in the interest of program integration and information sharing. The CAKN Data Management Plan specifies the standards by which data will be handled. Data management elements or principles common to more than one vital sign will be managed in a conventional manner to allow for greater comparison of data across the network, as well as to ensure further general data integrity.

6.5 Data Acquisition and Processing

Table 6-2 summarizes timing for data acquisition and other critical data management steps for the monitoring vital signs chosen by

the CAKN. Data for each of these vital signs will enter and flow through the system illustrated in Figure 6-2 and on the timeline shown in Table 6-3.

Vital signs shown in boldface represent data initially collected and managed by entities other than the CAKN. Standard operating procedures for incorporating these data with the main body of CAKN products are included in the protocols for those vital signs.

6.6 Quality Assurance and Control (QA/QC)

The network will establish and document protocols for the identification and reduction of error at all stages in the data lifecycle. Although specific QA/QC procedures will depend upon the individual vital signs being monitored and must be specified in the protocols for each monitoring vital sign, some general concepts apply to all network projects.

Each vital sign protocol will include specifics that address quality control. These may include:

- Field crew training
- Standardized data sheets
- Use of handheld computers
- Equipment maintenance and calibration
- Procedures for handling data (including specimens) in the field
- Data entry, verification and validation

Data entry after the field season represents a critical data life stage in terms of QA/QC. Each vital sign protocol also specifically addresses data entry procedures to be completed within the timeframe in Table 6.2. To facilitate data entry, data for each vital sign will be entered via customized MS Access applications tied to the primary CAKN server. These applications help enforce data standards by constraining the type, value, and format of data as appropriate to each vital sign.

The CAKN DMP presents several options for carrying out data verification (ensuring data on field sheets match data entered into a database) and validation (ensuring that the data make sense). Each vital sign protocol specifies procedures for completing proper verification and validation of data.

6.6.1 Laboratory Data

Several of the CAKN vital signs involve laboratory analysis conducted via contract with established laboratories. All data for a given vital sign, including lab results, will be housed in a distinct relational database accessed via custom applications built in MS Access. Laboratories that will be entering analysis results for a given vital sign will be supplied with a copy of the application so that data may be entered in the manner and format matching that of the rest of the data for a given monitoring parameter.

Table 6-3. CAKN vital sign data processing timing and products. Each vital sign will at a minimum have a report and GIS layer as a product. An asterisk next to the collection timing indicates additional laboratory analysis for the vital sign. Data for vital signs in bold are initailly collected and managed outside the NPS.

	Vital Sign Name	Collection	Entry/ Checked	Analysis report	Integrated
Air and Climate	**Air quality**	continuous			
	Climate	continuous			
	Snow pack	Sep.–May.	Jul.	Jul.	Aug.
Geology and Soils	Glaciers	Mar.–Apr.	Jun.	Jan.	Feb.
	Disturbance: volcanoes and tectonics	continuous			
	Permafrost	Jun.–Aug.	Oct.	Apr.	May
Water	**Disturbance: stream flood frequency and discharge**	Mar.–May.	Jul.	Jan.	Feb.
	River/stream flow	continuous			
	Water quality	Jun, Aug*	Sep.	Apr.	May
	Macroinvertebrates	Jun, Aug*	Sep.	Apr.	May
Biological Integrity	Disturbance: exotic species	Jun.–Aug.	Oct.	Apr.	May
	Insect damage	Jul.–Aug.	Oct.	May	Jun.
	Freshwater fish	Jun.–Aug.	Oct.	Apr.	May
	Bald eagles	mid May, late Jul.*	Sep.	Mar.	Apr.
	Golden eagles	Apr., late Jul.*	Sep.	Feb.	Mar.
	Passerines	Jun.–Aug.	Oct.	Apr.	May
	Peregrine falcons	Jul.–Aug.*	Oct.	Apr.	May
	Ptarmigan	Apr.–Jun.	Aug.	Feb.	Mar.
	Arctic ground squirrels	Apr.–Aug.	Oct.	Feb.	Mar.
	Snowshoe hare	Jun.–Jul.	Sep.	Apr.	May
	Small mammals	Jun.–Jul.	Sep.	Apr.	May
	Caribou	Jun., Sep.–Oct.	Dec.	Apr	May
	Moose	first snow (late Oct. in DENA; early-mid Nov. WRST, YUCH)	Jan.	Aug.	Sep.
	Sheep	Jul.–Aug.	Oct.	May	Jun.
	Wolves	Nov., Feb., Jun.*	Jan, Apr, Aug	Sep.	Oct.
	Brown bear	Mar.–May	Jul.	Jan.	Feb.
	Vegetation structure and composition	Jun.–Aug.*	Oct.	Apr.	May
	Subarctic steppe communities	Jul.	Sep.	May	Jun.
Human Use	**Human populations**	US Census: 10 yrs, AK data: <10 yrs			
	Consumptive uses of National Park natural resources	occurrence-based (hunting, seasonal, etc.)			
	Human presence/use	generally summer			
	Trails	Jun.–Aug.	Oct.	Apr.	May
Ecosystem Patterns and Processes	**Disturbance: fire occurrence and extent**	Jun.–Aug.	Oct.	Apr.	May
	Landcover	Mar., Oct.	Dec.		
	Sound	May–Oct.	Dec.	Mar.	Apr.
	Forage quantity/quality	Jun.–Aug.*	Oct.	Apr.	May
	Plant phenology	May–Sep.	Nov.	Mar.	Apr.

6.6.2 Documentation of Quality

The final step in data QA/QC is the preparation of summary documentation that assesses the overall data quality. A statement of data quality will be composed by each vital sign project leader and incorporated into formal metadata, as well as the CAKN primary data repository. Metadata for each data set/database will also provide information on the specific QA/QC procedures applied and the results of the review. Metadata and data will be available via both the CAKN website and the NPS NR-GIS natural resources data store.

6.7 Data Documentation

Metadata for all CAKN monitoring data will conform to FGDC guidelines and be parsed into three nesting levels of detail, each designed with a specific audience in mind. Level 1, or "Manager Level," will present an overview of the product crafted to impart quickly the essentials needed to understand the product. Level 2, or "Scientist Level," will present additional details that allow for rapid scientific assessment of the product. Level 3, or "Full Metadata," will contain all components of supporting information such that the data may be manipulated, analyzed, and synthesized with confidence.

Metadata will be available and searchable in conjunction with related data and reports via the CAKN website as well as the national I&M program NR-GIS metadata and data store.

6.7.1 Data Output for Analysis

It is recognized that any primary data repository can not meet all the analysis needs common to integrated natural resource data. However these needs must be met. Each monitoring vital sign protocol specifies the analyses to be conducted on the data. The primary CAKN data repository will house data such that they may be reconfigured for a variety of output formats including delimited ASCII and MS Excel. Sound relational database structure will allow for any number of data reconfigurations via built-in tools (e.g. in MS Access) or custom programming.

6.8 Data and Information Dissemination

Access to CAKN monitoring products will be facilitated via a variety of data and information systems employing tools that allow potential users to browse, query, and obtain data, information, and supporting documents easily. These systems include a primary CAKN-based server database and archival system and website, NatureBib, NR-GIS, NPSFocus, the Alaska Resource Library and Information Service (ARLIS) in Anchorage, and the AKRO GIS data clearinghouse accessible via either the internet or locally installed applications (especially the NPS GIS Theme Manager). Table 6.4 summarizes repositories for CAKN products.

Table 6-4. Repositories for CAKN Program output

Item		Repository
Reports	Digital	NPS Focus, CAKN data server
	Hard copy	ARLIS, park libraries
	Bibliography	NatureBib
Digital datasets (public)		NR-GIS
Digital project data and info (NPS staff) Raw, validated and analyzed data Metadata Submitted reports Digital photographs Digital presentations		CAKN data server (Fairbanks), Anchorage mirror server and for selected vital sign data: ADF&G, WRCC, US Census, US Fish & Wildlife
Project product materials (and catalogue) Vouchers Specimens		University of Alaska Museum, CAKN or park office (according to project protocol)
Non-product project items (hard copy)		CAKN office

Network products will also be available via data requests using file transfer protocol (FTP), attaching reports and other products with small file sizes to email, and shipping digital media such as DVD, CD-ROM, diskette, and magnetic tape.

6.8.1 Ownership, FOIA, and Sensitive Data

CAKN products are considered property of the NPS. However the Freedom of Information Act (FOIA) establishes generally a right for any person to access federal agency records that are not protected from disclosure by any exemption or by special law enforcement record exclusions. The CAKN complies with all FOIA strictures regarding sensitive data. Each vital sign project leader, as the chief data steward, determines data sensitivity in light of federal law and stipulates conditions for release of the data in the project protocol and metadata.

6.9 Data Maintenance, Storage, and Archiving

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

- Kept up-to-date with regards to content and format such that the data are easily accessed and their heritage and quality easily learned.
- Physically secure against environmental hazards, catastrophe, and human malice.
- Archived in a manner that expedites any contingency data validation needs.

6.9.1 Electronic Data and Information

- Primary data maintenance will be performed on the main CAKN server. The data and information content of CAKN files stored on this server will be kept current. Accompanying metadata files will reflect any data updates as well.

- A catalogue of the data and information on the CAKN server will be maintained on the CAKN website and reflect changes and updates to the primary data (on the CAKN server). National and regional repositories for CAKN data and information (see Table 6.3) will be updated to reflect current stores on the CAKN server. Additionally, program archives (see below) will also be updated to mirror content on the CAKN server.
- Latest versions of primary data will be available in conventional formats reflecting common data usages in the resource management community.

6.9.2 Digital Archiving and Security

- Data collected in the field will be archived in raw, checked, and analyzed conditions. A common metadata file will be associated with raw (source), checked, and analyzed versions of a given dataset. Metadata records will be stored with both hard copy and digital archive data.
- Associated digital content such as submitted project reports, photographs, presentations, etc., will be archived along with project data.
- Digital project files will be archived on servers in Fairbanks (CAKN server) and Anchorage (mirror server). The Fairbanks server will act as the primary data store and be completely backed up to the Anchorage server at least weekly. The Anchorage server will act as an offsite data archive and be accessible for data restoration purposes only.
- Digital project files will also be backed up weekly to an external firewire hard drive and stored offsite in Fairbanks. Additional, selected data backups will be made to CD and DVD as needed.

6.9.2 Hardcopy Data and Information

- The CAKN DMP includes a "project checklist" to guide project leaders in complying with archival directives.
- Physical items considered project products such as reports, maps, and posters will be catalogued and filed in the network's main office and accessioned through the NPS Rediscovery curatorial database.
- A copy of accessioned material will be archived according to NPS standards (http://www.nps.gov/policy/DOrders/DOrder24.html) and follow the procedures outlined in the CAKN DMP.
- Plant and animal specimens collected in the CAKN parks will be accessioned and housed at the University of Alaska Museum in Fairbanks under procedures established during the inventory phase of program development.

6.10 Water Quality Data

Water quality data collected to meet regulatory requirements is managed according to guidelines from the NPS Water Resources Division. This includes using the NPSTORET desktop database application at the parks to help manage data entry,

documentation, and transfer. The network oversees the use of NPSTORET according to the network's integrated water quality monitoring protocol and ensures the content is transferred at least annually to NPS Water Resource Division for upload to the STORET database (Figure 6-5).

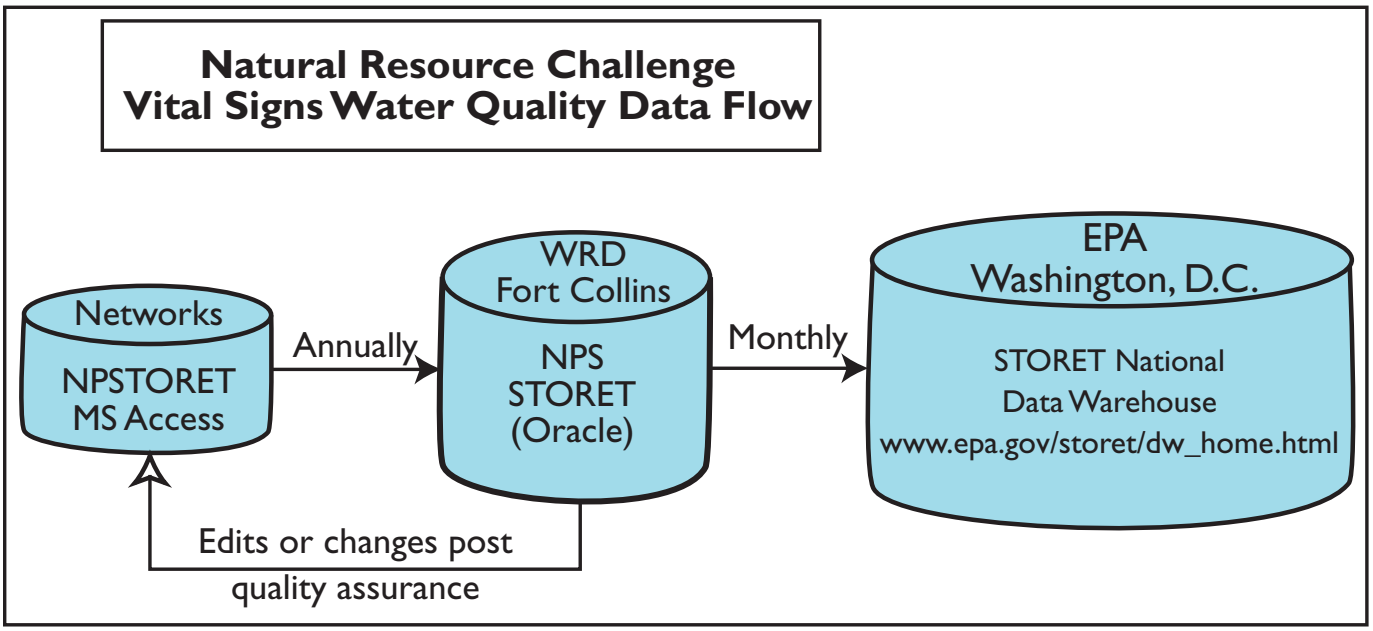

Fig. 6-5. Water Quality Data Flow

Chapter 7

Data Analysis and Reporting

In this chapter, we describe approaches to how data collected by the monitoring program will be analyzed, including who is responsible and how often analysis will occur. We also describe the various reports and other products of the monitoring effort, including what they will include, who the intended audience is, how often they will be produced and in what format, and who is responsible for these products.

In summary, the CAKN strategy towards data analysis and reporting rests upon providing sufficient funding for these activities so that they occur promptly—that is, to report on the previous phenological year (Oct-Sept) by the following March. The CAKN will also focus on producing an annual integrated "State of the Parks" report that effectively communicates the changes and trends observed in each Vital Sign to our primary audience—the natural resource managers of each park.

7.1 Data Analysis

For the purposes of this program, we have defined data analysis as the processes by which observations of the environment are turned into meaningful information. We have defined "data analysis" broadly to include all evaluations of data after the data are collected and entered into an electronic file. Thus, data analysis includes quality control checks that occur during summarization and exploratory data analysis and extends through to analytical procedures leading to conclusions and interpretations of the data. We present some general considerations on analysis of monitoring data and outline the general strategy that CAKN will take for all Vital Signs. We also describe the specific approaches currently planned for each Vital Sign.

7.1.1 Analysis of Monitoring Data—General Considerations and CAKN Strategies

Monitoring data pose challenges to analysis because of inherent temporal associations in the estimates. It is essential that we use statistical analyses that accommodate these associations. These approaches include time series analyses, longitudinal data analysis (including repeated measures), trend estimation (many methods), direct estimation of change, and cumulative summary (CUSUM) techniques. Application of these analytical methods will require working closely with statisticians throughout the initial design process and during subsequent analyses of program data.

Many of the difficulties typically encountered in analysis of monitoring data can be avoided by proper planning, including

the use of probability sampling designs. Appropriate analysis of monitoring data is directly linked to the monitoring objectives, the spatial and temporal aspects of the sampling design used, and management uses of the data. Analysis methods need to be considered when the objectives are identified and the sampling design is selected, rather than after the data are collected. Failure to adequately consider analysis methods during monitoring program development could result in use of sampling designs that are either inadequate or too complex to meet the monitoring objectives. The purpose of this portion of the CAKN monitoring plan, and of the specific Standard Operating Procedures (SOPs) on data analysis for each CAKN Vital Sign, is to ensure that the sampling designs and analysis methods we plan to use will allow us to meet our monitoring objectives.

The network has developed several strategies to guide the development of SOPs for the data analysis for the CAKN Vital Signs program. These strategies included the use of straightforward (equal probability) sampling designs for as many vital signs as possible (see Chapter 4). Sampling designs that are highly structured (i.e., include many stratifications) make subsequent analyses difficult. Having unstructured designs is important in long-term monitoring because it allows more flexibility in the analysis phase (Overton and Stehman 1995, 1996, Nusser et al. 1998). Another CAKN strategy is to work closely with statisticians in developing and implementing change detection analyses. For this purpose, the network is establishing a multiyear agreement with biometricians at the University of Alaska Fairbanks Institute of Arctic Biology.

A central tenet of the CAKN program is that data will be analyzed and reported promptly. Parks need to be alerted to changes in park ecosystems as soon as the changes can be detected—not several years after the fact. Thus, it is imperative that monitoring data be analyzed and reported on as soon as possible. Mechanisms to support prompt analysis and reporting have been built into the data management plan (e.g., data must be entered into the database within one month of returning from the field. Additional mechanisms will be established in the Data Analysis SOP for each Vital Sign to support prompt analysis and reporting.

One of the primary problems leading to long delays in analysis and reporting is a lack of explicit funding for this activity (Caughlan and Oakley 2001). Thus, the CAKN strategy includes providing adequate support to principal investigators (PIs) for data analysis. This will typically include hiring of staff to provide support so the PI has the time needed for analysis.

The first step in analysis is summarization (Mulder et al. 1999). This step is a critical part of overall quality control. The data need to be summarized promptly to identify missing values, outliers, and other problems related to data collection procedures and the data entry process (Jeffers 1994, Reid 2001). Routines for summarization will be prepared and codified in the SOPs for each Vital Sign. The exact form of the summaries will vary depending on the Vital Sign. In general, however, the approach will include use of graphical techniques to show the data in space and time, using measures of central tendency and variation.

The second step in analysis of CAKN data sets will employ an analysis method that allows us to determine immediately if something has occurred that is out of the bounds of expected variation. Under consideration for this use are the conformance metric developed by Debevec and Rexstad (2000) and the CUSUM approach (Manly and Mackenzie 2003). The conformance metric separates out sampling variation from total variation to provide a measure of the natural variation in an attribute due to ecological processes. Once we establish a baseline to characterize "normal" variability, we can view new observations of the attribute and determine how well they conform to the documented history of the attribute. The conformance metric is the probability that a new observation comes from the same underlying process as the baseline. Hence, a small conformance indicates a change. Using conformance as a metric of change allows information from each Vital Sign to be translated to a common reporting system (i.e., is everything going about as expected or not?) and can be pooled hierarchically to any desired level. In the similar CUSUM approach, charts are created that allow systematic deviations to be easily seen. Both approaches are relatively easy to carry out and can complement other approaches to analysis of changes and trend.

The third step in analysis of CAKN data sets will be in-depth analyses of change over time. Specific methods of change, trend, or temporal pattern detection for each Vital Sign will be used and reported at predetermined intervals. When appropriate, other analyses such as species-habitat relationships or community ordinations may also occur. The main approaches we currently intend to use for trend detection are time series analysis (Brockwell and Davis 2002), for climate attributes, and mixed linear models (Diggle et al. 1994, Pinheiro and Bates 2000) for most other attributes. Mixed linear models use information from the variance and covariance structure of the data to reduce correlations typical in repeated measures and time series data.

We expect the analysis methods used in the program to change over time. During the first five to ten years of the program, the

focus will be on summary of findings for a given year across the spatial scale of the network. Comparisons to previous years will be made if data are available. Once measurements have been made over three points in time, conformance can be calculated and analyses of trend can begin. After measurements have been made for longer periods, modeling of relationships among Vital Signs can begin, and time series analyses can be approached.

A variety of analytical software programs are available for data analysis. The CAKN is using R, a programming language and environment for statistical computing and graphics, as a primary arena for data analysis (Maindonald and Braun 2003). Customized R functions can be written to perform data analysis, generate graphical displays, and automate repetitive reports. Packaged R routines can be run locally on a workstation or delivered over the web (Debevec and Rexstad 2004). R is open-source software available at no cost. The network has started working in R for summarization of data for the "Vegetation Structure and Composition" and "Passerine Birds" Vital Signs, and will continue to work in this direction.

7.1.2 Initial Analysis Approaches for CAKN Vital Signs

The initial analysis approaches to be used for each Vital Sign to be monitored in the first phase of CAKN program implementation are shown in Table 7-1. We also identify, for each Vital Sign, the person who has the lead responsibility for data analysis. In some cases, the analysis may be conducted by a person outside of the National Park Service. In all cases, the person within the NPS designated to conduct the analysis or manage the agreement under which another person conducts the analysis, is identified.

In writing the standard operating procedures for data analysis for each CAKN Vital Sign, we have attempted to provide as much detail as possible about the initial steps of data analysis. At some point, however, the steps in analysis cannot be prescribed a priori, and we have therefore described suggested approaches that would be appropriate given the objectives and sampling designs used.

For analysis of climate data, we are currently working with the Western Region Climate Center to develop routine analyses for regular reporting. Analysis of snowpack data is conducted under the auspices of the Natural Resources Conservation Service according to established procedures, and the data are posted at the Western Region Climate Center. All air quality data from Denali are analyzed under the auspices of the NPS Air Quality Program according to their established procedures.

Current estimates of vegetation parameters that apply to the sampled areas in each park will be based on a six-year moving

Table 7-1. Summary of data analysis approaches and responsibilities for each Vital Sign included in the initial Central Alaska Network Vital Signs monitoring program.

Vital Sign	Data Analysis Approach	How Often?	Who is Responsible for Data Analysis?
Climate	Time Series Analysis	Data available in real-time; summary analyses performed annually	NOAA-National Weather Service, Western Region Climate Center under terms of agreement managed by Denali Environmental Specialist, Pam Sousanes
Snowpack	Mixed Linear Models	Annual	USDA-Natural Resource Conservation Service, Rick McClure, under terms of agreement managed by Denali Environmental Specialist, Pam Sousanes
Water Quality (Ponds)	Mixed Linear Models	Annual	Yukon Charley Rivers-Gates of the Arctic Aquatic Ecologist, Amy Larsen
Air Quality	Time Series Analysis	Annual	NPS National Air Quality Monitoring Program
Structure and Composition	Mixed Linear Models	Annual	Denali Botanist, Carl Roland
Passerines	Distance estimation to address detection bias Mixed Linear Models	Annual	Denali Wildlife Biologist, Carol McIntyre
Golden Eagles (DENA)	Mixed Linear Models	Annual	Denali Wildlife Biologist, Carol McIntyre
Peregrine Falcons (YUCH)	Mixed Linear Models	Annual	Yukon-Charley Rivers Wildlife Biologist, Nikki Guldager, working initially with Skip Ambrose
Moose	Mixed Linear Models	Every 3 years (for each park)	Yukon-Charley Rivers Wildlife Biologist, John Burch
Wolves	Aerial telemetry data to generate 95% minimum convex territories for each pack.	Annual	Denali Wildlife Biologist, Tom Meier

average of individual year estimates. Current estimates that apply to the sampled areas can be produced after one field season. Trends in vegetation parameters will be estimated using mixed linear models that potentially contain effects for year, site, and external covariates such as elevation. Spatial and temporal correlation in responses will be considered in the mixed linear model, and results will be adjusted if necessary. Low precision trend estimates can be produced after two field seasons. High-precision trend analyses can be produced beginning in year 7 after the first rotation of sampling effort to all mini-grids is complete.

A similar approach will be used for analysis of the passerine bird data, also collected within the mini-grid design. The revisit design for the passerine bird data has more structure in it to account for higher interannual variability. Another important feature of the passerine bird data analysis is the use of distance estimation to account for differences in species detectability.

Analysis methods for golden eagles, peregrine falcons, moose, and wolves will follow standard procedures currently in use for these long-standing studies. For golden eagles and peregrine falcons, analysis methods are straightforward for monitoring nesting territory occupancy and productivity. A new aspect to the golden eagle protocol is being added to assess sightability. Depending on results, the protocol could be revised to produce an estimate, rather than a count. For moose, an estimated population size is calculated using established programming (SMOOSE) developed by Ver Hoef (2001) and available on the internet from the Alaska Department of Fish and Game (http://winfonet.alaska.gov). The estimates are available immediately after the survey. For wolves, radio-tracking occurs throughout the year, and a home range program (Hooge and Eichenlaub 2000) is used to map pack territories. Population and density estimates are produced twice a year-in October at the beginning of winter and in April at the end of winter.

7.2 Reporting

Communicating the findings of the monitoring program is reporting. In this section of the Monitoring Plan, we begin by discussing general considerations about reporting and identifying general CAKN strategies about reporting. We then identify the main methods we will use for reporting to specific audiences, as well as the specific reports to be generated.

7.2.1 Reporting Monitoring Data—General Considerations and CAKN Strategies

Reporting is critical to the long-term success of the CAKN Vital Signs program. Results must be credible and delivered in a timely fashion to the appropriate audiences in a manner that is understandable to them. There are multiple audiences for monitoring data produced by the CAKN Vital Signs program, and each requires information formatted and presented in specific

ways. The main audience for monitoring data is the resource managers of each network park, and other managers in the National Park Service system, who will use the information to assist with their management decisions.

Although making monitoring findings available to resource managers and other audiences is the underlying reason for monitoring programs, failure to report or long delays in reporting are common problems. Sometimes the reasons for not reporting do not lie in reporting mechanisms per se, but are the result of problems earlier in the monitoring process (e.g., setting measurable objectives, sampling design, feasibility of carrying out the work, data management, data analysis). Thus, for the reporting end of the monitoring program to work well, all other parts of the monitoring program must also be functioning properly. As with data analysis, reporting is an activity that needs to be adequately funded so that reports are produced on schedule (Caughlan and Oakley 2001). Too often, reports are delayed while the next cycle of data collection takes place.

Producing reports that effectively communicate findings from the monitoring program is also critical. Oakley (2004) reviewed monitoring reports from a variety of programs and observed that key results often are buried in text and would be difficult for a busy manager to find. Monitoring reports can also be quite lengthy and difficult to read in their entirety. Thus, an important component of producing effective monitoring reports is to improve presentation of results. In this regard, increasing use of visual methods for communicating results (i.e., graphical techniques) is a key strategy. The network will work towards improving data presentations using some of the graphic techniques suggested by Tufte (1983, 1990, 1997), Cleveland (1993, 1994) and others.

The CAKN vision for reporting includes the following central themes: (1) We will prepare monitoring reports that are understandable and useful to our primary audience: park resource managers, (2) We will prepare reports promptly, and (3) All reports will be readily available. To achieve this vision, the network has adopted the following strategies:

1. The budgets for each Vital Sign will include adequate funding to support the production of required annual and periodic reports.
2. All monitoring data and all reports and information generated from the monitoring data will be made available promptly via the internet, subject to applicable law.

3. All written reports will follow the current format guidance set by the Alaska Region Inventory and Monitoring Program ((National Park Service, Alaska Region, undated).
4. All written reports will include a brief summary that includes the main findings presented in the report, using language understandable to a general audience not conversant with the specific technical details of the subject matter.
5. The use of graphical methods for presenting data following principles described by Tufte (1983, 1990, 1997) and Cleveland (1993, 1994) will be encouraged.

7.2.2 Initial Reporting Approaches

The list of reports to be produced by the CAKN is based on national guidance, modified to reflect CAKN reporting goals (Table 7-2). For administrative reporting, the network will rely on the "Annual Administrative Report and Workplan" required to be prepared in the fall of each year. For reporting of monitoring results, the network will use a variety of annual and periodic written reports, a biennial conference for the network, and participation in other scientific forums (e.g., scientific meetings, symposia, etc.). The network will also conduct periodic program and protocol reviews.

As discussed in previous chapters, the CAKN has structured its Vital Signs monitoring program around a holistic ecosystem model and has focused on creating an integrated program. The vision of an integrated program will be carried through in the reporting

Table 7-2. Reports to be produced by the Central Alaska Network Vital Signs Monitoring Program.

Type of Report	Purpose of Report	Primary Audience	How Often?	Peer Review Process
Annual Administrative Report and Work Plan	Account for funds and FTEs expended; Describe objectives, tasks, accomplishments, products of the monitoring effort; Improves communication within park, network, region, Program;	Superintendents, network staff, regional coordinators, and Servicewide program managers; admin. report used for annual Report to Congress.	Annual; due to WASO by November 8	Review and approval by Regional Office and Servicewide Program manager
Annual Reports for each Protocol or Project	Archive annual data and document monitoring activities for the year; Describe current condition of the resource and provide alert if data are outside bounds of known variation; Document changes in monitoring protocols; Communication within the park or network;	Park resource managers; network staff; external scientists	Annual; published each March	Peer reviewed at network level

(continued on next page)

Table 7-2. (continued)

Type of Report	Purpose of Report	Primary Audience	How Often?	Peer Review Process
Annual Report on "State of the Parks" for the CAKN Vital Signs Program	Describes current conditions of park resources; Report interesting trends and highlights of monitoring activities; Identifies situations of concern; Explores future issues and directions;	Superintendents; Park resource managers; network staff; external scientists; public	Annual; published each March	Peer reviewed at network level
Analysis and Synthesis reports—trends	Determine patterns/trends in condition of resources being monitored; Discover new characteristics of resources and correlations among resources being monitored; Analyze data to determine amount of change that can be detected by this type and level of sampling; Context – interpret data for the park within a multi-park, regional or national context; Recommend changes to management of resources (feedback for adaptive management);	Superintendents, park resource managers, network staff, external scientists	3-5 year intervals for resources sampled annually	Peer reviewed at network level
Program and Protocol Review reports	Periodic formal reviews of operations and results (5 year intervals); Review protocol design and products to determine if changes needed; Part of quality assurance – peer review process;	Superintendents, park resource managers, network staff, Servicewide Program managers, external scientists	5 year intervals	Peer reviewed at regional or national level
Scientific journal articles and book chapters	Document and communicate advances in knowledge; Part of quality assurance – peer review process;	External scientists, park resource managers, network staff	Varies	Peer reviewed by journal or book editor
CAKN Vital Signs Monitoring Conference	Review and summarize information on CAKN Vital Signs; Helps identify emerging issues and generate new ideas;	Park resource managers, network staff, external scientists	Biennial; in the spring (Feb, March or April)	Peer reviewed at network level
Other symposia, conferences, and workshops	Review and summarize information on a specific topic or subject area; Communication of latest findings with peers; Helps identify emerging issues and generate new ideas;	Park resource managers, network staff, external scientists	Varies	May be peer reviewed by editor if written papers are published
CAKN contributions to the national "State of the Parks" Report	Describes current conditions of park resources; Report interesting trends and highlights of monitoring activities; Identifies situations of concern; Explores future issues and directions	Congress, budget office, NPS Leadership, superintendents, general public	Annual	Peer reviewed at national level

stage by the annual production of a "State of the Parks" type report for the network. Initially, this report will be constructed from the summaries provided in the annual reports produced for each Vital Sign. The report will be short and will emphasize graphical summaries of the data. We will work toward incorporating conformance measures for each Vital Sign as an initial method of integrating monitoring findings. The first "State of the Parks" report will be produced in March 2006, following the first full year of program implementation.

As a network of subarctic parks, the CAKN annual work schedule is strongly tied to the annual climate cycle. The CAKN parks are typically covered by snow for ~8 months of the year and snow-free for only ~4 months. Although a majority of the field work for most Vital Signs occurs during the snow-free months, some Vital Signs are measured year-round, and others occur mainly in fall and winter. The differences in timing of the main field work leads to some challenges in scheduling of annual reporting and in producing a report that integrates all Vital Signs. Because the program is ecological, we have decided to use the phenological year (starting from freeze-up in October to following September) as the basis for reporting. All annual reports will be produced in March to describe conditions and changes occurring in the previous phenological year. The annual reports may also include available data for the current phenological year (e.g., fall caribou counts, snowfall, breakup prognosis), but the primary focus will be the previous year.

Chapter 8

Administration and Implementation of the Monitoring Program

This chapter describes our plan for administering the monitoring program. The network has developed a three-year (FY 2005–2008) plan under which monitoring of nine vital signs will begin, while development of protocols for monitoring of the other vital signs will be initiated. In this chapter, we describe the makeup of the Board of Directors and Technical Committee and the decision-making process of the network; the staffing plan; how network operations are integrated with other park operations; key partnerships; how in-house field work will be carried out; and the periodic review process for the program.

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

The Board of Directors for the CAKN includes the superintendent from each park in the network, the Alaska Region Inventory and Monitoring Coordinator, the Alaska Region Science Advisor, and the Network Coordinator (Table 8-1). One of the Superintendents serves as the Chairman for the Board and this position rotates among the Superintendents every two to three years.The three Superintendents are the voting members of the Board, and the other members serve as advisors to the Superintendents. A charter for the Board of Directors guides the function and operation of the board (http://www.nature.nps.gov/im/units/cakn/Documents/CAKN_Board_Directors_Charter.pdf). A key feature of the charter governing the CAKN Board of Directors decision-making is that all decisions are made by consensus.

Table 8-1. Composition of the Board of Directors for the Central Alaska Network.

Title	Name	Voting Member	Advisor to Board
Superintendent DENA	Paul Anderson, *Chairman*	X	
Superintendent YUCH	Dave Mills	X	
Superintendent WRST	Jed Davis	X	
Alaska Region Inventory and Monitoring Coordinator	Sara Wesser		X
Alaska Region Science Advisor	Bob Winfree		X
CAKN Coordinator	Maggie MacCluskie		X

The Technical Committee is composed of the Assistant Superintendent for DENA and the Chiefs of Cultural and Natural Resources for YUCH and WRST (Table 8-2). Two resource staff from each park provide subject area expertise for the program. The network coordinator serves as the Chairperson for the Technical Committee. Remaining members of the committee include the network Data Manager, the Aquatic Ecologist for YUCH (this position serves the three parks for various water-related issues), and the United States Geologic Survey, Biological Resources Division

Table 8-2. Composition of the Technical Committee for the Central Alaska Network.

Title	Name	Park
CAKN Coordinator, Chair	Maggie MacCluskie	CAKN
Data Manager	Doug Wilder	CAKN
Assistant Superintendent	Philip Hooge	DENA
Physical Scientist	Guy Adema	DENA
Botanist	Carl Roland	DENA
Chief of Cultural and Natural Resources	Devi Sharp	WRST
Wildlife Biologist	Mason Reid	WRST
Fisheries Biologist	Eric Veach	WRST
Chief of Cultural and Natural Resources	Tom Liebscher	YUCH
Wildlife Biologist	John Burch	YUCH
Wildlife Biologist	Nikki Guldager	YUCH
Aquatic Ecologist	Amy Larsen	YUCH
Biologist, Biological Resources Division	Karen Oakley	USGS

Liaison.
The Board of the Directors and the Technical Committee work in concert to accomplish the monitoring program (Fig. 8-1). The Board of Directors is the final decision-making body and is accountable for the entire network. The Technical Committee works with the Network Coordinator to formulate recommendations for all aspects of the program. The Network Coordinator then presents these recommendations to the Board of Directors for review, input, and approval. The Technical Committee also serves as the means by which park staff who are not on the Technical Committee may raise various issues for discussion or clarification. We also invoke the use of Work Groups to address issues that require more sustained discussion by a smaller number of people. During those times the network used Work Groups, the Work Group has prepared summary documents outlining the subject of interest and making recommendations to the Technical

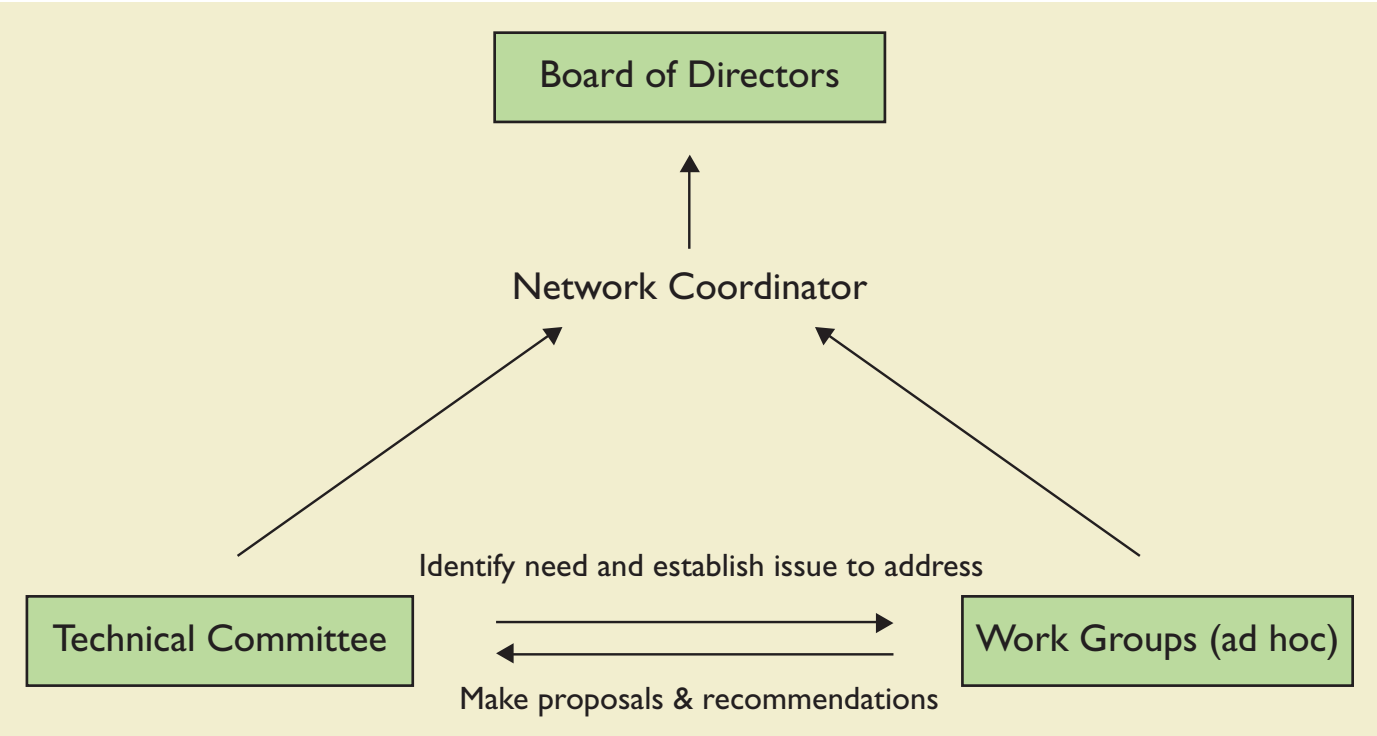

Fig. 8-1. Interaction between the Central Alaska Network Board of Directors, the Technical Committee and Work Groups.

Committee. The Technical Committee then arrives at a direction or position to work from, based upon the 'legwork' conducted by the Work Group.

In the Central Alaska Network, the Network Coordinator position serves several functions. One of the foremost of these is to ensure the communication of information among and between the many people and groups involved in the program. This includes the members of the Technical Committee (presently 15 people), the Board of Directors, the national program, the staff of the network parks, and cooperators in the program. This communication is accomplished in part by regular meetings of the Technical Committee (approximately four per year), the Board of Directors (four per year), and biweekly updates for the Chairman of the Board of Directors. The Network Coordinator is also responsible for managing the network budget and providing annual accountability of the funds. The Coordinator works with the Technical Committee to establish objectives for the program and in determining a means to implement the program while meeting the needs long-term data needs of the network parks. A final important component of the Network Coordinator is to ensure regular and thorough review of the program and to correct program components that are not meeting rigorous standards.

Since the inception of the network in 2001, the Board of Directors and Technical Committee have been extensively involved in developing the monitoring program. Over the past 3½ years, Technical Committee has held an average of four meetings per year and three to five teleconferences. The Board of Directors has typically met twice times per year and held two teleconferences. Board meetings have been timed to coincide with preparation of the Annual Administrative Report and Work Plan and the deadlines associated with the phased reporting process of the Vital Signs program. Our general process has been for the Technical Committee to work with the Network Coordinator on each phase of the program, then for the Network Coordinator to present the progress to the Board of Directors for review, input, and approval. Input from the Board is carried back to the Technical Committee for incorporation into the relevant phase of the program.

8.2 Staffing Plan

A key characteristic of the staffing plan for the CAKN is the substantial involvement of park staff in executing the program (Table 8-3). This is a strategic and deliberate decision made for several reasons. First, it is imperative for this program to be relevant to the parks, which is most directly accomplished by the full involvement of park staff in the program. The staff in the network parks have expressed significant interest in serving as Principal Investigators for various portions of the program, and the park management is supportive of contributing to the monitoring program in this fashion. Second, because our network is particularly large (21.7 million acres), the cost of operating a program on this scale is high. We face a balancing act between hiring people to conduct the monitoring program and having the operational funds to do the work. To help define the roles of the park staff, or any other cooperator, we have defined two levels of involvement:

- Principal Investigator: the individual designated to take overall responsibility within the network context for the design, conduct and reporting on a vital sign. He or she works with the Network Coordinator and Technical Committee to determine long-range directions for data collections. They oversee collation and summarization of the monitoring data.
- Park Lead: the staff member from a specific park who ensures that park-level interests are considered in the execution of the monitoring of a vital sign. They help the CAKN Biotechnician in learning about relevant park operations and complying with permitting and other requirements.

The initial staffing plan for the network is therefore fiscally conservative in that it incorporates the need for flexibility over the next three years as the program continues to mature and we learn what works best to accomplish the program. During FY 2005 the

Table 8-3. Roles of network and park staff in the Central Alaska Network FY 2005–FY 2009.

Position	GS Level	Type	Pay Periods to Network/ Year	Duty Station	Role in Vital Signs Program
Network Coordinator	12	Permanent	26	Fairbanks, AK	Acts as the primary coordinator for all aspects of the monitoring program. Works with the Technical Committee to formulate direction and administration of the program. Serves as advisor to the Board of Directors in making programmatic decisions and maintaining accountability of program.
Data Manager	11, CI	Permanent	26	Fairbanks, AK	Is the primary person responsible for all aspects of data management for the network. This includes establishing the flow of data from collection to reporting and archiving. Designs the architecture for World Wide Web dissemination of program information. Works with Principal Investigators to design appropriate databases for data collection and for integration of data.
Assistant Data Manager	7/9, CI	Term	26	Fairbanks, AK	Serves as the assistant to the Data Manager. Undertakes detailed database design work and programming as needed. Handles technical aspects related to delivery/communication of monitoring program information via the World Wide Web.
Stream Ecologist	11/12	Term	26	Fairbanks, AK	Primary responsibility is to develop monitoring program for moving water systems in the network under the aquatic framework developed by the Technical Committee. Determines and conducts any development work necessary to establish the monitoring work on moving water systems. Writes the full protocol for monitoring of such water.
Biotechnician 1	7	Term	26	To Be Determined	Act as main contacts regarding any logistics and permitting for monitoring work in a given park. They expedite all monitoring fieldwork in their park, assist with data collections their as well in the other network parks as appropriate.
Biotechnician 2	7	Term		To Be Determined	
Biotechnician 3	7	Term		To Be Determined	
Clerical Assistant	7	Term	26	Fairbanks, AK	Provides assistance to the network by helping to complete and file paperwork (travel, supervision), assist in preparing annual reports, entering budget information on financial systems, formatting correspondence, and arranges logistics for meetings. Also enters project information on tracking database to maintain program accountability.
Botanist	12	Permanent	13 (50% share with DENA)	Fairbanks, AK	Serves as the Principal Investigator for vegetation monitoring in the network. Is responsible within network context for design, conduct and reporting of vegetation monitoring. Oversees collation and summarization of data. Also serves on Technical Committee.

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Table 8-3. (continued)

Position	GS Level	Type	Pay Periods to Network/ Year	Duty Station	Role in Vital Signs Program
Physical Scientist	12	Permanent	13 (50% share with DENA)	Denali Park, AK	Serves as the general oversight for all physical environment monitoring in the network. Is responsible within network context for design, conduct and reporting of physical environment monitoring. Oversees collation and summarization of data. Also serves on Technical Committee.
Environmental Protection Specialist	9	Permanent	15.6 (50% share with DENA)	Denali Park, AK	Serves as the Principal Investigator for climate monitoring in the network. Is responsible within network context for design, conduct and reporting of climate monitoring. Oversees collation and summarization of data.
Denali Staff Working on Program but Paid from Park-base Funds					
Supervisory Wildlife Biologist (Large mammal)	12	Permanent	6.5	Denali Park, AK	Serves with the other large mammal Wildlife Biologists in network as Co-Principal Investigator for large mammal monitoring in the network. Is responsible within network context for design, conduct and reporting of large mammal monitoring. Oversees collation and summarization of data. Also serves on Technical Committee.
Wildlife Biologist (Avian)	12	Permanent	10	Fairbanks, AK	Is the Principal Investigator for Golden Eagle monitoring and Co-Principal Investigator for land-bird monitoring. Is responsible within network context for design, conduct and reporting of large mammal monitoring. Oversees collation and summarization of data. Also serves on Technical Committee.
Wrangell-St. Elias Staff Working on Program but Paid from Park-base Funds					
Wildlife Biologist (Large mammal)	12	Permanent	5	Copper Center, AK	Serves with the other large mammal Wildlife Biologists in network as Co-Principal Investigator for large mammal monitoring in the network and is the Principal Investigator of Bald Eagle monitoring. Is responsible within network context for design, conduct and reporting of large mammal monitoring. Oversees collation and summarization of data. Also serves on Technical Committee.
Botanist	12	Permanent	3	Copper Center, AK	Is the Park Lead for vegetation monitoring. Ensures that park-level interests are considered in the design and execution of that portion of the program.
Physical Scientist	12	Permanent	1	Copper Center, AK	Is the Park Lead for physical environment monitoring. Ensures that park-level interests are considered in the design and execution of that portion of the program.
Fisheries Biologist	12	Permanent	3	Copper Center, AK	Is the Park Lead for water and fish monitoring. Ensures that park-level interests are considered in the design and execution of that portion of the program. Also serves on the Technical Committee

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Table 8-3. (continued)

Position	GS Level	Type	Pay Periods to Network/ Year	Duty Station	Role in Vital Signs Program
Yukon-Charley Staff Working on Program but Paid from Park-base Funds					
Aquatic Ecologist	11	Permanent	10	Fairbanks, AK	This position serves aquatic needs for all parks in the network plus Gates of the Arctic and Western Arctic Parklands. Is the Principal Investigator for shallow lake monitoring in the network. Is responsible within network context for design, conduct and reporting of shallow lake monitoring. Oversees collation and summarization of data.
Wildlife Biologist (Large mammal/ furbearer)	11	Permanent	5.5	Fairbanks, AK	Serves with the other large mammal Wildlife Biologists in network as Co-Principal Investigator for large mammal monitoring in the network. Is responsible within network context for design, conduct and reporting of large mammal monitoring. Oversees collation and summarization of data. Also serves on Technical Committee.
Wildlife Biologist (Avian/ furbearer)	11	Permanent	10	Fairbanks, AK	Is the Principal Investigator for Peregrine Falcon monitoring and the Park Lead for passerine monitoring and furbearer monitoring. Is responsible within network context for design, conduct and reporting on Peregrine Falcon monitoring. Oversees collation and summarization of data. Also serves on Technical Committee.

network will hire three *term* positions. These positions will fulfill key needs of the program, including: (1) an assistant to the network *Data Manager,* (2) an *Outreach Specialist* to create materials to communicate information about the program and its results to network and park staff, managers, cooperators, and the general public, and (3) a *Stream Ecologist* to develop the monitoring plan for moving water systems further. Conversion of any of these positions to permanent is possible; final decisions on this, however, will not be made until FY2007.

8.3 Integration of Program with Park Operations

Being an integral part of operations in the network parks will be another key component to the successful execution of this program. As mentioned earlier, the network has adopted a strategy of using park biologists as Principal Investigators for carrying out most monitoring operations, and this strategy is a key part of how integration with park operations will be achieved.

We have gained some insight into how best to integrate with park operations by conducting pilot projects during FY2003. We believe the key to being integrated with park operations lies in allowing sufficient time for planning the various aspects of the monitoring program. Sufficient planning time allows appropriate dialogue with the myriad aspects of park operations to take place. To facilitate this, the network uses a two-year planning schedule to determine what work should occur so that points for integration with park operations can be identified and pursued (see Chapter 9 for the network schedule which reflects this).

For example, during FY 2005 the Outreach Specialist will meet with the Interpretation Divisions of all the parks to understand the many activities the Divisions conduct. The Outreach Specialist will work with each Interpretation Division to identify ways to integrate the Vital Signs Monitoring program within each park and develop a plan to accomplish this. We will take a similar approach with the other park divisions: initiating dialogue to understand the scope of work conducted by the division, then identifying points of integration with the division that allow both groups to meet their respective goals.

Another opportunity for integration comes in the form of the Network Coordinator taking part in the annual park meetings. By presenting information on what the network is doing and discussing future plans, another opportunity for integration with park operations occurs. Essentially, the network strategy for integration is to talk early and often with the park divisions.

8.4 Field Efforts to be Conducted by the CAKN

Field work conducted in the Central Alaska Network will represent a continuum of effort that ranges from work conducted

entirely "in-house" to work conducted by cooperators/partners. Because we are still undertaking protocol development for some of our vital signs, we cannot definitively state at this time exactly which field efforts will be conducted by the network vs. a contractor or cooperator. In Table 8-4 we present those efforts we are reasonably sure will be conducted by the network over the next three to five years. Future reviews of the program will include the question of whether specific field efforts should continue to be conducted by the network.

As for all field operations in CAKN parks, worker safety is paramount. The CAKN program will be operated in accordance with safety laws, regulations and policies. The primary method for assuring compliance with safety laws is through training, and all CAKN monitoring protocols have incorporated safety training into their standard operating procedures on training. Thus, in addition to receiving any required training in field methodology, field workers will also be required to receive standard safety training. For operations in Alaska parks, these typically include: DOI aircraft safety, helicopter manager training (for crew leaders), wilderness first aid, shotgun training, bear safety training, and watercraft safety. Parks typically hold training courses for these topics in late spring so that permanent and seasonal staff can be prepared for the field season. Budgets for each Vital Sign Protocol include the costs for network staff to attend required safety training.

8.5 Partnerships

Several partnerships are currently in place to accomplish some components of the monitoring program; these do not represent, however, the complete list of the partnerships the network plans to develop over the upcoming years. Due to the iterative process used in developing the program, we will continue to enlist more partners as our protocol development progresses. The agreements listed in Table 8-5 are currently assisting some part of monitoring program. Thus, it is logical that two of our agreements deal with monitoring of the physical environment, since our development of that portion of the program is more advanced than most of the other vital signs. The CAKN is presently participating in five other agreements to assist with protocol development of other vital signs.

8.6 Review Process for the Program

We have developed a review process (Table 8-6) for the program that is all-encompassing to evaluate the myriad facets of the program. On an annual basis, the Annual Administrative Report and Work Plan (AARWP) provides the Technical Committee and Board of Directors with an opportunity to review what has taken place and what is planned. This provides an annual opportunity to review and evaluate the program. What we must ensure is that *evaluation* takes place at this juncture, and that we do not adopt a

Table 8-4. Vital Signs for the Central Alaska Network under the Vital Signs Framework as developed for the National Park Service Vital Signs Monitoring Program.

National Vital Signs Framework Level 1	National Vital Signs Framework Level 2	Vital Sign Name	Field Efforts Conducted Solely by Network	Field Efforts Conducted by Network and Cooperator	Field Efforts Conducted Only by Cooperator
Air and Climate	Air contaminants	Air quality	X		
	Weather and Climate	Climate		X	
		Snow pack		X	
Geology and Soils	Glacial features and processes	Glaciers		X	
	Volcanic features and processes	Disturbance - volcanoes and tectonics		X	
Water	Surface water dynamics	Disturbance - Stream flood frequency and discharge	X		
		River/stream flow	X		
	Water chemistry	Water Quality	X		
	Aquatic macro-invertebrates and algae	Macroinvertebrates		X	
Biological Integrity	Invasive/Exotic plants	Disturbance - Exotic species		X	
	Insect pests	Insect Damage	X		
	Fishes	Freshwater fish		X	
	Birds	Bald Eagles	X		
		Golden Eagles	X		
		Passerines		X	
		Peregrine Falcons	X		
		Ptarmigan	X		
	Mammals	Arctic ground squirrels	X		
		Snowshoe hare		X	
		Small mammals		X	
		Caribou		X	
		Moose	X		
		Sheep	X		
		Wolves		X	
		Brown bear	X		
	Vegetation communities	Vegetation structure and composition	X		

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Table 8-4. (continued)

National Vital Signs Framework Level 1	National Vital Signs Framework Level 2	Vital Sign Name	Field Efforts Conducted Solely by Network	Field Efforts Conducted by Network and Cooperator	Field Efforts Conducted Only by Cooperator
	Terrestrial communities	Sub-arctic Steppe	X		
Human use	Point-source human effects	Human populations		X	
	Consumptive use	Consumptive uses of National Park natural resources		X	
	Visitor usage	Human Presence/Use	X		
		Trails	X		
Ecosystem Pattern and Processes	Fire and fuel dynamics	Disturbance - Fire occurrence and extent		X	
	Land cover / Land use	Landcover	X		
	Soundscapes	Sound	X		
	Productivity	Forage quantity/quality	X		
		Plant phenology	X		

Table 8-5. Partnerships for the Central Alaska Network monitoring program.

Partner	Type of Agreement	Renewal date	Work Accomplished
Biological Resources Division, United States Geological Survey	Interagency	Annual	* Liaison role for development of network monitoring program. Serves on CAKN Technical Committee * Principal Investigator of predator/prey research in DENA and caribou herd dynamics in WRST.
Natural Resources Conservation Service, U.S. Department of Agriculture	Cooperative	2009	* Yearly maintenance of climate monitoring stations in DENA and WRST. * Conduct snow surveys in DENA and WRST
Western Regional Climate Center, Desert Research Institute	Cooperative	2009	* Archive and deliver climate data via the World Wide Web * Develop analysis tools for CAKN climate data via the World Wide Web
Alaska Bird Observatory	Cooperative	2009	* Conducts passerine point count monitoring in DENA.
Institute of Arctic Biology, University of Alaska Fairbanks	Cooperative (CESU)	2009	* Develop analysis and reporting tools for use by the CAKN via the World Wide Web * Develop programming to geospatially render monitoring data over computer displays at network park visitor centers
Institute of Arctic Biology, University of Alaska Fairbanks	Cooperative	2008	* Conduct small mammal monitoring on 'legacy' plots in DENA

Table 8-6. Review process for the Central Alaska Network monitoring program.

Review	Timing	Who is Involved	Intent of Review
Annual Administrative Report and Work Plan	Annual	Technical Committee and Board of Directors	Provide yearly accountability for program. Report on accomplishments and explain goals and projects for next fiscal year.
Report to the Technical Committee	Biannual	All parties that collect data for the network, other invited experts as needed, Technical Committee, Board of Directors	Provide technical details on results and status of all data collection within program. Evaluate if goals are being met appropriately and if focus of program is consistent with goals. Also evaluate if operations of program are working on concert with other aspects of program.
10-year Program Review	Decadal	All parties that collect data for the network, other invited experts as needed, representatives of Technical Committee, Board of Directors	Provide synthesis of data collected by program, evaluate the utility to park management, evaluate administration/operations of program, make recommendations for improvement of all aspects of program.

mindset of 'business as usual'. This will be particularly important during the next three-five year period as the actual monitoring of vital signs and operation of the program are established.

Our second level of review for the program will take the form of our biannual Report to the Technical Committee. This will be a two-day symposium at which all park staff and cooperators conducting any portion of the program will give a technical presentation on results and the status of the work they are conducting. The second day of the meeting is for the Technical Committee only to discuss the presentations of the previous day further and to evaluate the merit of the work scientifically and operationally. The results and decisions from this review will be codified by subsequent presentation to the Board of Directors for their endorsement. This format is based on a review process used by some National Science Foundation Long-term Ecological Research sites (M. MacCluskie, pers. obs.) and is effective in keeping a program appropriately focused. The first Report to the Technical Committee was held in April 2004, and the next one will be held in spring 2006 after the first full field season of program implementation.

Finally, our third level of review will be in the form of a 10-year program review. This will be an expanded version of the Report to the Technical Committee review and will focus on presentation and discussion of what we have learned from the data collected and its relevance to park management. The presentation of data and syntheses would be the first two days of the meeting, with a subsequent two days for discussion and evaluation by the Technical Committee. At this juncture, decisions to phase out a

data stream or to adjust the focus of the program may be recommended to the Board of Directors. Evaluation of the administration and operations of the program would also be undertaken during this review. It may be most efficacious to use a separate work group to evaluate this aspect of the program. This work group could be composed of higher administrative personnel who would evaluate the program based on the goals and objectives of the program as determined by the Technical Committee and endorsed by the Board of Directors.

Chapter 9
Schedule

This chapter describes the plan for implementing the CAKN Vital Signs Monitoring program. For the protocols under development in the next three to five years (n = 26), we describe the key tasks or issues that must be addressed for each (Table 9-1). The CAKN plans to initiate monitoring of ten vital signs in 2006; an annual schedule of the frequency and timing of sampling for these ten vital signs is shown in Table 9-2. We also show the schedule for development and implementation of each vital sign through 2008 (Table 9-3).

In Table 9-1 we describe key issues that must be addressed in establishing protocols for each for the 26 vital signs. For some vital signs this may simply entail some coordination with an entity already collecting data we want (e.g., fire occurrence and extent). For others this will require a more detailed scoping of the vital sign, pilot data collection efforts, and/or determining analysis methods for the data (e.g., ptarmigan). In assigning a target year for protocol completion we have attempted to account for such differences to project the most feasible completion date possible.

For the ten vital signs we plan to begin monitoring in FY 2006, Table 9-2 depicts the frequency and timing of sampling. While some data will be collected continuously (e.g., climate data), other data will be collected for several days at one time of year (e.g., moose surveys). It can also be seen from this table that our field efforts are not entirely weighted to one season but are distributed throughout the calendar year.

Similar to the phased process each network takes to develop a monitoring plan, the CAKN is taking a phased approach to the implementation of vital signs monitoring. Table 9-3 illustrates our plan for doing so. For example, data collection for vegetation structure and composition in 2006 will be conducted in Denali and Yukon-Charley. In this instance, the Denali work will be ready for full implementation, while 2006 will be the initial year of data collection for Yukon-Charley. In 2007 data collection for Wrangell will be phased in also. By taking this approach we will be able to use previous experience from other parks to help us anticipate problem areas for the new parks.

As we progress through FY 2006 the network will be continually evaluating how implementation of the vital signs program is going. This evaluation will take place on a vital sign by vital sign basis, but

we will also evaluate how implementation as a whole is going and use that evaluation to help us adjust the 2007 plans as necessary.

Table 9-1. Additional tasks to be accomplished on protocols before monitoring will be implemented.

Target Year for Protocol Completion	Vital Sign	Key Issues to be Addressed Before Monitoring will be Implemented
2006	Bald eagles	Techniques for monitoring bald eagles are well established. Work focuses on database development and writing the protocol to NPS specification. Review of the protocol is also included.
	Caribou	Techniques for monitoring caribou in AK are well established. Work focuses on database development and writing the protocol to NPS specifications; review of the protocol is planned.
	Dall sheep	Techniques for monitoring sheep in AK parks are well established. Work focuses on database development and writing the protocol to NPS specifications. Review of the protocol will also take place.
	Human populations	Need to purchase pre-1990 U.S. census data. Will establish contract to determine procedures for data analysis and most effective means to communicate results. The full protocol must be written and reviewed.
2007	Disturbance: fire occurrence and extent	Need to work with AK Region Fire Ecologist to determine specifics needed to obtain data collected by FirePro or to harvest existing FirePro databases. Determinations of which tabular and spatial data the network wants will be made. The full protocol must be written and reviewed.
	Landcover	CAKN will assess the outcome of a FY2005 contract to examine existing remotely sensed imagery of CAKN parks and its utility for generating meaningful landcover classifications. We will then determine the platform to be used and can begin writing the protocol and have it reviewed.
	Sound	A scoping workshop is being held in Nov. 2004. Results from this will identify where monitoring will take place and the approach adopted by the CAKN. Data analysis applicable to the network program must be determined. The full protocol will be written and reviewed.
	Permafrost	During 2005 final reports analyzing available monitoring methods for permafrost will be received. Determination of which technique to use will be made. Locations or aerial extent of monitoring must be made. In 2006 the full protocol will be generated and reviewed to allow monitoring to begin in 2007.
	Brown bears	Techniques for monitoring brown bears in AK are well established. CAKN must determine the appropriate frequency of sampling for this monitoring. The full protocol must be written and reviewed.

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Table 9-1.(continued)

Target Year for Protocol Completion	Vital Sign	Key Issues to be Addressed Before Monitoring will be Implemented
2008	Disturbance: volcanoes and tectonics	Establishing this protocol will include acquiring data already collected by the USGS and determining the data analyses most applicable to the network. The full protocol needs to be written and reviewed.
	Disturbance: stream flood frequency and discharge	Full scoping of this vital sign will take place in 2005. Methodology of measurements must be determined. The sampling design and data analysis methods must be specified. The full protocol needs to be written and reviewed.
	Disturbance: river/stream flow	Ties to above vital sign through methodology. The sampling design and data analysis methods must be specified. The full protocol must be generated and reviewed.
	Disturbance: exotic species	Implementing this monitoring includes working with the Exotic Plant Management Team from the AK Region Support Office as they develop a monitoring program for exotic plants in the parks to ensure compatibility of objectives, data collection and analyses. A full protocol need to be written and reviewed.
	Freshwater fish	Focused scoping of this vital sign will take place in FY 2005. We plan on two years of development for this protocol that includes pilot data collection. Sampling design and extent of sampling through the network must be determined. The full protocol must be written and reviewed.
	Snowshoe hare	Establishing this protocol includes determining methodology to estimate hare abundance on grid-based sampling. A two-year pilot study is planned to determine the most appropriate estimation methods, including timing and analysis. The full protocol must be written and reviewed.
	Consumptive uses of National Park natural resources	We will begin development on this protocol in 2006, including establishing cooperation with the Alaska Department of Fish and Game to gain real-time access to harvest data collected by that agency. The full protocol must be written and reviewed.
	Human presence/use	Major issues include developing mechanisms to collect relevant data from backcountry rangers and to integrate these data with other data from the monitoring program. The full protocol must be written and reviewed.
	Trails	Major issues include incorporating this data collection with that conducted on park-wide sample grids and determining appropriate metrics and methods for data analysis. The full protocol must be written and reviewed.
2009	Subarctic steppe	This protocol will require a year of pilot work to determine how to sample this plant community in the least invasive manner. A database will be developed, and analysis methods will be determined. The full protocol must be written and reviewed.
2010	Forage quantity/ quality	Further scoping of the metric of interest and how to apply it network-wide will take place. A database will be developed, and analysis methods will be determined. The full protocol must be written and reviewed.
	Plant phenology	Further scoping of reliable measurement of this vital sign will take place. The full protocol must be written and reviewed.
	Ptarmigan	This vital sign will require a two-year pilot study to determine the best method to estimate ptarmigan abundance. A database will be developed, and analysis methods will be determined. The full protocol must be written and reviewed.

Table 9-2. Annual frequency and timing of sampling for the ten vital signs the CAKN plans to begin monitoring in FY 2006.

Vital Sign to be Sampled	Sample Type/ Interval	January	February	March	April	May	June	July	August	September	October	November	December
Air quality	Weekly	-	-	-	-	-	-	-	-	-	-	-	-
Climate	Continuously each month						Site maintenance						
Snow pack	Snow courses	*	*	*	*								
	Aerial surveys	*	*	*	*						*	*	*
	Snowtel - continuously						Site maintenance						
Vegetation structure/ composition							T						
Passerines						T							
Water quality/ quantity	Remote sensed sampling												
	Chemistry Vegetation Macroinverts						T						
Moose	Timing dependent on snow fall											**	
Wolves		**	**	**	**	**	**	**	**	**	**	**	**
Golden eagles					**			T					
Peregrines								T					

Legend:
* = single event in month (one day)
** = two to three day sampling event
- = weekly through month
T = training for observers

Table 9-3. Implementation schedule by park for vital signs in the CAKN from 2006–2008 (= develop protocol; X = conduct monitoring).*

Vital Sign	Park	2006	2007	2008
Air quality	DENA	X	X	X
	WRST	X	X	X
	YUCH	X	X	X
Climate	DENA	X	X	X
	WRST	X	X	X
	YUCH	X	X	X
Snowpack	DENA	X	X	X
	WRST	X	X	X
	YUCH	X	X	X
Glaciers	DENA	X	X	X
	WRST			
	YUCH			
Disturbance—volcanoes and tectonics	DENA		*	*
	WRST		*	*
	YUCH		*	*
Permafrost	DENA	*	X	X
	WRST	*	X	X
	YUCH	*	X	X
Disturbance—stream flood freq/discharge	DENA	*	*	*
	WRST	*	*	*
	YUCH	*	*	*
Water quality	DENA	X	X	X
	WRST	X	X	X
	YUCH	X	X	X
Macroinvertebrates	DENA	X	X	X
	WRST	X	X	X
	YUCH	X	X	X
Disturbance—exotic species	DENA		*	*
	WRST		*	*
	YUCH		*	*
Insect damage	DENA	X	X	X
	WRST	X	X	X
	YUCH	X	X	X
Freshwater fish	DENA	*	*	*
	WRST	*	*	*
	YUCH	*	*	*
Bald eagles	DENA			
	WRST	*	X	X
	YUCH			
Golden eagles	DENA	X	X	X
	WRST			
	YUCH			

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Table 9-3. (continued)

Vital Sign	Park	2006	2007	2008
Peregrine falcons	DENA			
	WRST			
	YUCH	X	X	X
Ptarmigan distribution/abundance	DENA		*	*
	WRST		*	*
	YUCH		*	*
Arctic ground squirrel	DENA		*	*
	WRST		*	*
	YUCH		*	*
Snowshoe hare	DENA	*	*	*
	WRST	*	*	*
	YUCH	*	*	*
Small mammals	DENA	*	X	X
	WRST			
	YUCH			
Caribou	DENA	*	X	X
	WRST	*	X	X
	YUCH			
Moose	DENA	X		
	WRST		X	
	YUCH			X
Sheep	DENA			
	WRST	*	X	X
	YUCH			
Wolves	DENA	X	X	X
	WRST			
	YUCH	X	X	X
Brown bears	DENA	*		X
	WRST	*		
	YUCH	*	X	
Vegetation structure/composition	DENA	X	X	X
	WRST		X	X
	YUCH	X	X	X
Subarctic steppe	DENA			
	WRST			
	YUCH		*	X
Human populations	DENA	*	X	X
	WRST	*	X	X
	YUCH	*	X	X
Consumptive uses of National Park natural resources	DENA	*	X	X
	WRST	*	X	X
	YUCH	*	X	X

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Table 9-3.(continued)

Vital Sign	Park	2006	2007	2008
Human presence/use	DENA	*	*	*
	WRST	*	*	*
	YUCH	*	*	*
Trails	DENA	*	*	*
Collected via other field efforts	WRST	*	*	*
	YUCH	*	*	*
Disturbance—fire occurrence/extent	DENA	*	*	X
	WRST	*	*	X
	YUCH	*	*	X
Landcover	DENA	*	*	X
	WRST	*	*	X
	YUCH	*	*	X
Sound	DENA	*	*	X
	WRST	*	*	X
	YUCH	*	*	X
Forage quantity/quality	DENA	*	*	*
	WRST	*	*	*
	YUCH	*	*	*
Plant phenology	DENA	*	*	*
	WRST	*	*	*
	YUCH	*	*	*

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Glossary of Terms Used by the NPS Inventory and Monitoring Program

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.

Attributes are any living or nonliving feature or process of the environment that can be measured or estimated and that provide insights into the state of the ecosystem. The term **Indicator** is reserved for a subset of attributes that is particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon 2002). See Indicator.

Biodiversity is short for "biological diversity" and is typically used to refer to the variety of life forms found on earth. Biodiversity may be used to describe the number of taxa found in a specific geographic area by levels of the taxonomic hierarchy (e.g., # of phyla represented, # of bird species, # of chironomid genera, etc.) Various metrics have been developed to describe biodiversity including species richness, Shannon-Wiener diversity index, etc.

Conceptual Models are purposeful representations of reality that provide a mental picture of how something works to communicate that explanation to others (Starfield et al. 1994).

Data, as defined by the CAKN Data Management Plan, include other products generated alongside the tabular and spatial data that are the primary targets for the data management efforts. These include raw data, derived data, documentation, reports and administrative records (see Chapter 6).

Data Analysis, as defined for this program, are the processes by which observations of the environment are turned into meaningful information. These include all evaluations after data are collected and entered into an electronic file. Data analysis includes quality control checks that occur during summarization and exploratory data analysis and extends through to analytical procedures leading to conclusions and interpretations of the data (see Chapter 7).

Data Management, as defined in the CAKN Data Management Plan, refers to the development of a modern information management infrastructure and procedures to ensure that relevant natural resource data collected by NPS staff, cooperators, researchers, and others, are entered, quality-checked, analyzed, reported, archived, documented, cataloged, and made available to others for management decisionmaking, research and education (see Chapter 6).

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.

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).

Ecosystem drivers are major external driving forces such as climate, fire cycles, biological invasions, hydrologic cycles, and natural disturbance events (e.g., earthquakes, droughts, floods) that have large scale influences on natural systems.

Ecosystem management is the process of land-use decision making and land-management practice that takes into account the full suite of organisms and processes that characterize and comprise the ecosystem. It is based on the best understanding currently available as to how the ecosystem works. Ecosystem management includes a primary goal to sustain ecosystem structure and function, a recognition that ecosystems are spatially and temporally dynamic, and acceptance of the dictum that ecosystem function depends on ecosystem structure and diversity. The whole-system focus of ecosystem management implies coordinated land-use decisions.

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.

Grid-based Sampling, as used in the Central Alaska Network, refers to the use of systematic grids to allocate sampling efforts over space for selected protocols, including vegetation, passerine birds, snow depth and moose.

Index Sites, as used in the Central Alaska Network, refers to how sampling locations for selected protocols, including climate, snowpack, peregrine falcons, and air quality were selected. For these vital signs, probability sampling designs were not possible due to cost, and measurement stations were established using professional judgement.

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 2002). 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.

Lentic refers to ecosystems composed of non-moving freshwaters, e.g., lakes, ponds and wetlands.

List-based Sampling, as used in the Central Alaska Network, refers to how sampling locations for selected protocols were selected by construction of a list of sample units and choosing a random sample of units from the list.

Lotic refers to ecosystems composed of moving freshwaters, e.g., rivers and streams.

Measures are the specific feature(s) used to quantify an indicator, as specified in a sampling protocol.

Membership Design refers to an aspect of drawing probability samples when sample units are assigned to panels. The membership design describes the way in which members of the population become members of a panel (see Chapter 4 and McDonald 2003).

Metadata represent the set of instructions or documentation that describe the content, context, quality, structure, and accessibility of a data set (Michener et al. 1997).

Panel refers to how sample units are grouped to facilitate sampling over time. Sample units in a panel will always be sampled during the same sampling occasion or time period. (see Chapter 4 and McDonald 2003).

Park Lead, as used in the Central Alaska Network, refers to staff members from a specific park who ensure that park-level interests are considered in the execution of monitoring for a vital sign (see Chapter 8).

Principal Investigator, as used in the Central Alaska Network, refers to the individual designated to take overall responsibility within the network context for the design, conduct and reporting on a vital sign. He or she works with the Network Coordinator and Technical Committee to determine long-range directions for data collections. They oversee collation and summarization of the data.

Protocols, as defined for this program, are detailed study plans that provide rationale for monitoring a Vital Sign, and provide instructions for carrying out the monitoring. Protocols consist of a narrative, standard operating procedures, and supplementary materials (Oakley et al. 2003).

Revisit Design refers to how visits to all panels in a sampling design will be scheduled over time (see Chapter 4 and McDonald 2003).

Sample Units are the smallest entities upon which measurements are taken (see Chapter 4 and McDonald 2003).

Standard Operating Procedures are detailed instructions for carrying out monitoring operations and form one part of Monitoring Protocol (Oakley et al. 2003).

Status, as used in this program, refers to the condition of a resource or vital sign at a given point in time.

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.

Trend, as used in this program, refers generally to directional change measured in resources by monitoring their condition over time. Trends can be measured by examining individual change (change experienced by individual sample units) or by examining net change (change in mean response of all sample units) (see McDonald 2003).

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).

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Appendix A

Summary of Legislation, National Park Service Policy, and Guidance Relevant to Development and Implementation of Natural Resources Monitoring in National Parks

Taken from NPS Inventory and Monitoring website: http://science.nature.nps.gov/im/monitor/LawsPolicy.htm

Public Laws	Significance to Inventory and Monitoring
National Park Service Organic Act (16 USC 1 et seq. [1988], Aug. 25, 1916).	The 1916 National Park Service Organic Act is the core of park service authority and the definitive statement of the purposes of the parks and of the National Park Service mission. The act establishes the purpose of national parks: "....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."
General Authorities Act of 1970 (16 USC 1a-1–1a-8 (1988), 84 Stat. 825, Pub. L. 91-383	The General Authorities Act amends the Organic Act to unite individual parks into the "National Park System". The act states that areas of the National Park System, "though distinct in character, are united through their inter-related purposes and resources into one national park system as cumulative expressions of a single national heritage; that individually and collectively, these areas derive increased national dignity and recognition of their superb environmental quality through their inclusion jointly with each other in one national park system preserved and managed for the benefit and inspiration of all the people of the United States...."
Redwood National Park Act (16 USC 79a-79q (1988), 82 Stat. 931, Pub. L. 90-545	This act includes both park-specific and system-wide provisions. This act reasserts system-wide protection standards for the National Park System. This act qualifies the provision that park protection and management "shall not be exercised in derogation of the values and purposes for which these areas have been established" by adding "except as may have been or shall be directed and specifically provided for by Congress." Thus, specific provisions in a park's enabling legislation allow park managers to permit activities such as hunting and grazing.
National Environmental Policy Act of 1969 (42 USC 4321-4370)	The purposes of NEPA include encouraging "harmony between [humans] and their environment and promote efforts which will prevent or eliminate damage to the environment... and stimulate the health and welfare of [humanity]." NEPA requires a systematic analysis of major federal actions that includes a consideration of all reasonable alternatives as well as an analysis of short-term and long-term, irretrievable, irreversible, and unavoidable impacts. Within NEPA the environment includes natural, historical, cultural, and human dimensions. Within the NPS emphasis is on minimizing negative impacts and preventing "impairment" of park resources as described and interpreted in the NPS Organic Act. The results of

Public Laws	Significance to Inventory and Monitoring
	evaluations conducted under NEPA are presented to the public, federal agencies, and public officials in document format (e.g. EAs and EISs) for consideration prior to taking official action or making official decisions.
Clean Water Act (33 USC 1251-1376)	The Clean Water Act, passed in 1972 as amendments to the Federal Water Pollution Control Act, and significantly amended in 1977 and 1987, was designed to restore and maintain the integrity of the nation's water. It furthers the objectives of restoring and maintaining the chemical, physical and biological integrity of the nation's waters and of eliminating the discharge of pollutants into navigable waters by 1985. Establishes effluent limitation for new and existing industrial discharge into U.S. waters. Authorizes states to substitute their own water quality management plans developed under S208 of the act for federal controls. Provides an enforcement procedure for water pollution abatement. Requires conformance to permit required under S404 for actions that may result in discharge of dredged or fill material into a tributary to, wetland, or associated water source for a navigable river.
Clean Air Act (42 USC 7401-7671q, as amended in 1990)	Establishes a nationwide program for the prevention and control of air pollution and establishes National Ambient Air Quality Standards. Under the Prevention of Significant Deterioration provisions, the act requires federal officials responsible for the management of Class I Areas (national parks and wilderness areas) to protect the air quality related values of each area and to consult with permitting authorities regarding possible adverse impacts from new or modified emitting facilities. The act establishes specific programs that provide special protection for air resources and air quality related values associated with NPS units. The EPA has been charged with implementing this act.
Endangered Species Act of 1973, as amended (ESA) (16 USC 1531-1544)	The purposes of the ESA include providing "a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved." According to the ESA "all federal departments and agencies shall seek to conserve endangered species and threatened species" and "[e]ach federal agency shall…insure that any action authorized, funded, or carried out by such agency…is not likely to jeopardize the continued existence of any endangered species or threatened species." The U.S. Fish and Wildlife Service (USFWS) (non-marine species) and the National Marine Fisheries Service (NMFS) (marine species, including anadromous fish and marine mammals) administers the ESA. The effects of any agency action that may affect endangered, threatened, or proposed species must be evaluated in consultation with either the USFWS or NMFS, as appropriate.
Environmental Quality Improvement Act of 1970 (42 U.S.C. 56 § 4371)	Directs all federal agencies, whose activities may affect the environment, to implement policies established under existing law to protect the environment.
Coastal Zone Management Act of 1972 (16 U.S.C. 33 § 1452)	"Congress finds and declares that it is the national policy—to preserve, protect, develop, and where possible, to restore or enhance, the resources of the Nation's coastal zone for this and succeeding generations."

Public Laws	Significance to Inventory and Monitoring
Marine Protection, Research, and Sanctuaries Act of 1972 (16 U.S.C. 32 § 1431)	Recognizes that the United States has historically protected "special areas of its public domain, but (that) these efforts have been directed almost exclusively to land areas above the high-water mark." For this reason Congress elected to recognize and protect "certain areas of the marine environment possess[ing] conservation, recreational, ecological, historical, scientific, educational, cultural, archeological, or esthetic qualities which give them special national, and in some cases international, significance." Specifically this law intends to "improve the conservation, understanding, management, and wise and sustainable use of marine resources; [to] enhance public awareness, understanding, and appreciation of the marine environment; and [to]) maintain for future generations the habitat, and ecological services, of the natural assemblage of living resources that inhabit these areas."
National Historic Preservation Act of 1966, as amended (16 USC 470 et seq.)	Congressional policy set forth in NHPA includes preserving "the historical and cultural foundations of the Nation" and preserving irreplaceable examples important to our national heritage to maintain "cultural, educational, aesthetic, inspirational, economic, and energy benefits." NHPA also established the National Register of Historic Places composed of "districts, sites, buildings, structures, and objects significant in American history, architecture, archeology, engineering, and culture." NHPA requires federal agencies take into account the effects of their actions on properties eligible for or included in the National Register of Historic Places and to coordinate such actions with the State Historic Preservation Offices (SHPO).
Wilderness Act of 1964 (16 USC 1131 et seq.)	Establishes the National Wilderness Preservation System. In this act, wilderness is defined by its lack of noticeable human modification or presence; it is a place where the landscape is affected primarily by the forces of nature and where humans are visitors who do not remain. Wilderness Areas are designated by Congress and are composed of existing federal lands that have retained a wilderness character and meet the criteria found in the act. Federal officials are required to manage Wilderness Areas in a manner conducive to retention of their wilderness character and must consider the effect upon wilderness attributes from management activities on adjacent lands.
Forest and Rangeland Renewable Resources Planning Act of 1974 (16 U.S.C. 36 § 1642	Mandates that the Secretary of Agriculture inventory and monitor renewable natural resources in National Forests, and has been cited as congressional authorization for the inventory and monitoring of natural resources on all federal lands. While this is not specifically directed in the act, it is perhaps indicative of a national will to account for and manage the nation's natural heritage in a manner that sustains these resources in perpetuity.
Surface Mining Control and Reclamation Act	The Surface Mining Control and Reclamation Act was enacted in 1977. It establishes a nationwide program to protect the environment from adverse effects of surface coal mining operations, establishes minimum national standards for regulating surface coal mining, assists states in developing and implementing regulatory programs, and promotes reclamation of previously

Public Laws	Significance to Inventory and Monitoring
	mined areas with inadequate reclamation. Underthe Act, the Secretary of the Interior is directed to regulate the conduct of surface coal mining throughout the United States for both federally and non-federally owned rights. The Act establishes the Abandoned Mine Reclamation Fund, which is for the reclamation of land and water affected by coal mining. Eligibility for reclamation under this program requires that the land or water had been mined for coal, or affected by coal mining, and had been inadequately reclaimed prior to the enactment of this act in 1977. Both public and private lands are eligible for funding. Sections 522(e)(1) and 533(e)(3) of the act specifically prohibit surface mining within the National Park Service, National Wildlife Refuge System, National System of Trails, National Wilderness Preservation System, or Wild and Scenic Rivers System. The act also prohibits surface mining that adversely impacts any publicly-owned park or place included in the National Register of Historic Sites. These prohibitions are subject to valid existing rights at the time of the Act, the exact definition of which remains the subject of administrative and legal action. How valid existing rights are ultimately defined will affect the ability of mineral owners to mine in the Recreation Area.
Geothermal Steam Act 1988	This act specifically calls for a monitoring program for certain parks with thermal resources: (1) The Secretary shall maintain a monitoring program for significant thermal features within units of the National Park System. (2) As part of the monitoring program required by paragraph (1), the Secretary shall establish a research program to collect and assess data on the geothermal resources within units of the National Park System with significant thermal features. Such program shall be carried out by the National Park Service in cooperation with the U.S. Geological Survey and shall begin with the collection and assessment of data for significant thermal features near current or proposed geothermal development and shall also include such features near areas of potential geothermal development.
Federal Advisory Committee Act	Creates a formal process for federal agencies to seek advice and assistance from citizens. Any council, panel, conference, task force or similar group used by federal officials to obtain consensus advice or recommendations on issues or policies fall under the purview of FACA.
National Parks Omnibus Management Act, 1998 (P.L. 105-391)	Requires Secretary of Interior to continually improve NPS' ability to provide state-of-the-art management, protection, and interpretation of and research on NPS resources. Secretary shall assure the full and proper utilization of the results of scientific study for park management decisions. In each case where an NPS action may cause a significant adverse effect on a park resource, the administrative record shall reflect the manner in which unit resource studies have been considered. The trend in NPS resource conditions shall be a significant factor in superintendents' annual performance evaluations. Section 5939 states that the purpose of this legislation is to: 1. More effectively achieve the mission of the National Park Service; 2. Enhance management and protection of national park resources by providing clear authority and direction for the conduct of scientific study in the National Park System and to use the information gathered for management purposes;

Public Laws	Significance to Inventory and Monitoring
	3. Ensure appropriate documentation of resource conditions in the National Park System; 4. Encourage others to use the National Park System for study to the benefit of park management as well as broader scientific value, and 5. Encourage the publication and dissemination of information derived from studies in the National Park System.
Government Performance and Results Act (GPRA)	Requires the NPS to set goals (strategic and annual performance plans) and report results (annual performance reports). The NPS Strategic Plan contains four GPRA goal categories: park resources, park visitors, external partnership programs, and organizational effectiveness. In 1997, the NPS published its first GPRA-style strategic plan, focused on measurable outcomes or quantifiable results.
EXECUTIVE ORDERS	
Off-Road Vehicle Use (Executive Orders 11644 and 11989)	Executive Order 11644, enacted February 8, 1972 and amended by Executive Order 11989 on May 24, 1977, regulates off-road vehicle use. If the enabling legislation allows the use of off-road vehicles, NPS is required to designate specific areas for off-road vehicle use. These areas must be "located to minimize damage to soil, watershed, vegetation, or other resources" (Section (3)(a)(1)). If it is determined that such use is adverse to resources, the NPS is to immediately close such areas or trails until the impacts have been corrected.
Floodplain Management (Executive Order 11988)	Executive Order 11988 was enacted May 24, 1977. It requires all federal agencies to "reduce the risk of flood loss,... minimize the impacts of floods on human safety, health and welfare, and ... restore and preserve the natural and beneficial values served by flood plains." To the extent possible, park facilities, such as campgrounds and rest areas, should be located outside floodplain areas. Executive Order 11988 is implemented in the National Park Service through the Floodplain Management Guidelines (National Park Service, 1993b). It is the policy of the National Park Service to 1) restore and preserve natural floodplain values; 2) to the extent possible, avoid environmental impacts to the floodplain by discouraging floodplain development; 3) minimize the risks to life and property when structures and facilities must be located on a floodplain; and 4) encourage nonstructural over structural methods of flood hazard mitigation.
Protection of Wetlands (Executive Order 11990)	Executive Order 11990 was enacted May 24, 1977. It requires all federal agencies to "minimize the destruction, loss, or degradation of wetlands, and preserve and enhance the natural and beneficial values of wetlands". Unless no practical alternative exists, federal agencies must avoid any activities that have the potential to adversely affect wetland ecosystem integrity. NPS guidance pertaining to this Executive Order is stated in Floodplain and Wetland Protection Guidelines (National Park Service, 1980).

Public Laws	Significance to Inventory and Monitoring
Executive Order 13112 on Invasive Species	This executive order was signed into law on February 3, 1999, to prevent the introduction of invasive species and provide for their control and to minimize the economic, ecological, and human health impacts that invasive species cause. Among other things, this Executive Order established the National Invasive Species Council and required the preparation of a National Invasive Species Management Plan to recommend specific, performance-oriented goals and objectives and specific measures of success for federal agency efforts concerning invasive species.
NPS POLICIES AND GUIDANCE	
NPS Management Policies—2001 (NPS Directives System)	This is the basic NPS servicewide policy document. It is the highest of three levels of guidance documents in the NPS Directives System. The Directives System is designed to provide NPS management and staff with clear and continuously updated information on NPS policy and required and/or recommended actions, as well as any other information that will help them manage parks and programs effectively.
NPS Directors Orders	Second level of NPS Directives System. Directors Orders serve a vehicle to clarify or supplement Management Policies to meet the needs of NPS managers. Relevant Directors Orders: DO-2.1 Resource Management Planning DO-12 Environmental Impact Assessment DO-14 Resource Damage Assessment & Restoration DO-24 Museum Collections Management DO-41 Wilderness Preservation & Management DO-47 Sound Preservation & Noise Management DO-77 Natural Resource Protection
NPS Handbooks and Reference Manuals	This is the third tier in the NPS Directives System. These documents are issued by Associate Directors. These documents provide NPS field employees with a compilation of legal references, operating policies, standards, procedures, general information, recommendations and examples to assist them in carrying out Management Policies and Directors Orders. Level 3 documents may not impose any new servicewide requirements, unless the Director has specifically authorized them to do so. Relevant Handbooks and Reference Manuals: NPS-75 Natural Resources Inventory & Monitoring NPS-77 Natural Resources Management Guidelines NPS Guide to Federal Advisory Committee Act Website: Monitoring Natural Resources in our National Parks, http://science.nature.nps.gov/im/monitor

Appendix B
Definition of Natural Resource Inventories, Monitoring, and Research

Natural resource inventories, monitoring, and research are closely related activities needed for effective science-based management of park resources, and the terms are sometimes confused.

A natural resource 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. Inventories contribute to a statement of park resources, which is best described in relation to a standard condition such as the natural or unimpaired state. Inventories may involve both the compilation of existing information and the acquisition of new information. They may be relative to either a particular point in space (synoptic) or time (temporal).

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". Natural resource monitoring is conducted primarily for two purposes: (1) to detect significant changes in resource abundance, condition, population structure, or ecological processes; or (2) to evaluate the effects of some management action on population or community dynamics or ecological processes. 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. Cause and effect relationships usually cannot be demonstrated with monitoring data, but monitoring data might suggest a cause and effect relationship that can then be investigated with a research study. The key points in the definition of monitoring are that: (1) the same methods are used to take measurements over time; (2) monitoring is done for a specific purpose, usually to determine progress towards a management objective; and (3) some action will be taken based on the results, even if the action is to maintain the current management.

Research is generally defined as the systematic collection of data that produces new knowledge or relationships and usually involves an experimental approach, in which a hypothesis concerning the probable cause of an observation is tested in situations with and without the specified cause. Research has the objective of understanding ecological processes and in some cases determining the cause of changes observed by monitoring, which is needed for determining the appropriate management response to threats. In general, monitoring is the tool used to identify whether or not a change occurred and research is the tool to determine what caused the change. While it is often hoped that ecological monitoring can help to explain complex relationships in ecological systems, such understanding often requires a more focused research investment. The design of sampling protocols for various types of park resources at different locations and spatial scales requires a research effort and is incorporated into the NPS approach for planning and designing long-term monitoring of park resources.

Appendix C
Framework for National Park Service Inventory and Monitoring

The NPS strategy to institutionalize inventory and monitoring throughout the agency consists of a framework having three major components: (1) completion of 12 basic resource inventories upon which monitoring efforts can be based; (2) a network of 11 experimental or "prototype" long-term ecological monitoring (LTEM) programs begun in 1992 to evaluate alternative monitoring designs and strategies; and (3) implementation of operational monitoring of critical parameters (i.e. "vital signs") in approximately 270 parks with significant natural resources that have been grouped into 32 vital sign networks linked by geography and shared natural resource characteristics.

Natural Resource Core Inventories

All natural resource parks must possess at least a minimal complement of resource inventory information in order to be able to deal effectively with park planning, management, and protection of natural resources. The minimal inventory information required by all parks has been defined in terms of 12 data sets that include a variety of biotic and abiotic ecosystem components. The 12 data sets are as follows:

- Natural resource bibliography
- Base cartographic data
- Geology map
- Soils map
- Weather data
- Air quality
- Location of air quality monitoring stations
- Water body location and classification
- Water quality data
- Vegetation map
- Documented species list of vertebrates and vascular plants
- Species distribution and status of vertebrates and vascular plants

Prototype Monitoring Programs

The prototype LTEM programs were established in the early 1990s primarily in an attempt to learn how to design scientifically credible and cost-effective monitoring programs in ecological settings of major importance to a number of NPS units. Much of the design, development, and testing of monitoring protocols is conducted in prototype parks in cooperation with scientists from the U.S. Geological Survey. Because of higher funding and staffing levels, as well as USGS involvement and funding in

program design and protocol development, the prototypes are expected to serve as "centers of excellence" that will be able to do more extensive and in-depth monitoring and continue research and development work to benefit other parks. Prototype LTEM programs possess a wealth of experience and expertise related to the development and implementation of ecological monitoring that can greatly benefit other parks throughout the NPS. The prototype programs provide mentoring assistance to other parks undertaking long-term ecological monitoring and provide technical assistance to staff from other parks on a wide variety of technical issues related to monitoring, including conceptual design, database management, data integration and analysis, and reporting of monitoring findings.

Vital Signs Networks

In FY 2000, as part of the Natural Resource Challenge, the NPS implemented a new strategy for natural resource monitoring in parks with significant natural resources, whereby 270 parks with significant natural resources (including all of the prototype parks) were organized into 32 networks linked by geography and shared natural resource characteristics (see map). The network approach will facilitate collaboration, information sharing, and economies of scale in natural resource monitoring and will provide parks with a minimum infrastructure for initiating natural resource monitoring that can be built upon in the future. As part of a new framework for inventory and monitoring, prototype LTEM programs are nested within a network structure and provide expertise and support to other parks in their network as well as providing protocols and expertise to parks throughout the NPS. The level of funding available through the Natural Resource Challenge will not allow comprehensive monitoring in all parks but will provide a minimum infrastructure for initiating natural resource monitoring in all parks that can be built upon in the future.

Parks in each of the 32 networks share funding and staffing provided by the Servicewide Inventory and Monitoring Program and other divisions of the Natural Resources Program Center and provide additional funding and staffing from other sources (e.g., base-funded positions, partnerships). Each of the 32 park networks is guided by a Board of Directors (usually comprised of park superintendents and the regional and network coordinators) who specify desired outcomes, evaluate performance for the monitoring program, and promote accountability. The working relationships and descriptions of the procedures the board uses to make decisions is codified in the form of a network charter signed by each of the park superintendents. An example of how the parks in each network might work together is contained in the following vision statement for the North Coast and Cascades Network:

- In response to the Natural Resources Challenge, the seven National Park Service units in the North Coast and Cascades Network work collaboratively to design and implement a Network Monitoring Program to focus collective efforts on inventory, monitoring, and research on natural ecosystems. This will result in a comprehensive body of knowledge that provides timely and relevant, scientifically credible information to Park managers and the public.

- Through these efforts we will be better able to understand, and explain to others, the status and trends in key components and indicators of Park ecosystems, and how they have and will respond over time to natural and human induced changes both from within and outside of Park boundaries.

- This comprehensive, integrated long-term ecological monitoring program provides for better protection, restoration, and maintenance of the natural ecosystems under NPS management.

- The Network Monitoring Program collaborates with complementary monitoring efforts of all levels of government, in order to achieve the greatest level of protection to natural resources and to contribute a body of knowledge to address broader, regional natural resource issues.

Appendix D

Current Status of Waterbodies in Central Alaska Network Parks Listed Under Section 303d of the Clean Water Act

Currently, three streams within Central Alaska Network parks are listed under Section 303d of the Clean Water Act. The state of Alaska lists the impaired streams in four tiers. The definitions for all tiers appear after the creek descriptions. All are included because of effects of mining. Cabin Creek, located in Wrangell-St. Elias, is a Tier 2 stream, listed for acid drainage from the Nabesna Mine, a manganese mine and patented claim. Caribou Creek, in Denali, is a Tier 1 stream, listed for turbidity from past gold mining activity. Slate Creek, also in Denali, is a Tier 2 stream, listed for turbidity from past antimony mining activity. Below, we provide information on the current status of these creeks relative to reclamation activities intended to bring the water quality into compliance with water quality standards. However, national GPRA goals do not require that we report on water bodies on Tier 1.

Cabin Creek

Alaska Department of Environmental Conservation and NPS staff visited the mine site in June 1997 to discuss specifics of a recovery plan with the owner of the Nabesna Mine property. Acidic tailings below the mine site (located on NPS managed lands) may be a contributing factor in compromising the water quality of Cabin Creek. Recovery plan objectives include increasing the low pH of the acidic tailings, revegetating the tailings with indigenous species, and reconstruction of the existing drainage ditches around the tailings to divert stormwater run-off away from Cabin Creek. Final implementation and subsequent waterbody recovery analysis has not yet occurred, and Cabin Creek remains on the Tier II Section 303(d) list.

Caribou Creek

Alaska Department of Environmental Conservation staff conducted a helicopter tour of the watershed in June 1997 with the NPS to ascertain the degree of past mining activity in and adjacent to the waterbody. Miles of the waterbody have been extensively placer mined. The waterbody has lost its sinuosity along segments of the upper half of the watershed. The NPS priority for the watershed is to continue the process to obtain title to private mining claims. Since the mining claim acquisition process may take at least three to five more years, development of a waterbody recovery plan is unlikely to begin until the acquisition

process is near completion. Thus, Caribou Creek will remain on the Tier I Section 303(d) list for the next several years.

Slate Creek

Alaska Department of Environmental Conservation and NPS staff inspected the antimony mine area (at the creek headwaters) in June 1997 to discuss specifics of the waterbody recovery plan. Recovery plan implementation began in August 1997. The recovery plan includes restoration objectives for four acres of disturbed upland and stream channel areas in the vicinity of the old antimony mine site. Restoration objectives include placement of fill over the exposed antimony ore body, reconfiguration of the stream channel, increasing the pH of acidic soils, and revegetation of disturbed soils with willow and alder seedlings. Full implementation of the recovery plan will address any water quality issues of the waterbody. Full recovery of the waterbody was expected by April 2000 but has not yet been achieved. Review of the recovery plan is needed prior to moving this water to Tier III. Under Tier III, water quality of the recovered stream will be monitored until the stream is no longer affected by water quality degradation.

Alaska State Definitions of Tiers 1–4

Tier 1 Waters that require assessments, verification of pollution and controls in place, or needed.

Tier 2 Waters which have had completed assessments and now required a water body recovery plan of a Total Maximum Discharge Load (TMDL) calculation.

Tier 3 Water which will be monitored for recovery status.

Tier 4 Waters that are not water quality limited that require no further action.

Appendix E

Objectives Presented in the Subject-area Strategies Prepared for the CAKN Scoping Workshop in April 2002

Objective	Physical Environment	Flora	Aquatic	Fauna
1	Monitor and record weather conditions at representative locations in order to identify long and short-term trends, provide reliable climate data to other researchers, and to participate in larger scale climate monitoring and modeling efforts.	Monitor change structure of vegetation cover at landscape level for network.	Determine diversity of ponds/streams across network characterizing physical, chemical, and biological condition.	To identify patterns in the distribution and relative abundance of organisms
2	Monitor snowpack and ice on/off trends.	Monitor changes in the taxonomic composition (and species-area relations) within the vegetation cover of the network at a landscape scale.	Detect change in community structure and indices of productivity in ponds and headwater streams.	To predict species distribution based on a suite of ecological or environmental variables;
3	Monitor permafrost trends at representative sites.	Monitor the density and basal area of selected plant species at a landscape scale.	Map watersheds within each park.	To predict changes in faunal components in relation to changes in vegetation and physical components.
4	Monitor glacier trends and conditions.	Monitor changes in the amount, distribution, and character of fuels across the landscape of the network.	Monitor landscape level changes in water types across network.	To provide direction for future research to investigate observed faunal community patterns.
5	Gauge the flow of a representative drainage system in each region.	Monitor changes in the degree, extent, and distribution of selected forest insect damage at the landscape scale for network.		
6	Support air quality monitoring efforts of the Air Resources Division – Alaska Region.	Monitor changes in the distribution and abundance of lichen species in network parks at a landscape scale.		
7	Locate and design monitoring plans to effectively complement ecological monitoring efforts of the other three spheres within the Central Alaska Network monitoring program and other, larger-scale monitoring programs.	Monitor changes in the evidence of human use of the landscape of our network parks, and related impacts to vegetation resources of these parks at a landscape scale.		
8	Relate and present the composite suite of physical climatic change data, including winter snowpack trends, permafrost, glacier mass balance, ice on/off temporal trends, and meteorology data, so that it can be conveniently analyzed with other ecological monitoring data to make inferences on cause and effect relationships within the various ecosystems, such as population dynamics and vegetation changes.	Monitor distribution of thermokarst processes at a landscape scale and monitor the depth of the active layer in sample sites across network parks.		

Objective	Physical Environment	Flora	Aquatic	Fauna
9		Monitor the annual area burned by fire in network parks at a landscape scale.		
10		Monitor the percentage of the landscape in the following condition classes: ice/snow, standing water, streams (flowing water), barren terrestrial, vegetated terrestrial		
11		Monitor changes in the "appearance" of the vegetation and of the landscape through time.		

Appendix F
Overview of CAKN Program Development March 2001–October 2004

The Washington Support Office (WASO) has provided guidance to networks in how they should approach development of their monitoring programs. WASO's recommended approach involves seven steps:

1. Form a network Board of Directors and a Science Advisory committee.
2. Summarize existing data and understanding.
3. Prepare for and hold a Scoping Workshop.
4. Write a report on the workshop and have it widely reviewed.
5. Hold meetings to decide on priorities and implementation approaches.
6. Draft the monitoring strategy.
7. Have the monitoring strategy reviewed and approved.

The CAKN, as an entity, began in 2000, when funds for planning and carrying out biological inventories were received. No coordinating staff were hired for the inventories, and initial planning efforts and actions related to starting the monitoring program were taken by existing staff of CAKN parks, with significant involvement of the Regional I&M Coordinator and Regional Science Advisor. The main activities in late 2000 and early 2001 were drafting of a network charter to form the Board of Directors, drafting of a position description and beginning the hiring process for a Network Coordinator, and naming of a Technical Committee. Appendix E details the structure and personnel of the CAKN.

With the hiring of the Network Coordinator in June 2001, the Central Alaska Network began formal development of its monitoring program and has followed the WASO guidelines since its inception. The primary developments are outlined in Table 2, and a narrative summarizing this development follows.

Table F-1. Development milestones of the Central Alaska Network Monitoring program.

Date	Milestone
2001	
March	Board of Directors established.
June	Network Coordinator begins.
July	Technical Committee appointed and approved.
August	Begin preparations for Scoping Workshop.
September	Yukon-Charley and Wrangell park-level workshops held.
October	Park priorities assimilated by Technical Committee. Work Groups established
November	Work Groups established. Intensive work begins to prepare for Scoping Workshop.
2002	
April	Scoping Workshop held in Fairbanks.
May	Network Database Manager begins.
June	Integration between CAKN and Denali Long-term Ecological Monitoring program formalized.
July	Intensive work begins to prepare Phase I Report.
September	Phase I Report completed.
October	Annual Work Plan for 2003 determined. Interdisciplinary Team begins to develop conceptual framework for program.
December	Study plans for projects to piloted in 2003 written.
2003	
February	Conceptual framework for network developed.
March	Progress report on conceptual framework written and circulated to Technical Committee.
July	Prioritization process of vital signs initiated. Drafting of the Phase II report begins.
August	Prioritization process finalized. Phase II report draft completed.
November	Phase II report completed.
December	Phase II report submitted to WASO.
2004	
January	"Short list" of vital signs determined. Annual work plan finalized.
April	First bi-annual Report to the Technical Committee held.
May	Network and park staff begin writing Protocol Development Summaries.
August	Protocol Development Summaries completed and posted on network website.
September	FY06-08 operational/implementation plan developed. FY05 work plan drafted.
October	Phase III report drafted.
November	CAKN Board of Directors approves Phase III report and endorses 3-year implementation plan
December	Phase III report submitted to WASO.
2005	
September	Vital Signs Monitoring Plan submitted and approved by National Monitoring Coordinator.

June 2001. Network Coordinator begins position.

August–October 2001. In August 2001, the Technical Committee held its first meeting during which the process for decision-making was determined. Also at that meeting a timeline was developed that would allow the network to be prepared for the Scoping Workshop in April 2002. Based on that timeline, we held park-based meetings to discuss the monitoring program with park staff and to determine their priorities for the program during September and October of 2001. We did not hold a meeting at Denali because a monitoring program has been in place there since 1992.

In October 2001, the Technical Committee reconvened to discuss and assimilate the results of the park-based meetings. Based on the discussion at this meeting, we established four Work Groups (Aquatics, Physical Components of the Ecosystem, Flora, and Terrestrial Fauna), with each person on the Technical Committee taking part in one group. Additional Park staff, or external experts were recruited to take part in Work Groups where necessary.

November 2001–March 2002. After the Work Groups were established, each group began meeting individually to establish a strategy for approaching the monitoring program for that ecosystem component. These strategies were intended to be starting points for discussion during the Scoping Workshop and to facilitate fitting the components of the ecosystem monitoring program together. Additionally, the Technical Committee met three times in person and twice by conference call to be updated on Work Group level progress and the plan for the Scoping Workshop. A notebook with background information about the network and summarizing the Technical Committee's approach to the program was prepared.

April 2002. The Scoping Workshop was held, and invited guests provided helpful input on the goals and direction of the program. During this meeting an overall framework to the monitoring program was developed that couches work in the context of "extensive" and "intensive" objectives. Additionally, the Technical Committee and invited experts agreed on the importance of a common sample design for the program. During this workshop it was also recognized that the CAKN planning process was very similar to re-prioritization of the Denali LTEM program and that a true integration between the programs would confer many advantages to both programs as well as economy of effort.

May–July 2002. Specifics of the integration between CAKN and the Denali LTEM program were outlined and agreed upon by

the Board of Directors. A formal document regarding the integration was prepared and submitted to WASO for approval. Writing of the Phase I Report was initiated.

August–October 2002. The Phase I Report was written and submitted for review. A new work group (the Interdisciplinary Team) was initiated for the purpose of developing an encompassing framework to the CAKN monitoring program. The team was tasked with generating several possible frameworks for presentation to the Technical Committee. The Annual Administrative Report and Work Plan was written, approved by the Board of Directors, and submitted to WASO.

November 2002–January 2003. The Interdisciplinary Team presented initial thinking on a conceptual framework to the Technical Committee. The key development at the time was a model that potentially allowed a means to cut across the terrestrial-aquatic interface in considering ecosystems. Based on the subject area strategies developed for the Scoping Workshop, the Technical Committee identified pilot work to conduct during the 2003 field season. Principal Investigators were identified for each project, and study plans for each project were submitted. An annual work plan for the Denali LTEM program was drafted and approved by the Board of Directors.

February–April 2003. Study plans for pilot field season work were reviewed by the Technical Committee, and Principal Investigators made revisions as necessary. The Interdisciplinary Team finalized the conceptual framework for the program and prepared a progress report summarizing the work to date.

May–July 2003. Field work for pilot projects was conducted. The Network Coordinator met with park staff to discuss the conceptual framework and the meshing of proposed vital signs. Work was also initiated on the Phase II report.

August–September 2003. The Technical Committee discussed the list of vital signs and put them into initial prioritized order. The Denali Prototype program was fully integrated into the CAKN program with the submission of a joint Annual Administrative Report and Work Plan.

October–December 2003. The conceptual framework to the program with a prioritized list of vital signs was presented to the Board of Directors and approved. The Phase II report was finished and submitted to the Alaska Regional Inventory and Monitoring Coordinator for review. The Annual Administrative Report and Work Plan for 2004 was drafted and submitted to WASO.

January–March 2004. The "short-list" of vital signs was determined and prioritization confirmed with Technical Committee. Preparation for the Biannual Report to the Technical Committee began.

April–July 2004. The Biannual Report to the Technical Committee was held at which all current network projects are reported on and evaluated. Network staff and park staff drafted and finalized the two-page Protocol Development Summaries for each vital sign the network plans to implement in the next three to five years.

August–November 2004. An implementation and staffing plan for the CAKN was developed and presented to the Technical Committee for discussion/review. The FY 2005 Annual Administrative Report and Work Plan was prepared. The CAKN Board of Directors approved both the FY 2005 work plan and the Phase III report.

December 2004–September 2005. The Phase III report was submitted to the National Monitoring Coordinator for review. Revisions were made in spring 2005, and the final draft of the report (the Vital Signs Monitoring Plan) was submitted for approval in September 2005.

Appendix G
Natural Resources of Central Alaska Network Parks

Yukon-Charley Rivers National Preserve

Yukon-Charley encompasses 1 million hectares (2.5 million acres) of subarctic vegetation and complex landforms. Yukon-Charley is in eastern interior Alaska and borders Yukon Territory, Canada (Fig. 1-2). The small bush communities of Eagle, Eagle Village, Circle City, Central, and Circle Hot Springs are the closest communities to the preserve.

The large and historically important Yukon River and nearly undisturbed Charley River offer an intriguing contrast in river ecosystems, and provide human access to this roadless area. The Yukon and its tributaries provide important habitat for both anadromous and resident fish. Annual runs of three Pacific salmon species help define a cycle of life important to cultural traditions thousands of years old. The Yukon River corridor within Yukon-Charley is characterized by south-facing bluffs vegetated by unique plant communities believed to represent steppelands more widespread during the Pleistocene. Historic and present human activity has had little impact on populations of rare endemic plants. In contrast to the turbid and massive Yukon River, the Charley River, which flows into the Yukon, is a clearwater river whose entire watershed is contained within the preserve.

Geologic and paleontologic resources in Yukon-Charley are significant. The exposed sedimentary record is nearly complete back to Precambrian formations. North of the Yukon River lies the most ancient terrane in Alaska, perhaps the original continental margin. Highly fossilized formations reveal important evidence of very early marine and estuarine life forms and the environment in which they lived.

The combination of complex geologic structure, severe semi-arid continental climate, frequent occurrence of fire, and discontinuous permafrost soils have interacted over time to create a complex mosaic of taiga and tundra biotic communities. A diversity of subarctic flora and fauna reflect this combination of physical processes, largely unaffected by Pleistocene glaciation. Hundreds of species of vascular and non-vascular plants create a mosaic of wildlife habitats and provide for a variety of human uses. Some plant associations may represent relict "arctic steppe" communities isolated by the passage of time and climate change (Young 1976). Four

narrowly endemic plant species are listed as species of concern for federal threatened or endangered status (Murray and Lipkin 1987).

A rich ecological assemblage of native subarctic mammals thrives in the Yukon-Charley's diverse habitats. Dall sheep, moose, and two distinct caribou herds are found throughout the area. Fourteen species of furbearers inhabit the preserve, of which marten and lynx are the most economically valuable. Grizzly and black bears also occur throughout the preserve. Small mammals, including mice, voles and shrews, are important in the food web. The hardy wood frog is the lone native amphibian. A climate characterized by seasonal extremes precludes the occurrence of reptiles.

At least 160 species of birds, most of them migrants, occur within Yukon-Charley. This geographic location allows for unusual observations of errant bird species from more southern and eastern temperate regions. The once endangered American peregrine falcon attains one of the densest breeding populations in North America, with an estimated at 100-125 pairs breeding on Yukon River and Charley River cliffs within the preserve. This spectacular bird is one of 17 species of raptors found in the area.

Many fish, wildlife, and plant species are important for contemporary subsistence uses by local Athabaskan and non-native peoples in the seasonal economy of the region. The Preserve is an area of compelling archeological potential. Evidence suggests that this region was geographically and environmentally suitable for very early human habitation. It may have seen intensive use, perhaps continuously since initial occupation, up to the present period of Athabaskan habitation.

The two most significant geographic attributes for prehistoric peoples were the presence of the Yukon River and the absence of an extensive Wisconsin glaciation. The Yukon was a migration route, leading populations from Beringia into interior Alaska and the northern temperate zone. Lack of glaciation provided favorable living conditions for early occupants and perhaps concentrated wildlife into accessible areas. This region's archeological resources could well illuminate the controversial timing and nature of the peopling of the New World (Griffen and Chesmore 1988).

Three aspects of the natural resources of Yukon-Charley stand out as especially important from a regional and national context. All are directly related to the presence of the Yukon River and its important tributaries within the preserve. These resources are: (1) arctic steppe plant communities associated with river bluffs; (2) breeding peregrine falcons, and (3) the rivers themselves.

Arctic Steppe Plant Communities

The arctic steppe plant communities that occur within Yukon-Charley are unique assemblages of native species on south-facing river bluffs (Wesser and Armbruster 1991) along the Yukon (Edwards and Armbruster 1989) and Charley rivers and other Yukon tributaries. These plant communities contain four species of concern: *Cryptantha shackletteana, Draba murrayi, Eriogonum flavum* var. *aquilinum,* and *Podistera yukonensis*. Only two isolated populations of *C. shackletteana* and *P. yukonensis* have been discovered.

In the past, botanists from the United States, former Soviet Union, and Canada have conducted research on Yukon, Charley, and Kandik river bluffs in an attempt to inventory species present in representative communities. According to Murray et al. (1983) the portion of the upper Yukon within the Preserve includes "… the most extensive system of steppe bluffs and also the largest array of endemic and disjunct taxa…" found in Alaska. Yukon River surveys (Roland 1990) included photo-documentation and plant sampling at 8 bluffs including Woodchopper bluff, Biederman bluff, Kathul Mountain, Nation bluff, and Montauk bluff. Surveys on the Kandik River revealed the presence of *Draba murrayi,* and two other steppe plants, *Erysimum asperum* var. *angustatum,* and *Phacelia mollis* (Roland 1991). Charley River surveys revealed communities very similar to those investigated on Yukon River bluffs, and several rare species were documented (Roland 1990).

Botanists have also sporadically visited representative sites in the Ogilvie Mountains north of the Yukon to examine communities present there. The northeast corner of the Preserve contains the only extension of the Canadian Ogilvie Mountains into Alaska. Geologically distinct, the Ogilvies provide unique habitat for plant assemblages. Investigation of these communities may provide documentation for range extensions for a number of rare plants currently known to occur only in Canada.

Past research suggests that arctic steppe species exist at the limits of their environmental tolerance and therefore may be sensitive to climate changes. Arctic steppe communities are considered modern remnants of past vegetation types that may have been widespread during the Pleistocene (Edwards and Armbruster 1989). These remnant communities may provide botanists with the most tangible examples of a landscape long since vanished. Current increased interest in monitoring the effects of global climate change could lead to utilization of these communities as indicators of changes in climatic variables. Because of their geological stratigraphy and exceptional ecological significance, four bluffs supporting arctic steppe communities have been proposed for inclusion in the National Natural Landmark System.

Peregrine Falcons

Yukon-Charley was established in part to ensure the protection of habitat for and populations of the then endangered American peregrine falcon. Yukon-Charley provides nesting habitat for one of the densest populations of peregrine falcons within any federally protected area in North America. Listed by the U.S. Fish and Wildlife Service under the Endangered Species Act, the peregrine falcon has become a symbol of conservation. Recovering from a well-documented decline throughout North America 25 years ago, populations are now more secure. Peregrine falcon populations within Yukon-Charley are used as index populations for the U.S. Fish and Wildlife Service's endangered species recovery plan.

Rivers

Yukon-Charley contains important inland freshwater resources including the entire 0.44 million hectare (1.1 million acre) Charley River watershed. Yukon-Charley's enabling legislation defined the foremost purpose to "maintain the environmental integrity of the entire Charley River basin…for public benefit and scientific study." Because of its value as a virtually undisturbed free-flowing river, the Charley has been designated a Wild River in the National Wild and Scenic Rivers System. The Tatonduk, Nation, and Kandik rivers, which originate from Canadian headwaters, each exhibit unique ecosystems and physical characteristics. The Kandik River may exhibit one of the highest levels of primary productivity found in an interior Alaska stream. While some small tributaries have historically sustained activities that altered stream flows, water quality, and aquatic habitat (e.g., placer mining), these four large Yukon River tributaries remain essentially pristine.

The Yukon River also holds regional and national significance as one of the five largest rivers in North America, 206 km (128 mi.) of which flows from the Canadian border through Yukon-Charley. The Yukon River drains watersheds in nearly half of Alaska, three-quarters of the Yukon Territory, and parts of British Columbia. The turbid Yukon River has historically sustained the effects of human development as the human population fluctuated dramatically throughout the past 100 years. For example, much of the Yukon River corridor was logged to provide fuel for steamships during the gold rush days.

The anadromous and resident fishes (approximately 14 species) of the Yukon and its tributaries (including the Charley River basin) are valuable components of the natural ecosystems for which Congress established Yukon-Charley. They are very important to consumptive users that live along the Yukon and depend on harvest from annual salmon runs. Late summer runs of chinook and chum salmon are harvested using primarily gill nets and fish wheels. To a lesser extent, Arctic grayling , northern pike, and

whitefish are harvested along clear-flowing Yukon tributaries near Eagle, Circle City, or various other locations accessible by light aircraft or boat.

Denali National Park and Preserve

Denali is located in interior and southcentral Alaska (Fig. 1-3) and is composed of 2.4 million hectares (6 million acres). Most of Denali is accessible only by foot, dogsled, or aircraft. Only one road provides vehicular access, mainly during the summer season. This road runs westward through the northern portion of the mountains to Kantishna. The small communities of Healy, McKinley Village, Cantwell, and Talkeetna are adjacent to the eastern park boundary. Bush communities adjacent to the western and northern boundaries include Minchumina, Nikolai, Telida, and McGrath.

Near the geographic center of Alaska, Denali surrounds Mt. McKinley, which hinges the great arc of the Alaska Range (Brown 1993). From Mt. McKinley's high buttresses and perpetual ice fields, glaciers descend radially, sculpting great gorges in the granite and sediments of the cluster peaks that form the massif. Then the landscape falls away through barren rock canyons to lake-dotted tundra benches, flat and treeless, and finally, to wide valleys formed by turbid glacial rivers, their braided beds flanked by spruce forest (Brown 1993).

The Alaska Range is a barrier to air movements and precipitation from maritime influences to the south, thus creating a transitional climate. Areas on the south side of the range are significantly wetter, with twice the precipitation of the north side. Temperatures on the south side of the range have less variation and tend to be warmer in winter and cooler in summer. North of the Alaska Range, a continental climate prevails.

Soils in mountainous areas are sparse because such areas consist of steep, rocky slopes, icefields, and glaciers with very thin or no soils. These soils are characterized by poor drainage, shallow permafrost, and thick surface layers of partially decomposed organic matter. Permafrost is intermittently present throughout the lowlands north of the Alaska Range and is continuous at higher elevations both north and south of the Range. Thicknesses up to 30 m (100 ft.) have been recorded on the north side near the park entrance.

Denali's vegetation is characteristic of subarctic areas where the growing season is less than 100 days and soils are nutrient-poor. The taiga, or boreal forest, is found at the lowest elevations and consists of black spruce, with stands of white spruce, paper birch, and aspen on better drained sites. Understory vegetation consists of low shrubs, herbs, mosses and lichens. Tree line is encountered

at 792 m (2,600 ft.), and forests give way to shrublands consisting of moist tundra plants such as dwarf birch, willows, and sedges. Above 1,036 m (3,400 ft.), shrubland is replaced by alpine tundra, which consists of low growing mats of avens only a few centimeters high.

Many headwater drainage systems originate in the Alaska Range. Streams of glacial origin are common and are characterized by shallow, swift flows over gravel beds. Many of these streams and rivers are silty, braided, and have wide gravel floodplains filling mountain valleys. Clear streams, fed primarily by snowmelt and precipitation, also occur throughout the area. Outside of the mountains, especially in the northwest lowlands, there are many meandering rivers and streams with slow currents. The mountains contain few lakes, although water-filled kettles on moraines and ponds from beaver-dammed creeks occur in places. Many lakes and ponds occur in the northwestern lowlands.

For at least 11 millennia, humans have been seasonally attracted to Denali because of concentrations of game animals (Brown 1993). Subsistence activities in Denali are dynamic and diverse with hunting usually occurring in the fall and winter months, fishing concentrated during summer and fall, and trapping efforts in mid- to late winter months when snow cover is adequate and fur is prime. Berry picking and use of plant greens occurs in the summer and fall months. Timber harvest usually occurs in winter when frozen rivers, lakes, and snow make access and transportation more efficient. Subsistence harvests vary considerably from year to year due to such factors as weather, migration patterns, natural cyclic population fluctuations, or from political and regulatory factors.

Three aspects of the natural resources of Denali stand out as especially important from a regional or national context. These resources are mountains and glaciers, wildlife, and designation as an international biosphere reserve.

Mountains and Glaciers

Much of Denali is mountainous. Elevations range from 60 m (200 ft.) to 6,193 m (20,320 ft.) at the top of Mt. McKinley, the highest peak in North America. One-third of the park and preserve consists of mountains and ridges about 1219 m (4,000 ft.) in elevation.

Currently, glaciers cover 17% of the land area of the park, and much of Denali's landscape was shaped by glaciers. Glaciers are numerous and tend to be larger and longer on the south side of the range than on the north. The larger glaciers range between 56 and 72 km (35–45 mi.) long. The largest glacier on the north side is the 55 km (34 mi.) long Muldrow Glacier.

Wildlife

Denali was created originally (as Mt. McKinley National Park) in 1917 mainly because of its wildlife resources (Mech et al. 1998). In the early years, scientific interest in Denali centered on the large mammals because the park's status as a game refuge offered scientists the unique opportunity to study the life histories of animal populations over a significantly large range of the subarctic (Brown 1993).

Denali is well known for its diversity of wildlife. Based on current information, there are ten species of fish, one amphibian, 37 species of mammals, and 167 species of birds known in the park. There are an unknown number of species of invertebrates.

Large mammals include moose, caribou, wolves, grizzly and black bears, and Dall sheep. Scientific studies of wolves and their prey have been conducted in Denali for over 60 years, starting with the work of Adolph Murie described in his classic monograph, *The Wolves of Mount McKinley* (Murie 1944). The Denali study is the second longest comprehensive study of wolves and their prey in the world (Mech et al. 1998).

Although much of the emphasis on Denali's wildlife focuses on larger mammals, Denali supports a large suite of smaller carnivores, rodents, lagomorphs, insectivores, and at least one species of bat. These species inhabit a variety of habitats across Denali and form integral links in Denali's food web. Many of the furbearers, beavers, and snowshoe hare are important resources for subsistence users in Denali. Many of the rodents are prey sources for many larger omnivores and carnivores. For instance, beavers are one of the primary alternate prey animals for wolves in summer, especially in Denali's western half (Mech et al. 1998), grizzly bears may prey heavily on mice and voles when they are available, and golden eagles depend heavily on snowshoe hare and arctic ground squirrel during the breeding season. Many herbivores, including snowshoe hare and arctic ground squirrel, are important forces in browsing and dispersing vegetation across the landscape. Little is known about the distribution and abundance for most of these species across the park.

Denali's birds include species whose ranges include six continents, all converging on this rich subarctic landscape each spring to breed. At least 149 species of birds occur regularly in Denali. Of these, nearly 80% are migratory. In 2001, the American Bird Conservancy recognized Denali for its significance in the ongoing effort to conserve wild birds and their habitats and designated Denali a Globally Important Bird Area. Partners in Flight Working Group, a partnership of organizations concerned with conservation of neotropical passerine bird species, identified 19 bird species as

"priority species" for Central Alaska. Sixteen of these priority species are known to occur in Denali. Denali supports many studies on birds including the longest ecological studies of golden eagles and gyrfalcons in the subarctic and arctic regions of North America (e.g., McIntyre 1995).

Twenty-two species of waterbirds (loons, grebes, swans, and ducks) breed in Denali. Trumpeter swans and Tule greater white-fronted geese are two migratory waterfowl species that are of particular interest in Denali. The numerous wetlands on the southside and in the northwestern portion of Denali support an abundance of breeding waterfowl, including at least 400 pairs of trumpeter swans. The Tule greater white-fronted goose, a subspecies of the greater white-fronted goose, is considered "at risk" by the International Waterfowl Research Bureau. This subspecies uses and breeds in wetlands adjacent to the Kahiltna River, Lake Creek, the vicinity of the Tokositna Glacier, and in wetlands along the Petersville Road.

International Biosphere Reserve

Denali is a designated as an International Biosphere Reserve under the United Nations Educational and Scientific and Cultural Organization Man and the Biosphere Program. The purposes of biosphere reserves are to assure worldwide protected areas where long-term ecological research will be possible on natural processes to compare with human altered areas and to assure protection of genetic diversity.

Wrangell-St. Elias National Park and Preserve

Wrangell-St. Elias encompasses 5.3 million hectares (13.2 million acres) in southcentral Alaska (Fig. 1-4). The park extends to the Canadian border on the east and to the Northern Gulf of Alaska on the south. The small communities of Glennallen, Copper Center, Chitina, Nabesna, and Slana are adjacent to the park, located on state highways that follow the western and northern border of the park. McCarthy is a small community located within the park near the historic Kennicott mine and is accessible by a 97 km (60 mi.) gravel road. Another gravel road, the Nabesna Road, travels towards the center of the park from the northern boundary.

Wrangell-St. Elias spans three climatic zones (coastal, transitional, and continental), and includes four major mountain ranges (the Wrangell Mountains, Chugach Mountains, St. Elias Mountains, and the Alaska Range). Large expanses of open, low elevation terrain occurs within the Copper River basin, a relic of the huge proglacial Lake Ahtna, which formed behind an ice dam at the confluence of the Copper and Chitina Rivers during the Pleistocene. The valley floor is now covered with braided river channels and surficial deposits mixed from alluvium and glacial outwash. Most

of the rivers and streams in Wrangell-St. Elias are heavily influenced by glacier activity.

Water resources within Wrangell-St. Elias include vast expanses of wetlands and numerous lakes and ponds. Over 1.2 million hectares (3 million acres) of the park are palustrine (marsh-like) wetlands. There are over 18,400 hectares (46,000 acres) of natural lakes including six large lakes and over 500 small ponds and lakes under 400 hectares (1,000 acres) in size. Dynamics of water processes in the landscape are controlled in part by the extreme winter weather. Five different types of permafrost occur commonly throughout the park, strongly affecting surface water dynamics. Ice flows and periodic ice jams can cause brief but sometimes catastrophic flooding in low-lying areas.

Several aspects of the natural resources of Wrangell-St. Elias stand out as especially important from a regional and national context. These resources are: (1) geological processes including glaciation and volcanism, (2) a diverse flora revealing landscape history, (3) rivers, including rivers with major anadromous fish populations, (4) wildlife, and (5) designation as an international biosphere reserve.

Geologic Processes Including Glaciation and Volcanism

Wrangell-St. Elias is noted for its geological diversity. The region has attracted researchers to investigate volcanism, glaciation, plate tectonics, and quaternary geology. The Nizina and Chitistone Canyons are areas where the geologic record is well represented and extensively exposed. The geologic history clearly exhibits the dynamic nature of the processes involved in the formation of the Wrangell and St. Elias mountain ranges.

A defining characteristic of the mountain ranges in Wrangell-St. Elias is heavy glaciation. The park contains over 1.6 million hectares (4 million acres) of glaciers including the Nabsena Glacier, which is over 71 km (44 mi.) long. Several of North America's highest peaks are within the park including Mt. St. Elias (5,489 m [18,008 ft.]) and Wrangell Mountain (4,269 m [14,005 ft.]), an active volcano. From these mountains flow hundreds of glaciers varying tremendously in size. The Malaspina is one of the largest piedmont lobe glaciers, and the aforementioned Nabesna Glacier is one of the longest valley glaciers. Other glaciers, such as the Hubbard Glacier, terminate at tidewater and are known for their surging and retreating. Extensive ice fields also occur within the mountain ranges.

The area is seismically active because the Yakutat terrane—the underlying plate just offshore of the park—is accreting to North America. The associated volcanism—the park has recorded nine volcanic episodes in the last decade—and active fault zones gener-

ate frequent earthquakes. The park also contains numerous geysers, hot springs or thermal pools. This area of volcanic activity is known as the Wrangell Volcanic Field, and it covers more than 104,000 hectares (400 square mi.), extending through the middle of the park from the international border to Glennallen.

Flora Revealing Landscape History

Wrangell-St. Elias encompasses a unique cross section of boreal, subarctic, and coastal ecosystems in Alaska with floristic influences from Beringia, the Yukon, the Arctic, and the Pacific Mountain systems. The diversity of plant communities in this region is unsurpassed for a park unit in Alaska due in part to the expansiveness of the park, the three climatic zones it covers (maritime, transitional, continental) and the wide variety of geologic features found within its boundaries.

Large areas within Wrangell-St. Elias have never been surveyed botanically. This is most obvious in the range maps in the Flora of Alaska (Hulten 1969) in which the "Wrangell Void" is seen for many taxa in areas where these taxa are expected to occur. Inventory work over the last decade, however, has significantly advanced our understanding of the flora of Wrangell-St. Elias. Currently, there are 832 vascular plant species documented by vouchers within Wrangell-St. Elias. Major plant communities in Wrangell-St. Elias can be described based on their topographic locations. These communities occur in lowlands, uplands, sub-alpine areas, and alpine areas.

The south-facing bluffs along the White, Nabesna, Chitina and Copper Rivers are similar to the steppe found in Yukon-Charley but not as extensive. Numerous rare and endemic plant species have been found in these communities, which may be refugia. Other unique plant communities in Wrangell-St. Elias are associated with distinctive landforms and lithologies such as sand dunes, mud volcanoes, volcanic ash, limestone, lakes, and wetlands. These communities often harbor uncommon species and species with disjunct distributions. Alaska-Yukon endemic species are more common in the Alaska Range and northern Wrangell Mountains. This trend corresponds to our understanding of plant migration after the Pleistocene Epoch from refugia in the upper Yukon Valley, the Alaska Range and Beringia, the northern part of Wrangell-St. Elias being closest to these migration corridors. In addition, there may have been unglaciated refugia within the Late Wisconsin ice sheet adjacent to Lake Ahtna in the northwestern region of the park, and in the dry northern interior of the Park bordering the Tanana Valley and the southeastern edge of Beringia. As described for the steppe communities of Yukon-Charley, these refugial communities and communities with rare

plants and disjuncts may be at the edges of their ranges and may be sensitive to environmental changes.

There are 76 vascular plant species in the park's flora which have an Alaska Natural Heritage state rank of three or less (known from fewer than 100 localities) and are treated as rare species by the National Park Service. Although none of the rare species are considered threatened or endangered by the U.S. Fish and Wildlife Service, three species (*Cryptantha shacklettenana*, *Carex laxa* and *Taraxacum carneocoloratum*) are listed as Species of Concern. The rare flora is distributed somewhat evenly throughout the mountain ranges of the park, but there is a predominance of rare plants in the Chitina River basin. There is a trend for rare plants to occur in the alpine zone, above 1200 m elevation, in dry sites, in the alpine-herb talus slope plant community, on southerly aspects and on slopes of 20–40°. Rare plant populations are often at the edges of their geographic and ecological ranges and may be good indicators of environmental changes for ecological monitoring.

Rivers and Fish

Four large river watersheds occur within the Wrangell-St. Elias—the Copper, Chitina, White, and Tanana rivers—dividing the landscape, with major salmon fisheries in the summer overlaid by access routes across the frozen surfaces in the winter. Wrangell-St.Elias is home to a tremendous array of fish resources. Fish habitat ranges from large glacial rivers and streams to small clear water streams, as well as a range of lentic habitats ranging from tundra ponds to large lakes. With hundreds of miles of streams draining into two of Alaska's largest river systems, Wrangell-St. Elias contains a diverse range of fish species as well as many abundant populations, including salmon populations that support large fisheries. The Copper River and most of its tributaries are migration routes for sockeye, coho, chum, and king salmon, and this river supports important subsistence fisheries within park boundaries. Small lakes and clear water tributaries contain lake trout, Dolly Varden, burbot, grayling, cutthroat and rainbow trout, sculpin, suckers, and whitefish.

Anadromous fish, including salmon and rainbow steelhead trout, dominate the fish communities in the Copper River. These fish transport large quantities of marine derived nutrients into otherwise nutrient-poor systems. These marine derived nutrients support many of our aquatic ecosystems. Dolly Varden and slimy sculpins inhabit many of what appear to be inhospitable, steep, silt-laden glacial streams. Lake trout and arctic grayling dominate many of our lake systems as the top predator in the aquatic food web. Some of the northernmost populations of rainbow steelhead trout occur within Wrangell-St. Elias.

Wildlife

Protection of fauna populations, especially mammals, birds, and fish, was an important consideration in establishment of Wrangell-St. Elias. Based on current information, there are 16 documented and 14 expected species of fish, four species of amphibians, 239 species of birds, and approximately 38 species of terrestrial mammals and nine species of marine mammals that occur in Wrangell-St. Elias. The park is also home to an unknown number of invertebrate species.

Large mammals are common in the park and are also an important subsistence resource. Dall sheep, grizzly bear, black bear, caribou, and moose are large species that inhabit the park. Smaller mammal species, including snowshoe hare, arctic ground squirrel, red squirrel, and marten, provide a food base for larger mammalian and avian predators as well as some subsistence takes and fur trapping.

Alaska's system of National Parks and Preserves contains approximately 40% of the population of Dall sheep. Wrangell-St. Elias alone contains >25% of both the statewide population and harvest of Dall sheep in Alaska. Two small caribou herds are found in the park: the Mentasta herd and the Chisana herd. The Mentasta herd is a small caribou herd that uses the slopes of Mount Sanford and Mount Drum in northern Wrangell-St. Elias. The Chisana herd resides further east in the Chisana area. Moose are another important ungulate species. Moose are a major prey species for wolves and grizzly bears. The park has populations in all areas including a small population in the Malaspina Forelands. Most of the large ungulate species found in the park are subject to subsistence hunts.

The park supports a diversity of small mammals. They are an important prey base which supports predators like the gray wolf. Small mammal inventory work in 2001 and 2002 has greatly expanded our understanding of their presence and occurrence in Wrangell-St. Elias (Cook and MacDonald 2002b). The discovery of the tiny shrew at Carden Hills and Braye Lakes in the northeastern corner of the park constitutes a new species for Wrangell-St. Elias and significantly expands the known range of the species. This study also provided the first documentation of the water shrew and tundra shrew in Wrangell-St. Elias and provided new information on several other species, including meadow vole, long-tailed vole, brown lemming, northern bog lemming, and singing vole.

Three species of bats occur in the general area of Wrangell-St. Elias. Little brown bats occur south of the Yukon River and are known to occur in the park. Silver haired bats and Keen's bat occur in southeast Alaska and may occur in Wrangell-St. Elias near Yakutat.

Harbor seals inhabit the coastal waters of Icy and Disenchantment Bays in southern Wrangell-St. Elias; their populations are largely unknown. Sea otters are present, and Steller sea lions occur in both Icy and Disenchantment Bays. Dall's porpoise and harbor porpoise, and five species of whales have been recorded in or near the bays.

There are records for 239 species of birds in the park with approximately 53 species listed as residents. Wrangell-St. Elias has two passerine migratory routes that pass through the park and an abundance of coastal bird communities in Icy Bay. Surveys have been conducted of seabirds, bald eagles, and trumpeter swans.

International Biosphere Reserve

In 1979, the United Nations Educational and Scientific and Cultural Organization established the geographic region now containing both Wrangell-St. Elias and Kluane National Park as a World Heritage Site. This area was specifically noted for its importance in representing "incredible geological processes," namely glacier dynamics, and "premier wilderness". In 1992, Glacier Bay National Park and Preserve and Tatshenshini-Alsek Provincial Park were added to the World Heritage designation making the combined 9.2 million hectares (23 million acres) one of the largest protected areas in the world.

Appendix H
Park-specific Resource Preservation Concerns

Coastal Concerns in Wrangell-St. Elias

Unlike the other parks in the network, which are landlocked, Wrangell-St. Elias includes 201 km (125 mi.) of coastline and 558 hectares (1,395 acres) of intertidal lands. The coastal area of Wrangell-St. Elias also includes rapidly moving tidal glaciers, whose advances and retreats create an especially dynamic environment. Resource preservation issues relating to Wrangell-St. Elias coastal areas mainly concern marine mammals and birds, and lack of information about their population status and trends.

The status of harbor seals in Wrangell-St. Elias, specifically Icy Bay, is largely unknown, yet these areas appear to be important breeding and feeding grounds. Several factors may affect seal and sea lion populations in this area. Local residents have reported declines in Steller's sea lions in Yakutat Bay. A sea lion rookery/haul out area along the Malaspina forelands supported about 200–300 animals in the early 1980s. Harbor seals may be experiencing similar declines but no data are available. Proposed development of private lands in the Icy Bay area could affect unstudied pinniped populations. Offshore oil leasing in the northern Gulf of Alaska may occur west of Icy Bay and south of Yakutat Bay. Marine mammals are at risk from potential oil spills and pollution if oil is developed in adjacent offshore areas. Logging is occurring along west and east of Icy Bay. Increases in logging and related boat traffic may disturb seals. Increases in tourism in Icy Bay by cruise ships and kayakers trying to observe calving glaciers may also disturb seals hauled out on icebergs. Commercial fishing occurs throughout Yakutat Bay and may affect seal populations.

Steller's sea lion populations in western Alaska have declined severely since the early 1980s. Decreasing population trends were first documented in the eastern Aleutian Islands, where they are most dramatic, and later in the central Gulf of Alaska. From 1956 to 1985 populations from the central Gulf of Alaska to the central Aleutian Islands declined 52%. As a result of these documented declines, the Steller's sea lion was declared threatened under the U.S. Endangered Species Act in November 1990. As with harbor seals, Steller's sea lion populations in southeast Alaska do not appear to be declining, although monitoring efforts here have been patchy and information from Wrangell-Saint Elias suggest declines may be occurring in the Yakutat area.

Marbled and Kittlitz's murrelets are two marine bird species whose populations have declined in some areas in recent years. Wrangell-St. Elias coastal areas could be important, especially for Kittlitz's murrelets, who favor glacial waters for feeding. Recent surveys in 2002 should reveal the relative importance of Wrangell-St. Elias coastal areas to these and other marine birds.

Military Training Overflights in Yukon-Charley Rivers

Fairbanks, located only 160 km (100 mi.) southwest of Yukon-Charley, is home to Eielson Air Force Base. Eielson supports the northernmost U.S. fighter wing in the world, the 354th Fighter Wing. Their Thunderbolt II and F-16 Viper aircraft provide the United States with combat-ready forces capable of reaching anywhere in the Northern Hemisphere at a moment's notice. Eielson is also home to Cope Thunder, the largest aerial exercise in the Pacific region, held four times a year. To support training of the 354th Fighter Wing and Cope Thunder exercises, a number of Military Operations Areas have been established. Because of its proximity to Fairbanks, Yukon-Charley falls within some of these Military Operations Areas.

Four Military Operations Areas cover the entirety of Yukon-Charley. These Military Operations Areas support low to medium flight intensities. Projected military traffic is 7–18 aircraft per day during routine training and 164–206 per day during Major Flying Exercises (Lawler and Haynes 1998). Supersonic activity is allowed at or above 1,524 m (5,000 ft.) above ground level. Flight restrictions occur seasonally along the Yukon, Charley, and Kandik river corridors in order to protect nesting peregrine falcons and over the Cirque Lakes area in early summer to protect Dall sheep during lambing. The Federal Aviation Administration recommends a minimum altitude of 610 m (2,000 ft.) above ground level for aircraft flying over park and wilderness areas to minimize disturbance to wildlife and visitors. Military jet aircraft flights are most concentrated in the southwest corner of the preserve.

Lacking authority over air space and military operations, the NPS options are limited to determining the effects of flights on its resources. Extreme low-level (under 610 m [2000 ft.] above ground level) military flight activities occur throughout Yukon-Charley creating high noise events with occasional sonic booms. Mammalian and avian wildlife species are subjected to various levels of disturbance associated with low-level jet activity. Peregrine falcons, Dall sheep, caribou, grizzly bears, and other raptors all inhabit steep, elevated terrain and are therefore more susceptible to disturbance of low flying aircraft. Aircraft following natural terrain features likely disturb river bluff inhabitants. More frequent jet activity in summer coincides with nesting and parturition times for

most raptor, ungulate, and predator species. This overlap in activities can potentially exaggerate impacts to populations.

Although not common occurrences, crashes within Yukon-Charley have occurred in the past (DiFolco 1998), and the potential for crashes will increase in the future as jet aircraft activity in Military Operation Areas over Yukon-Charley increases. This brings an additional risk to the resources. Military aircraft carry large quantities of fuel and other hazardous materials that contaminate a large area of soil, vegetation, and aquatic resources when a crash occurs. Containment of spills and other crash impacts is further complicated by military security concerns and the delay in NPS staff receiving access to the site.

Appendix I
Past and Current Monitoring in Central Alaska Network Parks

Physical Environment

Features of the physical environment within Central Alaska Network parks that are monitored include weather, air quality, ultraviolet-B (UV-B) radiation, seasonal snow characteristics, and glaciers. Except for glacier monitoring at Denali, the parks conduct none of these efforts independently. These monitoring programs are generally conducted in partnership with others as part of national or statewide programs. The partners include the National Weather Service (weather), Alaska Fire Service (weather), Environmental Protection Agency (UV-B radiation), Natural Resources Conservation Service (snow), and the National Park Service Air Quality Division (air quality).

Weather

Weather conditions in Central Alaska Network parks are monitored in a variety of locations by two main programs: the National Weather Service and the Alaska Fire Service. These programs are aimed at providing real-time weather data for aviation, fire management, and other human activities. At Denali, a number of additional weather monitoring activities also occur.

National Weather Service: The National Weather Service operates weather stations at an array of sites in the Central Alaska Network region; only two are located actually within a park: one at Denali Park Headquarters and one at McCarthy. The nearest site to Yukon-Charley is at Eagle. A number of sites are located around the perimeter of Wrangell-St. Elias, including Yakutat, Chitina, Gulkana, Slana, Nabesna, and Northway. Sites near Denali include Healy, Nenana, and Minchumina. Many of the sites have been operated continuously since 1949, but others have been operated intermittently. Data at these sites are collected daily and include temperature and precipitation. Data are available on the web at: http://www.wrcc.dri.edu/summary/climsmak.html.

The Denali Park Headquarters record is the longest climate record from a mountainous site in western North America (Juday 2000). These data are affectionately referred to as the "doggy data" because the weather station is located in the dog kennels at park headquarters. The doggy data are of great interest to many researchers and are one of the most frequently requested data sets from the park (Sousanes 2000). They can be found at

the aforementioned website operated by the National Weather Service, as well as at http://fnemd-1.iab.uaf.edu/statserver/

Alaska Fire Service: The second type of weather monitoring that occurs in Central Alaska Network parks is conducted as part of the wildland fire management program of the U.S. Department of the Interior. This program, managed by the Alaska Fire Service, collects current weather, primarily during the fire season, for use in fire behavior modeling. These data are collected via Remote Automated Weather Stations, referred to as RAWS. The stations remotely transmit data every hour. The attributes measured include air temperature, average wind speed and direction, peak wind speed and direction, precipitation, relative humidity, fuel temperature, and solar radiation.

There are currently a total of 19 RAWS in or near Central Alaska Network parks. In north central Yukon-Charley, stations are located at Ben Creek and just to the east of the preserve in Eagle. These RAWS are maintained year round. Data may be intermittent during periods of low light in the winter. In and near Denali, RAWS are located at seven sites: Healy, Ruth Glacier, Talkeetna, Telida, Lake Minchumina, McKinley River, and Wonder Lake. In and near Wrangell-St. Elias, RAWS are located at ten sites: Jatahmund Lake, Kenny Lake, May Creek, Northway, Slana, Tazlina, Chisana, Chitina, Gulkana, and Chistochina. Weather data from all Alaska RAWS are immediately available on the Internet at http://fire.ak.blm.gov/scripts/wx/viewctrl.asp.

Additional Weather Monitoring at Denali: In addition to the National Weather Service and Alaska Fire Service programs, several other weather monitoring efforts occur at Denali. The Denali Long-term Ecological Monitoring Program includes the operation of six weather stations in the Rock Creek watershed near park headquarters. These stations were established in 1992. These weather stations are arrayed on an elevational gradient from 724 m (2,367 ft.) to 1,346 m (4,400 ft.). The Denali Long-term Ecological Monitoring Program has recently begun coordinating with the park's Maintenance Division to record snow depths and temperatures along the park road corridor. The addition of air temperature and relative humidity sensors along the road will provide valuable information for both practical and scientific aspects of the road corridor conditions. Weather data are also collected at the air quality monitoring site at Denali Park headquarters because weather data are needed to interpret air quality data. The latest developments in weather monitoring at Denali include the establishment of a high-altitude weather station on Mt. McKinley and the addition of weather stations with satellite telemetry capabili-

ties at Toklat Road Camp, Stampede Mine Airstrip, and Dunkle Mine Airstrip.

Air Quality

The only air quality monitoring site in Central Alaska Network parks is located at Denali. The air quality monitoring program has been operating without interruption since 1980. It is primarily funded through the National Park Service's Air Resources Division, which manages a nationwide network of stations. The goal of air monitoring is to monitor the spatial and temporal trends of airborne contaminant concentrations through a nationwide array of monitoring stations. The air quality station at Denali includes monitoring instruments from various nationwide air quality monitoring networks, including:

- National Atmospheric Deposition Program (NADP)
- Interagency Monitoring of Protected Visual Environments (IMPROVE)
- National Park Service Gaseous Pollutant Monitoring Network (for ozone)

Support from the Denali Long-term Ecological Monitoring program supplements the national program funding and allows park and regional goals to be met in addition to the nationwide objectives funded by the Air Resources Division. Recently some additional air quality monitoring near Denali has been conducted in relation to the Healy Coal Mine.

In the past, air quality monitoring at Denali has been restricted to measurement of the air. Recently, there has been interest in also monitoring for air pollution effects, and the Western Region of the NPS has created the Western Airborne Contaminant Assessment Program. As part of this program, lichen samples were collected in Denali in 2002 to support the development of protocols to assess airborne contaminant accumulation and effects in lichen communities. Results of this work will guide protocol development for air pollution effects monitoring in Alaska.

Ultraviolet Radiation

As for air quality, the only monitoring site for UV-B radiation within the network is at Denali. In September 1996, the National Park Service and the U.S. Environmental Protection Agency signed an interagency agreement to cooperate on a program of long-term monitoring of environmental stressors in National Park System (NPS) units and research the effects of the stresses on ecosystems. This program is called the Park Research and Intensive Monitoring of Ecosystems Network (PRIME Net). Denali was selected as one of the PRIME Net locations, and a Brewer spectrophotometer was set up at Denali Park headquarters, adjacent to the air quality monitoring site.

A Brewer spectrophotometer measures different wavelengths of light and focuses on the ultraviolet spectra (UV-B radiation is in the 300–320 nm range of light). The instrument tracks the sun as it monitors the variation in solar irradiance throughout the day. It also records other data such as total column ozone and ambient concentration of gases. These data are then used to calculate the dose of ultraviolet radiation at the surface of the Earth. Because of the influence of sun angle, clouds, and other forms of air pollution, the seasonal variation in UV-B detected at the surface is large. Therefore, it will take many years of monitoring to detect trends in the incidence of UV-B.

Seasonal Snow Cover

Central Alaska Network parks are covered by snow for eight to nine months a year, and the timing, depth, and condition of the snow cover are important for understanding hydrological conditions and many other aspects of the regional ecosystem. As for weather, monitoring of the seasonal snow cover is accomplished in cooperation with other agencies, in this case, the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS). NRCS establishes a variety of snow measurement systems (e.g., aerial snow markers, snow pillows) in major watersheds throughout the state to allow prediction of annual water supply.

Within Central Alaska Network parks, snow measurements have been made at Denali for many years. The ten snow course and aerial markers located in and around Denali are visited on a monthly basis during the snow season, usually November through May. In 2002, additional snow markers and courses were added to cover variable terrain more effectively and integrate with other long-term monitoring programs. Two additional snow courses were installed in the summer of 2002 at Stampede Mine Airstrip and Dunkle Mine Airstrip. These sites are co-located with new weather stations installed at the same time. Additional aerial markers were established at sites on the south side of the range near the Eldridge Glacier, Tokosha Mountains, Upper West Fork Yentna, the confluence of the Lacuna and Yentna Glaciers, and near the Pika Glacier.

Snow measurements have not been made at Yukon-Charley until very recently. In 2001, six aerial markers were established at a diversity of sites that represent various elevations, slopes, aspects and terrain. Markers are read from the air via Cessna 185 planes within two days prior to 1 November, 1 December, 1 January, 1 February, 1 March, 1 April, and 1 May. During winter of 2001–02, a snow course was also established at Coal Creek. The course consists of five stations spaced every 5 m. Prior to establishment of these sites in Yukon-Charley, the only snow information for this area

was from Mission Creek in Eagle. At this site, a snow pillow, snow course, and precipitation gauge are used to obtain snow density, depth, and water content.

The NRCS measures snow at a number of sites in the vicinity of Wrangell-St. Elias. These include snow courses at Chistochina, Dadina Lake, Jatahmund Lake, Kenny Lake, May Creek, Mentasta Pass, Sanford River, Tazline, and Tolsona Creek.

All snow course data are compiled by major river basin and published by the NRCS. The data are available at their web site: http://www.ak.nrcs.usda.gov/

Recently, additional snow monitoring has been conducted at Denali in relation to snow machine activities in the park. The current effort is a special study but could be continued into the future, depending on management needs. In this project, the physical aspects of the snowpack that allow adequate support of snowmachine travel without causing adverse impacts to vegetation and soils are measured. In 2002, the depth and density of the snowpack in the Broad Pass area south of Cantwell, and along the Stampede Corridor were studied by visiting established sites on a bi-weekly schedule. The study began in the early season (late November–December) to determine if the areas used by snowmachiners and within the boundaries of the park had adequate snowcover for travel without disturbance to resources.

Glaciers

Currently, glacier monitoring within Central Alaska Network parks occurs only at Denali. However, glaciers in Wrangell-St. Elias have received extensive study by glaciologists. Some of these studies are long term, but we have not yet evaluated their potential role in the network. The U.S. Geological Survey operates two long-term glacier monitoring sites in Alaska as part of its Benchmark Glacier Program. These include the Gulkana Glacier (located in the Alaska Range north of Wrangell-St. Elias and west of Denali) and the Wolverine Glacier (located on the Kenai Peninsula).

At Denali, glacier monitoring is included in the Denali Long-term Ecological Monitoring Program. Since 1991, mass balance measurements are conducted on two index glaciers (Traleika, Kahiltna) and a benchmark glacier (East Fork Toklat), maintaining one of the longer glacier monitoring records in Alaska. Measurements of mass balance and movement are made in late May and early September, at the end of the accumulation and ablation seasons, respectively. Benchmark glacier monitoring is more intensive than index glacier monitoring, and 11 long-term measurement stakes were surveyed and assessed for mass balance trends

in 2002. In addition, in cooperation with the second year of a three-year project, three field surveying campaigns were completed on the Muldrow Glacier to characterize "normal" glacier movement (as opposed to "surging" movement). An identified trend in the historical movement patterns of the Muldrow Glacier suggests that a dramatic surge could be imminent (within a few years).

Aquatic Environment and Biota

Compilation of current monitoring of water quality, quantity, and biological attributes of water bodies in Central Alaska Network parks is still underway. Monitoring of the aquatic environment relies heavily on the U.S. Geological Survey (USGS) for water quantity and water quality measurements. Currently, biological monitoring of aquatic resources is minimal.

Water Quantity and Quality

Within Yukon-Charley, the USGS maintained water flow gauging stations on the 70-mile River and Alder Creek from 1910–1912. Flume Creek was monitored in 1910 and 1913. The Kandik River was monitored from 1994–2000, the Nation River from 1991–2000 and the Yukon River at the town of Eagle from 1950–2000. There are presently water flow gauging stations maintained by the USGS on the Yukon (by Eagle), Nation, and Kandik rivers. Water level measurements are used to equate discharge. Current data and historical information is available on the Internet for every half-hour interval (http://www.ak.water.usgs.gov).

At Wrangell-St. Elias, USGS gauging stations have been operated in and around the park for many years; few of them (6 of 17) have been located within the boundaries, however. There are currently no active gauging stations within Wrangell-St. Elias. The longest record is from 1950–1990 just outside the boundary of the park on the Copper River near the town of Chitina. Most other records are three to six years in length and range from the early 1900s to the late 1970s.

At Denali, water flow measurements of Rock Creek were made as part of the Denali Long-term Ecological Monitoring program, but these have been discontinued. An inventory of water quality in Denali streams was conducted in the mid-1990s. A cooperative study with USGS was initiated in 2001 at Denali to determine the occurrence and distribution of polyaromatic hydrocarbons in park aquatic environments. Semi-permeable membrane devices designed by USGS scientists at the Columbia Environmental Research Center to mimic the bioconcentration of hydrophobic organic contaminants were deployed in stream systems in Denali to collect polyaromatic hydrocarbons over an extended period of time.

In Wrangell-St. Elias, baseline limnological studies were conducted of Copper, Tanada, and Ptarmigan Lakes in 1993. These lakes are sites the park has identified as being likely to be developed, and the information is intended to serve as a baseline to assess rates of lake eutrophication.

Biological Monitoring of Aquatic Habitats

In 1992 macroinvertebrate sampling began in Rock Creek in Denali. The goal of the sampling was to develop a baseline data set and establish methodologies that could be used for long-term ecological monitoring. However, data collected in 1992–1993 showed that Rock Creek supported only three taxa. Therefore, in 1994, 27 sites along the park road were examined for the presence of macroinvertebrate taxa. Results from this work showed that streams and rivers could clearly be divided into separate groups based upon their invertebrate fauna. Protocol development for macroinvertebrate monitoring in Denali streams has continued to the present, and recommended protocols are expected this year.

The only other biological monitoring of aquatic habitats in Central Alaska Network parks is of salmon. In Yukon-Charley, the Alaska Department of Fish and Game began conducting surveys for spawning salmon in the early 1970s, prior to the establishment of Yukon-Charley as a preserve. Summer chum salmon and fall King and coho salmon are counted from fixed-wing aircraft on the Charley, Nation, Kandik, Tatonduk, and 70-mile Rivers. The surveys are conducted at least every three years and are dependent on availability of money, suitable weather and qualified observers.

In Wrangell-St. Elias, Tanada Lake provides spawning and rearing habitat for two sockeye salmon stocks. In 1991, monitoring was initiated on the lake to 1) determine if variations in water quality and zooplankton biomass correlate with variations in adult sockeye salmon escapement into the lake; 2) to determine if lake productivity is affecting juvenile sockeye survival. Two sampling stations were established in 1991. Each station is sampled six times (once a month) beginning in late May at breakup (ice-off) through the end of October (approximate time of ice-on). Water samples at each station are taken at 1 m and 40 m. Parameters measured include: temperature and dissolved oxygen profiles to a maximum depth of 55 m, light penetration, conductivity, total dissolved solids, pH, alkalinity, hardness, and secchi disk transparency. Water samples are analyzed for total solids, total dissolved solids, suspended solids, total phosphorus, total filterable phosphorus, total Kjeldahl nitrogen, total ammonia, nitrate and nitrite, reactive silicon, particulate organic carbon, total particulate phosphorus, total particulate nitrogen, chlorophyll-a, and phaeophytin.

Vegetation

At Yukon-Charley, landcover classification maps of vegetation community types were created in 1998 with 1991 Landsat™ satellite imagery (Ducks Unlimited 1998). Due to the large role that fire and succession play in the Yukon-Charley ecosystem, it is important to update landcover maps. Not only do large areas directly burn within the preserve within a ten-year period, but an even larger percent of the preserve is in early successional stages (10–30 year old burns) that are known to change rapidly in structure and composition. Yukon-Charley vegetation maps need to be viewed as dynamic products that need periodic updating in order to monitor landscape changes in vegetation and be useful for wildlife habitat studies. Currently, there is no program for vegetation monitoring at Yukon-Charley.

A fire effects study in the Upper Yukon area includes plots within Yukon-Charley. Fifteen randomly located permanent plots were established in September 1999 in order to examine vegetation recolonization rates and succession following fire in black spruce forest. All plots are accessible by riverboat and by foot. Study plots are arranged along four randomly chosen transects that are approximately two miles apart. Each transect has 3–4 plots that are placed 200 m apart. Plots are circular with a 10 m radius. Point intercept methods are used to obtain percent cover of all vegetation species. Depth of active layer is sampled concurrently at intercept points. Photo points were established, and standing dead, downed dead, and live tree density and diameter at breast height (DBH) were measured.

Vegetation monitoring has been an important component of the Denali Long-term Ecological Monitoring program since its inception in 1992. The approach for vegetation monitoring was modified in 2001 in response to reviewers' comments received in 1997. The present objective of the program is to detect landscape-level changes in the vegetation cover of the park that occur over decadal time scales via randomly chosen permanent plots. Across elevation gradients of forest, treeline, and tundra, white spruce reproduction and seed germination are measured on permanent vegetation plots, each of which is sampled on an eight-year rotation. More intensive monitoring will continue to take place in the Rock Creek watershed, which was the original focus area of the monitoring program. It is anticipated that process-related variables such as growth and reproduction of tree species and vegetation phenology will be examined in a small subset of the landscape-level permanent plots in the future.

At Wrangell-St. Elias, a major study of the effects of a spruce bark beetle infestation that occurred in the mid-1990s was made. Part of this study included establishment of permanent plots with

the intention of revisiting them. This study also established permanent photo points at a number of sites, including along the McCarthy road.

Birds

Only one park in the network, Yukon-Charley, has conducted an intensive inventory of bird populations to assess overall presence and distribution of birds. In 1998, Yukon-Charley was selected to receive funding from the NPS Servicewide Inventory and Monitoring Program to conduct this intensive inventory work on birds. The goals of the project were to: 1) design and implement an avian inventory plan in Yukon-Charley with methodology suitable for large parks and preserves that have minimal access; and 2) to obtain geographic data layers to characterize habitat. Specific objectives for the inventory included determining associations between bird abundance by species and habitat characteristics during the breeding season and to extrapolate the information to obtain park-wide abundance and distribution estimates. The program also sought to document owl species presence/absence by ecological subsections.

A variety of bird monitoring occurs in Central Alaska Network parks. The efforts are focused on waterfowl, raptors, and passerines. Some seabird surveys have also occurred along the Wrangell-St. Elias coast.

Waterfowl

An annual count of trumpeter swans was conducted in Wrangell-St. Elias from 1984–1992. Data on population size, annual breeding effort, and locations of brood rearing and staging areas were collected. The U.S. Fish and Wildlife Service conducts swan surveys, generally every five years, and portions of Denali have been included in that monitoring effort.

Raptors

At Wrangell-St. Elias, surveys were initiated in 1989 and continued until 1994 to document the presence and distribution of bald eagle nest sites along the Copper and Chitina River corridors. Yukon-Charley has partnered with the U.S. Fish and Wildlife Service to monitor occurrence and productivity of peregrine falcons nesting along the Yukon and Charley Rivers since the early 1980s. Observers float the rivers annually to observe peregrines and produce an annual estimate of their productivity. Golden eagle and gyrfalcon nesting ecology has have been monitored continuously at Denali since 1988. Work is focused in the northeast section of the park for these species. The goal of this monitoring is to examine nesting ecology of both species and measure survival and sources of mortality of birds.

Passerines

Passerine bird populations are monitored via a variety of methods by various programs. Within Central Alaska Network parks, these

include the Breeding Bird Survey, off-road point counts conducted in accordance with Boreal Partners in Flight methods, and the Monitoring Avian Productivity and Survivorship program. The latter program involves use of mist nets to capture birds so they can be marked and recaptured. This allows population parameters such as productivity and survivorship to be measured. Another program that occurs in network parks is the Christmas Bird Count.

The Breeding Bird Survey is commonly called the BBS. The BBS is organized by the USGS and Canadian Wildlife Service and is a continent-wide program that deploys observers on maintained roads. BBS routes are present within Central Alaska Network parks in Denali and Wrangell-St. Elias (Yukon-Charley has no roads). BBS survey routes have been conducted along the Denali Park road since 1992. Within Wrangell-St. Elias, BBS routes have been conducted along the Nabesna and McCarthy roads since 1989. Each survey route is 24.5 miles long with stops at 0.5-mile intervals. At each stop, a 3-minute point count is conducted. During the count, every bird seen within a 0.25-mile radius or heard is recorded. Surveys start one-half hour before local sunrise and take about five hours to complete.

In Alaska, where the road system is relatively limited, other methods of documenting passerine bird populations are important. The methodology for this is called the "off-road point count" and has been developed under the Partners in Flight program. Specific off-road point count methods have been developed for Alaska. Off-road point counts have been conducted in all Central Alaska Network parks.

In Wrangell-St. Elias, off-road points counts were initiated near the McCarthy road, the Nabesna road, May Creek and the settlement of Chisana in 1993. Between eight and 20 routes are conducted annually. Routes are walked, and approximately every 200 m observers listen for all bird calls for an eight-minute period. Additionally, the distance from the observer to the bird is recorded. Off-road point counts were also conducted at Wrangell-St. Elias in 1997 and 1998 at four study sites within areas of spruce bark beetle infestation. These sites could be revisited in future years to monitor the response of bird populations to response of the vegetation to the death of mature white spruce trees.

In Yukon-Charley, avian populations are estimated annually in the Coal Creek area by conducting off-road point counts. This work was initiated in 1997. As part of the aforementioned intensive inventory of Yukon-Charley bird populations, which used a probability-based design, off-road point counts were conducted at many sites in Yukon-Charley. This inventory was designed with the idea

that it could be the basis for long-term monitoring of passerine bird populations in the preserve.

In Denali, both on-road point counts (essentially BBS-type surveys) and off-road point counts have been conducted (mainly in spruce forest) in the Denali Park road corridor as part of the Denali Long-term Ecological Monitoring Program. This work continued between 1992 and 2001. In 2002 major changes in passerine monitoring were proposed in response to comments received from reviewers in 1997. The revised objectives of the passerine monitoring are to describe spatial patterns of species distribution and develop indices of species relative abundance. In addition passerine monitoring would also describe and assess the spatial and temporal variability of bird assemblages and describe how passerine populations and communities respond to changes in vegetation and climate. Pilot work to assess the co-location of passerine and vegetation monitoring was undertaken in 2002 on the park-wide vegetation monitoring plots.

Mist netting of passerines under the Monitoring Avian Productivity and Survivorship Program has also occurred at Denali as part of the Denali Long-term Ecological Monitoring Program. Mist net stations have been operated in Denali since 1992. Results from Denali stations are thought to be essential for understanding population trends of passerines on a continental scale in North America. Peer reviews of the Denali program in 1996 and 1997 suggested the program needed to address several issues to best serve the needs of Denali, including a thorough review of the data collected to date. The U.S. Geological Survey (USGS), Biological Resources Division, Alaska Science Center is currently spearheading an analysis of the mist net data on a statewide scale. Results from these analyses will provide Denali and the network with guidance on continuing the mist netting program.

Mammals

Mammal populations monitored in Central Alaska Network parks include small mammals, furbearers, snowshoe hares, wolves, grizzly bears, caribou, moose, Dall sheep, and mountain goats. In Wrangell-St. Elias and in Yukon-Charley, monitoring of ungulates and wolves is conducted by or in close cooperation with the Alaska Department of Fish and Game in relation to harvest management. In Denali, a long-term study of wolf-prey relationships has been conducted, continuing work started by Adolph Murie in the 1940s.

Small Mammals

Monitoring of small mammal population dynamics in the road corridor of Denali has been conducted since 1992. In 2002, the eleventh year of sampling in the Rock Creek watershed was conducted in an effort to document patterns of inter- and

intra-annual variation in small mammal abundance. Other sites in Denali where small mammal populations have been monitored include the west end of the park road along the McKinley Bar trail, and at two additional locations along the park road (Teklanika River and Stony Creek).

Furbearers and Snowshoe Hares

In Yukon-Charley, track surveys of marten, lynx, fox and snowshoe hares were conducted beginning in 2001 using aerial videography techniques. The purpose of this effort is to develop and test the methodology, with the expectation that the method will be used in many locations in interior Alaska to monitor population indices for furbearer species. Annual track counts will provide an index to population trend, as well as provide animal locations for habitat selection analyses. Random transects will be placed across the landscape and will be flown at approximately 500 feet above ground level. High-resolution digital video footage is taken from a camera port in the belly of a Cessna 185. A global positioning system (GPS) is linked into the camera system to assign XY coordinates to each video frame. Visibility correction factors are presently being developed for different terrain and habitat types. Footage is viewed in the office, and data entered into a database that includes track species, location, days since snowfall, and various habitat parameters. Surveys will be repeated every three years in order to monitor changes in population size, distribution, and habitat selection. This effort will be continuing in 2002 to finish development of the monitoring protocol.

In Wrangell-St. Elias, another method of evaluating snowshoe hare abundance has been used. An index of snowshoe hare abundance is determined based on hare pellet transects. Each year, hare pellets are enumerated along predetermined transects along the McCarthy and Nabesna roads, along May Creek and near the settlement of Chisana. This methodology is based on that used at the Kluane boreal forest study site in Yukon Territory, Canada.

Wolves

In Yukon-Charley, wolves are presently being monitored using radio telemetry methods. This monitoring effort is in response to a wolf sterilization program being conducted by the Alaska Department of Fish and Game in areas adjacent to the preserve. Wolves that reside in Yukon-Charley are exempt from the program and are being used as a reference population for the sterilization effort. This wolf monitoring program will continue until sterilization efforts are complete in 2003. After 2003, less expensive and labor intensive snow tracking methods may be employed every three years to monitor the Yukon-Charley wolf population, following methods of Becker (1991) and Becker and Gardner (1992).

At Denali, wolf monitoring has been conducted since the 1980s as part of long-term research into wolf-prey dynamics. The overall goal of this work is to monitor population characteristics of wolves and their major prey species (caribou and moose) in sufficient detail to understand the population trends of each species in the context of the interrelationships that comprise the Denali wolf/prey system. This work strives to gain understanding of the roles that winter severity, differential landscape use, and relative vulnerability of prey species play in wolf/prey relationships in Denali and, ultimately, in determining the abundance and population trends of all three species.

Moose

Beginning in 1994, aerial moose surveys have been conducted within the northern portion of the Yukon-Charley. This portion comprises 51% of the preserve and occurs from the Charley Foothills to the northern preserve border. Methods described in Gasaway et al. (1986) are followed for this survey. Surveys provide estimates of fall population size, sex and age composition, and trend across years. At Wrangell-St. Elias, moose surveys are conducted in cooperation with the Alaska Department of Fish and Game and Tetlin National Wildlife Refuge. Trend counts have been determined annually since the 1950s.At Denali, moose population monitoring has been conducted as a part of the wolf-prey study.

Caribou

The Alaska Department of Fish and Game monitors the Forty-Mile Caribou herd whose range includes Yukon-Charley. Radio collars are used to locate the herd in the fall just prior to calving and just after calving. Aerial photo counts are then used to obtain overall population estimates and sex and age composition. Cow:calf, cow:yearling, and cow:bull ratios and population size trends are monitored annually, and this monitoring effort is expected to continue into the future.

In Wrangell-St. Elias, the Mentasta caribou herd is surveyed via a cooperative effort between the park, the Alaska Department of Fish and Game, and the USGS-Alaska Science Center. These surveys were initiated in the early 1970s and are conducted annually.The Chisana caribou herd survey is conducted by the park and the Alaska Department of Fish and Game. The herd has been surveyed annually since the late 1980s.

The Denali Caribou Herd has been monitored intensively as part of the wolf-prey study.

Dall Sheep

Surveys to estimate the population of Dall sheep in Wrangell-St. Elias were initiated in 1949 and have been conducted consistently since the 1960s. For these surveys the park in broken into 31

units, and the population is estimated for each unit. In Yukon-Charley, aerial sheep surveys are conducted every three years in areas available to Dall sheep within the preserve in order to monitor population trends. These areas are broken down into survey units for comparisons between years: 5580 (area along NW border of YUCH), Twin Mountain, Cirque Lakes, Charley River, Sorenson Mountain, Diamond Fork, and Copper Creek. Surveys are conducted from the end of June through the beginning of July during which ewes, lambs, yearlings, and rams are counted. When available, a sightability correction factor is calculated from radio-collared sheep to obtain a population estimate. In Denali, the Dall sheep population has been studied in various years, but no consistent monitoring effort has been conducted.

Mountain Goat

The Alaska Department of Fish and Game conducts a population survey for mountain goats annually on McColl Ridge in the upper Chitina River valley. Fixed-wing aircraft are used for this survey and an index to population size is obtained.

Appendix J

Ecoregions and Ecological Units of Central Alaska Network Parks

This appendix provides more detailed descriptions of the specific ecoregions found in the Central Alaska Network parks than is presented in the body of the report. **Summary descriptions of Level 1 Ecoregion Types and ecoregions are taken verbatim from Nowacki et al. in press.** More detailed ecological unit mapping has been undertaken for the three Central Alaska Network parks as part of the Inventory and Monitoring Program (Clark 2002, Swanson 1999, Swanson 2001), and lists of the detailed ecological units found in each ecoregion within each park are also included. This appendix therefore includes ecoregions information about network parks from the statewide perspective of Nowacki et al. (in press) and the park-specific perspectives of other mapping efforts.

The more detailed mapping efforts have been conducted with different levels of on-the-ground information and somewhat different approaches. Denali ecological units are currently being delineated in the process of soil mapping. This effort is being conducted by Mark Clark of the U.S. Department of Agriculture Natural Resources Conservation Service. Detailed ecological mapping of Wrangell-St. Elias and Yukon-Charley was conducted by Dave Swanson, a private consultant. While the mapping of Denali units has included substantial field work (including soil pits and vegetation observations) over a six year period, the Yukon-Charley and Wrangell-St. Elias efforts were based on examination of maps of existing information about soils, geology, land cover, etc. Another caveat to keep in mind is that the Yukon-Charley effort preceded development of the Nowacki et al. in press ecoregions map, and boundaries of the detailed ecological units do not exactly match the boundaries of the broader ecoregions of Nowacki et al. (in press). In the Wrangell-St. Elias effort, the detailed ecological units were mapped within the ecoregion boundaries of Nowacki et al. (in press).

Intermontane Boreal (22% of CAKN)

These areas experience extreme seasonal temperature changes from long, cold winters to short, moderately warm summers. Boreal woodlands and forests cover much of this undulating landscape. The continental climate is fairly dry throughout the year, and forest fires rage through summer droughts. This intermontane terrain sandwiched between the Brooks and Alaska Range remained largely ice-free during the last ice age, forming part of the "Beringia Corridor" (Pielou 1991).

Kuskokwim Mountains (0.1% of CAKN)

This **subdued terrain** is comprised of **old, low rolling mountains** that have eroded largely without the aid of recent past glaciations. A **continental climate** prevails with seasonal moisture provided by the Bering Sea during the summer. Mountains are composed of eroded bedrock and rubble, whereas intervening valleys and lowlands are composed of undifferentiated sediments. Thin to moderately thick permafrost underlies most of the area. **Boreal forests** dominate, grading from white spruce, white birch, and trembling aspen on uplands to black spruce and tamarack in lowlands. Tall willow, birch, and alder shrub communities are scattered throughout, particularly where **forest fires** burned in the recent past. Rivers meander through this **undulating landscape** following fault lines and highly eroded bedrock seams. These mountains support abundant moose, bears, beavers, and scattered caribou herds.

North Ogilvie Mountains (5.3% of CAKN)

This terrain consists of flat-topped hills and eroded remnants of a former plain. This area represents the western extent of the North America stable platform onto which terranes radiating from the Pacific and Arctic Oceans have attached. Sedimentary rocks, especially **limestone**, underlie most of the area. Ridgetops and upper slopes are often barren with **angular, frost-shattered rock outcrops** (resembling castellations) surrounded by **long scree slopes**. These are characteristics of an **unglaciated** area that has undergone long periods of erosion. Shallow soils have developed in rocky colluvium on mountainsides where landslides, debris flows, and soil creep frequently occur. On lower slopes, soils are deeper, more moist, and underlain by extensive permafrost. **Low shrub tundra** of willow, alder, and birch and **aspen and spruce woodlands** occur at lower elevations. These mountains are the source of many streams that eventually feed the Porcupine, Yukon, and Peel Rivers. Lakes are relatively rare. A **strong continental climate** prevails, with prolonged frigid winters lasting from October to May and cool, short summers. Brown bears, wolverine, Dall sheep, caribou, lemmings, and pikas are common inhabitants of these mountains.

Ecological Units within Yukon-Charley Rivers National Preserve

- Biederman Hills
- Yukon River Valley
- Tintina Hills
- Kandik Tableland
- Ogilvie Foothills
- Hard Luck Lowland
- Ogilvie Lime/Dolostone Mountains
- Snowy Domes

Tanana-Kuskokwim Lowlands (10.1% of CAKN)

This **alluvial plain** slopes gently northward from the Alaska Range. The undifferentiated sediments of fluvial and glaciofluvial origin are capped by varying thicknesses of eolian silts and organic soils. Sand dune fields and glacial moraines occur in some areas. A dry **continental climate** prevails with cool summers and cold winters. Even though a rain shadow exists due to the neighboring Alaska Range, **surface moisture is rather abundant** due to the gentle topography, patches of impermeable permafrost, and poor soil drainage. Permafrost is thin and discontinuous, and temperatures are near the melting point. **Collapse-scar bogs and fens** caused by retreating permafrost are frequent and related to climate warming since the Little Ice Age. Streams flowing across this north-sloping plain ultimately drain into one of two large river systems—the Tanana or Kuskokwim. Groundwater-charged seeps and springs are common in gravel deposits. **Boreal forests** dominate the landscape with black spruce in bogs, white spruce and balsam poplar along rivers, and white spruce, white birch, and trembling aspen on south-facing slopes. The coldest, wettest areas on permafrost flats support birch-ericaceous shrubs and sedge tussocks. Tall willow, birch, and alder communities are scattered throughout. The mosaic of habitats supports moose, black bears, beavers, porcupines, trumpeter swans, and numerous other waterfowl.

Ecological Units within Denali National Park and Preserve

- Kuskokwim Plain–Eolian Lowlands
- Kuskokwim Plain–Lowland Flood Plains and Terraces
- Kuskokwim Plain–Minchumina Basin Lowlands

Ecological Units within Wrangell-St. Elias National Park and Preserve

- Jatahmund Basin Floodplains and Terraces subsection
- Jatahmund Basin Moraines Subsection

Yukon-Old Crow Basin (0.5% of CAKN)

This gently sloping basin along the Porcupine River is comprised of **depositional fans, terraces, pediments, and mountain toeslopes** that ring the **Yukon and Old Crow Flats**. The surfaces surrounding the flats are largely unglaciated and products of millions of years of weathering of the surrounding mountains. Here, deep deposits of colluvial, alluvial, and eolian origin are underlain by continuous masses of permafrost. The **marshy flats** have developed in deep alluvial and glaciolacustrine deposits underlain by discontinuous permafrost. The poorly drained flats and terraces harbor **vast wetlands** pockmarked with dense concentrations of thaw lakes and ponds. On the flats, water levels of lakes are often maintained by spring flooding rather than precipitation. Active fluvial processes are etched throughout the topography featuring **deltaic fans, terraces, and floodplains**.

Opaque with glacial silts and shoreline mud, the Yukon River forms an **aquatic maze** of islands, sandbars, meander sloughs, and oxbow lakes as it crisscrosses the lower flats. The rich aquatic habitats support tremendous concentrations of **nesting waterfowl** (in the millions!) and other migratory birds and an abundance of moose, bears, furbearers, northern pike and salmon. A **dry continental climate** prevails with considerable seasonal temperature variation. Arctic high-pressure systems prevail during the winter, bringing clear and frigid weather. In contrast, summers are short but relatively warm. Vegetation varies with soil drainage grading from wet grass marshes and low shrub swamps to open black spruce forests to closed spruce-aspen-birch forests on better-drained uplands. Summer **forest fires** are common.

Ecological Units within Yukon-Charley Rivers National Preserve

- Thanksgiving Loess Plain
- Little Black River Hills

Yukon-Tanana Uplands (6.4% of CAKN)

These **broad, rounded mountains** of moderate height are underlain by the metasedimentary Yukon-Tanana terrane. This terrane is a composite of transported crust blocks that includes former volcanic island arcs and continental shelf deposits. Most surfaces are comprised of bedrock and coarse rubble on ridges, colluvium on lower slopes, and alluvium in the deeply incised, narrow valleys. **Climate is strongly continental** with warm summers and very cold winters. The region is underlain by discontinuous permafrost on north-facing slopes and valley bottoms. In valley bottoms, permafrost is thin, ice-rich, and relatively "warm." Vegetation is dominated by white spruce, birch, and aspen on south-facing slopes, black spruce on north-facing slopes, and black spruce woodlands and tussock and scrub bogs in valley bottoms. Floodplains of headwater streams support white spruce, balsam poplar, alder, and willows. Above treeline, low birch-ericaceous shrubs and *Dryas*-lichen tundra dominate. This area has the **highest incidence of lightning strikes** in Alaska and the Yukon Territory, causing frequent forest fires. Caribou, moose, snowshoe hares, marten, lynx, and black and brown bears are plentiful. The area's abundant cliffs are important to peregrine falcons. The clear headwater streams are important spawning areas for chinook, chum, and coho salmon.

Ecological Units within Yukon-Charley Rivers National Preserve

- Charley Foothills
- Upper Charley Mountain Tundra
- Upper Charley Valleys

- Three Fingers Supalpine Basin

Ecological Units within Wrangell-St. Elias National Park and Preserve

- Carden Hills Subsection
- Snag-Beaver Creek Plain Subsection
- Wellesley Mountains Subsection

Alaska Range Transition (26.1% of CAKN)

Boreal forests occur within the basins and troughs fringed by the Alaska Range. This area is considered transitional since some climatic moderation is afforded by the nearby Pacific Ocean (i.e., maritime moisture). Ice sheets heavily scoured this area during the last glaciation, and small ice gaps and glaciers still exist at high elevations.

Alaska Range (18.9% of CAKN)

A series of accreted terranes conveyed from the Pacific Ocean fused to form this **arcing mountain range.** In turn, these towering mountains harbor a complex mix of folded, faulted, and deformed metamorphic rocks. **Landslides and avalanches** frequently sweep the steep, scree-lined slopes. Discontinuous permafrost underlies shallow and rocky soils. Because of the Alaska Range's height, a **cold continental climate** prevails, and much of the area is barren of vegetation. Occasional streams of Pacific moisture are intercepted by the highest mountains and help feed small **icefields and glaciers.** At the glacier's termini, swift **glacial streams with heavy sediment** loads course down mountain ravines and braid across valley bottoms. Alpine tundra supports populations of **Dall sheep and pikas** on mid and upper slopes. Shrub communities of willow, birch, and alder occupy lower slopes and valley bottoms. Forests are rare and relegated to the low-elevation drainages. Brown bears, gray wolves, caribou, Dall sheep, and wolverines are common denizens in the Alaska Range.

Ecological Subsections within Denali National Park and Preserve

- Alaska Range–Teklanika Alpine Mountains and Plateaus
- Alaska Range–Teklanika Boreal Mountains and Plateaus
- Alaska Range–Toklat Basin Lowlands
- Alaska Range–Interior Alpine Floodplains, Terraces and Fans
- Alaska Range–Interior Lowland Floodplains, Terraces and Fans
- Alaska Range–South Central Nonvegetated Alpine Mountains
- Alaska Range–South Central Alpine Mountains
- Alaska Range–South Central Borea and Subalpine Mountains
- Alaska Range–Nonvegetated Alpine Mountains
- Alaska Range–Interior Glaciated Uplands
- Alaska Range–Interior Glaciated Lowlands
- Alaska Range–Alpine Outer Range and Kantishna Hills
- Alaska Range–Boreal Outer Range and Kantishna Hills

- Alaska Range–Interior Boreal Mountains
- Alaska Range–Interior Alpine Mountains

Ecological Units within Wrangell-St. Elias National Park and Preserve

- Jack Valley Subsection
- Mentasta Sedimentary Mountains Subsection
- Nabesna Basin Subsection
- Southern Mentasta Mountains Subsection

Cook Inlet Basin (0.4% of CAKN)

This gently sloping lowland was buried by ice and flooded by proglacial lakes several times during the Pleistocene. The basin floor is comprised of **fine-textured lacustrine deposits** ringed by coarse-textured glacial tills and outwash. **Numerous lakes, ponds, and wetlands** attract large numbers of **waterfowl** (including trumpeter swans) and shorebirds. Dolly Varden and whitefish occur in fresh waters. Several river systems support recovering salmon runs and resultant bear and raven populations. The basin is generally free of permafrost. A mix of maritime and continental climates prevails with moderate fluctuations of seasonal temperature and abundant precipitation. This climate, coupled with the flat to gently-sloping, fine-texture surfaces give rise to **wet, organic soils** that support **black spruce** forests and woodlands. Ericaceous shrubs are dominant in open bogs. Mixed forests of white and Sitka spruce, aspen, and birch grow on better-drained sites and grade into tall shrub communities of willow and alder on slopes along the periphery of the basin. A mixture of wetland habitats supports numerous moose, black bears, beavers, and muskrats.

Ecological Subsections within Denali National Park and Preserve

- Cook Inlet Glaciated Lowlands
- Cook Inlet–Lowland Flood Plains, Terraces and Fans

Copper River Basin (6.8% of CAKN)

This mountain basin lies within the former bed of Glacial Lake Ahtna on **fine-textured lacustrine deposits** ringed by coarse glacial tills. The basin is a **large wetland complex** underlain by thin to moderately thick permafrost and pockmarked with thaw lakes and ponds. A mix of **low shrubs and black spruce forests and woodlands** grows in the wet organic soils. Cottonwood, willow, and alder line rivers and streams as they braid or meander across the basin. Spring floods are common along drainages. **Arctic grayling, burbot, and anadromous sockeye salmon** are common fishes. Black and brown bears, caribou, wolverines, and ruffed grouse are present throughout these wetland habitats. The **climate is strongly continental**, with steep seasonal temperature variation.

The basin acts as a cold-air sink, and winter temperatures can be bitterly cold.

Ecological Units within Wrangell-St. Elias National Park and Preserve

- Ahtna Lacustrine Plain Subsection
- Chitina Valley Floodplains and Terraces Subsection
- Chitina Valley Moraines and Hills Subsection
- Duck Lake Plain Subsection
- Kotsina-Kuskalana Hills and Terraces Subsection
- Middle Copper River Floodplain and Terraces Subsection
- Natat Plain Subsection
- Tanada Moraine Subsection
- Upper Copper River Floodplains and Terraces Subsection
- Wrangell Mountains Toeslope Subsection

Coast Mountains Transition (21.9% of CAKN)

The high mountains on the interior side of the coast mountains are exposed to a peculiar mix of climates. Because of their sheer height, these mountains capture ocean-derived moisture as it passes inland. Yet, due to their proximity to the interior, these mountains possess a fair degree of seasonal temperature change similar to a continental climate. Climatic influences change with elevation, with maritime conditions on mountaintops (feeding ice caps and glaciers) grading to continental conditions at their base (boreal forests).

Wrangell Mountains (16.3% of CAKN)

This **volcanic cluster of towering, ice-clad mountains** is at the northwest edge of the St. Elias Mountains. This exceedingly steep, rugged terrain is the result of the ongoing collision of the Pacific and North American tectonic plates. Here, relatively recent volcanic flows and debris form a carapace over the Wrangellia terrane. The Wrangell Mountains possess a **peculiar mix of climates** because of their size and geographic location (i.e., on the interior side of the coastal mountains). The sheer height of the Wrangell Mountains allows interception of moisture-laden air emanating from the north Pacific Ocean. The abundant maritime snows feed **extensive icefields and glaciers** interspersed by **dull gray ridges** draped with rock shard slopes and patches of **alpine meadows**. The climate grades to dry continental at lower elevations where the Wrangell Mountains abut the cold-air basin of the Copper River. **Shrublands of willow and alder** with scattered spruce woodlands ring the lower slopes. Spruce and cottonwood grow along larger drainages. The Wrangell Mountains are highly dynamic due to **active volcanism, avalanches, landslides, glaciers, and stream erosion**. Soils are thin and stony and underlain by discontinuous permafrost. Its best-known denizen, the **Dall sheep,** roams throughout the area along with

mountain goats, brown bears, caribou, wolverines, and gray wolves.

Ecological Units within Wrangell-St. Elias National Park and Preserve

- Baldwin Mountains Subsection
- Cheshnina Plateaus and Valleys Subsection
- Cross Range Subsection
- Drum-Sanford Footslopes Subsection
- Jacksina Lava Plateau Subsection
- Jarvis Range Subsection
- McCarthy Mountains Subsection
- Mt. Drum Subsection
- Mt. Sanford Subsection
- Mt. Wrangell Mountainside Subsection
- Nabesna Mountains Subsection
- Regal Range Subsection
- Tanada Mountains Subsection
- Wrangell Icecap Subsection

Kluane Range (5.6% of CAKN)

The Kluane Range encompasses the drier interior portion of the St. Elias Mountains spanning from the ablation zone (area where glacial ice melts faster than it accumulates) eastward to a fault line scarp along the Shakwak Valley. It is **generally ice-free** except for occasional glaciers extending from the St. Elias icefields. The area has a **dry continental climate**. It lies within a **partial rain shadow** of the St. Elias Mountains whereby moisture from the Pacific Ocean is effectively wrung from the atmosphere as weather systems rise over these towering peaks. Deformed sedimentary and volcanic rocks of the Wrangellia and Alexander terranes underlie this area. The **high-relief topography** has been exposed to mass wasting, stream erosion, and glacial scouring. Thin and rocky soils have developed in the colluvial veneer that covers most surfaces. Swift streams cascade down steep mountainsides where **scree movement, rock falls, landslides, and soil creep** occur. **Permafrost is discontinuous** with the presence of frost action features such as solifluction lobes, ice-wedge networks, and patterned ground. Vegetation is principally **alpine tundra and barrens** of lichens, prostrate willows, and ericaceous shrubs. Taller shrub communities occur at mid elevations. White spruce is found on lower slopes and valleys along the eastern boundary. Alpine and subalpine habitats support an abundance of Dall sheep, mountain goats, brown bears, caribou, moose, wolves, and wolverines.

Ecological Units within Wrangell-St. Elias National Park and Preserve

- Chisana Basin Subsection
- Nutzotin Igneous Mountains Subsection
- Nutzotin Sedimentary Mountains Subsection
- Solo-Beaver Valley Subsection
- Southern Nutzotin Hills and Mountains Subsection
- White River Basin Subsection

Coastal Rainforest (29.6% of CAKN)

These coastal areas adjacent to the North Pacific Ocean receive copious amounts of precipitation throughout the year. Seasonal temperature changes are limited due to proximity to open ocean. These areas warm sufficiently in the summer to allow trees to grow and dominate at lower elevations. Massive ice fields and glaciers are common in the mountains.

Chugach-St. Elias Mountains (29.3% of CAKN)

Arcing terranes of Pacific origin have been thrust onto the North American continent forming a **rugged ice-clad mountain chain** surrounding the Gulf of Alaska. This is the largest collection of icefields and glaciers found on the globe outside the polar regions. These towering mountains of faulted and folded sedimentary rocks intercept an **abundance of maritime moisture,** mainly in the form of snow. **Huge icefields, snowfields, and glaciers** surround steep angular and cliffy peaks that are mantled with hanging glaciers; isolated small peaks called nunataks poke up sporadically in the middle of the broad glaciers. In the summer, glacial meltwaters form rivulets and plunge down vertical ice shafts called moulins to join vast amounts of water flowing along the base of glaciers. Where they exude onto coastal flats, glaciers spread to form expansive lobes that gush water at their edges. Some glaciers run all the way to tidewater. Ice sheets swelled during past glaciations, inundating surrounding lands along the coast, as well as the Interior. The sheer height of these mountains, together with their expansive icefields, forms an effective barrier for interior species, except along the Alsek and Copper River corridors. **Thin and rocky soils** exist where mountain summits and slopes are devoid of ice, snow, and active scree. Here, **alpine communities** of sedges, grasses, and low shrubs grow which, in turn, support Dall sheep, mountain goats, hoary marmots, pikas, and ptarmigan. Glaciers and icefields have receded, leaving **broad U-shaped valleys**, many with sinuous lakes. Here, deeper soils have formed in unconsolidated morainal and fluvial deposits underlain by isolated pockets of permafrost. Alder shrublands and mixed forests grow on lower slopes and valley floors where moose and brown and black bears forage.

Ecological Units in Wrangell-St. Elias National Park and Preserve

- Bagley-Seward Icefield Subsection
- Bremner Valley Subsection
- Bering and Stellar Glaciers Subsection
- Churchill-Bona Massif Subsection
- Chitina Moraines Subsection
- Chitina and Logan Glaciers Subsection
- Copper River Canyon Subsection
- Icy Bay Foothills Subsection
- Icefield Ranges and Glaciers Subsection
- Malaspina Glacier Subsection
- Mt. Bear Massif Subsection
- Mt. Logan Massif Subsection
- Northern Chugach Cirque-Glacier Mountains Subsection
- Northern Chugach Foothills Subsection
- Northern Chugach Glaciers and Ridges Subsection
- Nikolai Butte Subsection
- Robinson Mountains Subsection
- Southern St. Elias Mountains Subsection
- Sulzer-Natazhat Mountains Subsection
- Tana Valley Subsection
- University-Centennial Mountains Subsection
- Waxel-Barkley Ridge Subsection
- White-Hawkins Massif Subsection
- Western St. Elias Foothills Subsection
- Yahtse and Guyot Glaciers Subsection

Gulf of Alaska Coast (0.3% of CAKN)

Lush, **lichen-draped temperate rain forests** of hemlock and spruce interspersed with open wetlands blanket the shorelines and adjacent mountain slopes along the Gulf of Alaska. A **cool, hypermaritime climate** dominates with minor seasonal temperature variation and extended periods of **overcast clouds, fog, and precipitation**. Snow is abundant in the winter and persists for long periods at sea level. Permafrost is absent. Tectonic events have raised and submerged various portions of the coastline through time. Common forest animals include black and brown bears and Sitka black-tailed deer. Bald eagles, common murres, Bonaparte's gulls, Steller's sea lions, harbor seals, and sea otters teem along its endless shorelines. **Numerous streams and rivers** support Dolly Varden, steelhead trout, and all five species of **Pacific salmon**. Salmon spawning runs deliver tremendous amounts of nutrients to aquatic and terrestrial systems. A fjordal coastline and archipelago exists around Prince William Sound and points west where continental ice sheets repeatedly descended in the past. Here, fjords formed where glacier-carved terrain filled with seawater after deglaciation. At the head of fjords lie broad U-shaped valleys that have steep, deeply incised side walls draped

with hanging glacial valleys. A coastal foreland extends from the Copper River Delta southeast to Icy Point, fringed by the slopes and glacier margins of the Chugach-St. Elias Mountains. Here, unconsolidated glacial, alluvial, and marine deposits have been uplifted by tectonics and isostatic rebound to form this relatively flat plain. Because of its geographic position, the foreland is water-drenched through persistent maritime precipitation and overland runoff from the mountains. The organic soils shed water slowly and are blanketed with wetlands among meandering and braided silt-laden streams. Temperate rain forests of hemlock and spruce grow sporadically where soil drainage affords (e.g., moraines, stream levees, and uplifted beach ridges). Rare dusky Canada geese and trumpeter swans nest on these wet flats where brown bears, Sitka black-tailed deer, and moose roam.

Ecological Units within Wrangell-St. Elias National Park and Preserve

- Malaspina Foreland Subsection

Appendix K
Vital Signs Identified During Park Brainstorm Sessions

During fall 2001, park-level brainstorm session were held to initiate discussion of the vital signs monitoring program and to get feedback on the types of information parks desired from the program. The table below lists all topics identified by park staff that attended the sessions. Note that a session was not held at DENA because of their existing Long-term Ecological Monitoring program.

Table 1. Initial list of potential vital signs for the Central Alaska Network. Lists of potential vital signs for Wrangell-St. Elias National Park and Preserve (WRST) and Yukon-Charley Rivers National Preserve (YUCH) identified by park staff during fall 2001 for consideration as vital signs in the Central Alaska Network Monitoring program. List for Denali National Park and Preserve (DENA) represents topics currently monitored at Denali as part of the prototype Long-term Ecological Monitoring Program.

Potential Vital Sign		WRST	YUCH	DENA
Air Quality	Visual distance	X		
	Air quality as affected by generators at McCarthy/ Kennecott	X		
	Road dust	X		
	Persistent organic pollutants	X		
Water Quality	Nitrogen, phosphorous, oxygen, metals			
	Water flow rates	X	X	
	Ground water	X		
	Point source pollution		X	
	Water temperature	X		
	Turbidity	X		
Physical Environment	Climate	X		X
	Permafrost	X		
	Snow characteristics	X	X	X
	Ice in/out dates	X	X	
	Glacial ablation	X		X
	Weather	X	X	X
	Fire	X	X	X
	Fuels		X	X
	Ice & mud coring	X		
	Streambed morphology		X	X
Vegetation Changes		X	X	
Lake Size		X		
Sound	Aviation	X	X	
	Generators	X		
	Snowmachines	X		
Wildlife	Swans	X		
	Bald eagles	X		

Potential Vital Sign		WRST	YUCH	DENA
	Golden eagles	X		X
	Frogs on McCarthy Road	X		
	Squirrels	X		
	Salmon carcass counts	X		
	Fish habitat		X	
	Small mammals	X	X	X
	Aquatic insects	X	X	X
	Marine mammals	X		
	Fish abundance		X	
	Bear/human impacts	X		
	Ungulate status & trends	X		X
	Predator/prey relationships		X	
	Population demography in relation to habitat use		X	
	Fauna population genetics		X	
	Passerine bird populations			X
Vegetation	Structure & composition			X
	White spruce growth/reproduction			X
	Land cover changes	X	X	
	Mushrooms	X		
	Lichens pollutants	X	X	
	Aquatic biodiversity	X	X	
	Non-native plants	X		
	Grazing	X		
	Human impacts on local sites	X	X	
	Berry production	X		
	Wood use for campfires	X		
	Fire succession		X	
	Arctic steppe communities		X	
Nutrient Cycling			X	
Landscape Pattern of Fire				
Human Use	Timber resources	X		
	Cruise ship impacts	X	X	
	Flightseeing	X		
	Harvest of animals	X	X	
	Human visitation/consumption	X	X	
	Airstrip landing	X		
	River use	X	X	
	Human input	X	X	
	ATV	X		
	Land status	X		
	Human use change resulting from fire		X	

Appendix L
Protocol Development Summaries

Central Alaska Network
Protocol Development Summary

Air Quality

Andrea Blakesly, Air Specialist
Denali National Park and Preserve

Protocol: Air Quality Monitoring at Denali National Park and Preserve: Monitoring Ozone, Pollutant Compounds in Wet and Dry Deposition (Fallout), and Particulates Affecting Visibility

Parks Where Protocol will be Implemented: DENA

Justification/Issues Being Addressed

Under the Clean Air Act, park managers have a responsibility to protect air quality and related values from the adverse effects of air pollution. Protection of air quality in national parks requires knowledge about the origin, transport, and fate of air pollution, as well as its impacts on resources. To be effective advocates for the protection of park air resources, NPS managers need to know the air pollutants of concern, existing levels of air pollutants in parks, park resources at risk, and the potential or actual impact on these resources. Through the efforts of park personnel, support office staff, and the NPS Air Resources Division, the NPS meets its clean air affirmative responsibilities by obtaining critical data and using the results in regulatory-related activities.

Although current air quality in CAKN parks is considered pristine (by national standards), the CAKN recognizes air pollution from global and regional industrialization as a potential driver of ecosystem change in network parks (MacCluskie and Oakley 2003). Arctic haze has been documented to occur in DENA (Shaw 1995). Air quality in CAKN parks is also affected by wildland fires and volcanic eruptions. Air quality was designated a Vital Sign for the network because of its importance as both an anthropogenic and natural driver of change.

Within the NPS, air quality monitoring is managed nationally through participation in several established programs, each targeting a specific aspect of air quality. Denali, designated as a Class 1 park under the Clean Air Act (where the most stringent standards apply), has been the site of air quality monitoring since 1985. CAKN will use data from the DENA site to monitor air quality in the network. The network will monitor concentrations of compounds known to be generated by industrial activities and

to act as pollutants (e.g., sulfate), in both wet and dry deposition. The network will also monitor composition and concentrations of particulates that affect visibility. Ozone concentrations will be monitored because they are component of DENA being part of the Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring network in the Air Resources Division

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

Objectives of the nationwide NPS Air Quality Monitoring Program are:

1. Determine levels of air pollutants in parks and correlate to observed effects.
2. Identify and assess trends in air quality.
3. Determine compliance with National Ambient Air Quality Standards.
4. Provide data for the development and revision of national and regional air pollution control policies.
5. Provide data for atmospheric model development and evaluation.
6. Use information to inform the public about conditions/trends in national parks.
7. Determine which air pollutants in parks contribute to visibility impairment.

Generally, the CAKN objectives for air quality are to monitor the spatial and temporal trends of airborne contaminant concentrations through a nationwide array of monitoring stations. The specific air quality monitoring objectives for CAKN are:

1. Monitor weekly levels of pH, sulfate, nitrate, ammonium, chloride, calcium, magnesium, potassium, and sodium in precipitation falling at DENA headquarters through participation in the National Atmospheric Deposition Program (NADP).
2. Monitor the chemical composition and mass of coarse and fine particulate matter in the air that contributes to reduced visual clarity at DENA headquarters through participation in the Interagency Monitoring of Protected Visual Environments (IMPROVE) program.
3. Monitor hourly levels of ground level ozone, in concert with meteorological attributes necessary to interpret the ozone data (wind speed and direction, temperature, Δ temperature, relative humidity, solar radiation, and precipitation) at DENA headquarters, through participation in the NPS Air Resources Division Gaseous Pollutant Monitoring network.
4. Monitor the weekly levels of sulfate, sulfur dioxide, nitrate, ammonium, and nitric acid falling as dry deposition at DENA headquarters through participation in the Clean Air Status and Trends Network (CASTNet) program.
5. Integrate air quality data from the DENA site with data from other CAKN Vital Signs to monitor the ecological condition of CAKN parks.

Basic Approach

As noted above, airborne contaminant monitoring is conducted through the nationwide NPS air quality monitoring network. The basic approach to monitoring air quality in CAKN will be to rely on the data gathered by the existing air quality programs. At this time, it is not expected that CAKN Vital Signs monitoring funds will be used for developing additional airborne contaminant monitoring methods.

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Development Schedule, Budget, and Expected Interim Products

The DENA air quality monitoring protocol comprises the standard operating procedures for each nationwide air quality monitoring network. These procedures are defined by the respective monitoring network steering committees. The narrative portion of the DENA protocol was completed in 1997, and this will be revised to meet national I&M program requirements (Oakley et al. 2003). The only aspect of air quality monitoring at DENA that needs development for incorporation into the CAKN Vital Signs monitoring program concerns data reporting. Currently, all data are managed at the national level and reported at the national scale (i.e., Denali in comparison to other sites). Mechanisms to facilitate the integration of the air quality data into CAKN reporting and data analysis schemes at the network scale will be developed through consultation with the network Data Manager.

The protocol will be developed on the following schedule:

Fiscal Year	Expected Interim Products
December 2004	Develop mechanisms to facilitate use of DENA air quality data by CAKN. Revised air quality narrative to accompany existing SOPs.
FY 2005	Complete protocol
FY 2006	Implement

The NPS Air Resources Division and Denali National Park and Preserve provide funding for air quality monitoring in Denali, following the prescribed national standards.

Central Alaska Network
Protocol Development Summary

Climate and Snowpack

Pam Sousanes, Environmental Protection Specialist
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Protocol: Monitoring Climate and Snowpack Change in Central Alaska Parks

Parks Where Protocol will be Implemented: DENA, WRST, YUCH

Justification/Issues Being Addressed

Climate, by determining the temperature and precipitation regimes for any ecosystem, is widely recognized as one of the most fundamental drivers of ecological condition. A predominant feature of climate in high-latitude regions is the presence of a seasonal snowpack. The snowpack is a major influence on hydrology, vegetation, and faunal communities (Jones et al. 2001). Accordingly, the Central Alaska Network identified climate—and snowpack, as the dominating feature of the regional climate—as an important Vital Sign (MacCluskie and Oakley 2003). The Central Alaska Network encompasses strong climate gradients, from the maritime climates in the southern parts of WRST where it borders the North Pacific Ocean, to the strongly continental climates found in northern parts of DENA and YUCH. These climate gradients are intrinsic to the ecosystem patterns and vegetative and faunal communities found in CAKN parks. In general, Alaska has a sparse dispersion of climate monitoring sites (Simpson et al. 2002). Currently, the few permanent long-term climate monitoring sites in the CAKN region are biased towards low elevation areas of human habitation bordering the parks, and there are large regions within CAKN parks (with their complex topography) with no climate monitoring stations at all (e.g., YUCH). Records of precipitation are especially important to documenting climate and understanding climate effects on ecosystems, but measuring precipitation is technically quite difficult at windy locations where most of the precipitation comes in the form of snow. Total annual precipitation is often greatly underestimated, and comparisons of precipitation patterns among years are difficult because estimates are biased. Strategic deployment of climate stations in the CAKN parks will provide data not heretofore available on the climate patterns in the parks, which is necessary for understanding changes in the freshwater and terrestrial plant and animal communities. In addition, the climate stations will provide real-time weather data which is of immediate use in park management operations. Climate data from the CAKN will also contribute

significantly to understanding of Alaska climate by filling in some of the big gaps in the existing multi-agency climate monitoring station network and by contributing to accurate measurement of winter precipitation.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

A main objective of the strategy is to monitor and record weather conditions at sites representing the major gradients of climate in the network, to identify long and short-term trends, to provide reliable climate data to other researchers, and to contribute to larger-scale climate monitoring and modeling efforts.

The specific monitoring objectives of the Climate and Snowpack Vital Sign are:

1. Work with the National Weather Service (NWS) to maintain the integrity of the existing NWS Cooperative sites with long-term weather records located in and adjacent to CAKN. ***Justification:*** *The NWS Coop site at Denali Headquarters has the longest climate record for a high-elevation mountain station on the Pacific coast of North America. Some of the other coop sites in and near CAKN also have long records. These data are extremely valuable as anchor points (in both space and time) as we expand the climate monitoring network in the region.*
2. Record long-term trends in temperature and precipitation through fully instrumented sites placed in the CAKN parks to capture primary gradients in network climate. ***Justification:*** *Measurements of temperature and precipitation will provide information on the primary driver of ecosystems that in turn affects all other components being monitored within the program.*
3. Monitor annual patterns of snowpack extent, depth, and duration within CAKN by working with the USDA-Natural Resources Conservation Service (NRCS) to maintain the integrity of existing seasonal snowpack monitoring snow courses and aerial snow markers within the CAKN parks and to add stations as necessary to improve the spatial coverage of snowpack monitoring within the network.
4. Monitor total annual precipitation and daily accumulation patterns with high accuracy by working with the USDA-NRCS to establish at least one recording precipitation gauge in each CAKN park as part of the SNOw TELemetry (SNOTEL) network. ***Justification:*** *Accurately recording year-round precipitation is extremely challenging. The NRCS has a well designed system (SNOTEL) in place for recording year-round precipitation, and these stations can be placed at carefully selected locations within the network. The SNOTEL sites have proven to be the most accurate instrumented sites to document all forms of year-round precipitation in Alaska, including cumulative snowfall water equivalencies.*

5. Monitor hourly wind speed, solar radiation, and relative humidity at all climate stations established by CAKN to provide information on secondary climate drivers and localized climate. ***Justification:*** *These measurements are standard measurements that can easily be added to an existing station that is recording air temperature and precipitation. These data are useful for a variety of research projects including vegetation studies, avian monitoring, fire ecology, as well as management issues such as building specifications, aviation, and safety.*
6. Maximize the utility of the CAKN climate data for use in analyses of climate and its effect on ecosystems at local to global scales, by making all climate data collected by CAKN available over the Internet in convenient formats in a timely fashion. ***Justification:*** *The CAKN has prioritized the need to monitor the potential of global climate change and climate patterns to influence species and ecosystems within the parks. While the existing long-term dataset at a number of National Weather Service Cooperative Observer Stations in and around DENA, WRST, and YUCH offer a substantial history and a head start toward meeting this objective, additional climate stations will provide more information in the remote areas that lack basic data. These stations, once placed, will provide critical climate information with the intent of operating undisturbed for the next 50–100 years.*

Basic Approach

The basic approach to climate and snowpack monitoring in CAKN will be (1) ensure that long-term NWS and NRCS stations and sites with long data sets continue to operate indefinitely (existing co-op stations, snow courses, aerial snow markers), (2) add snow courses to improve the spatial coverage of snowpack monitoring (3) add fully instrumented climate stations at sites within the three parks to capture a broader range of the extreme climatic gradients found in the network, and (4) establish one to several SNOTEL stations within the network to begin a record of accurate precipitation measurements, and (5) distribute all data electronically through the Western Regional Climate Center web page.

Over the last two years, the network has been researching technical specifications for climate monitoring stations, deploying stations for testing, and analyzing potential sites. Details of climate monitoring equipment were developed through a scoping process with regional experts. Based on our work, we have decided that the standard station will include a ten-foot mast on a tripod base, and utilize a Campbell Scientific Inc. CR10X data logger and Seimac High Data Rate GOES satellite data transmitter. The basic instrumentation of each station will include air temperature, relative humidity, wind speed and direction, and incoming solar radiation. Additional instrumentation on an augmented station includes a tipping bucket rain gauge and acoustic snow depth sensor.

During the summer of 2003, we identified and evaluated a number of potential new climate station sites. These potential new sites were presented to climatologists in multiple agencies for review. SNOTEL sites will also be installed within the three parks. These stations will have the full complement of meteorological sensors plus a year-round precipitation gauge (shielded) that accurately records both snowfall and rainfall. Additional NRCS snow courses or aerial markers will be placed in areas selected by NPS/NRCS staff to complement the climate stations and provide better spatial coverage for snowpack information.

The Western Regional Climate Center (WRCC) will archive and disseminate the data. The hourly data from the automated stations will be disseminated for public viewing and use (in near real-time) via the internet. WRCC maintains a dynamic website complete with data querying capacity. Data products available on the WRCC website are daily summary (with wind chill and heat index), monthly summary, time series graphs, wind rose graphs and tables, data lister, data inventory, and station metadata. We have entered into a MOU with WRCC through which they will develop web-based tools to develop reports and analysis that is specific to each user's needs, as well as a standard template for annual reporting.

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Fiscal Year	Expected Interim Products
FY 2004	Continue field testing of new stations in 5 locations.
FY 2005	Draft protocol completed by December 1, 2004.
	Implement climate stations in summer 2005
	Establish 1 SnoTel site
	Data available on WRCC web site
FY 2006	Implement

Central Alaska Network
Protocol Development Summary

Glaciers

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Protocol: **Monitoring Changes in Glacial Extent and Mass Balance in Central Alaska Parks**

Parks Where Protocol will be Implemented: **DENA, WRST**

Justification/Issues Being Addressed

The CAKN has adopted a holistic view of network ecosystems and will monitor the major physical drivers of ecosystem change and responses of the two major components of the biota: plants and animals. Glaciers and glacier systems are dominant and dynamic physical features of two of the three parks (DENA, WRST) in CAKN, and are a driver of landform and ecosystem change in them. Glaciers are inextricably tied to climate and the hydrological cycle. Because glacier systems are regulated solely by climate fluctuations, they provide a reliable record of long-term climate change that has already occurred. Upper elevation climate is nearly impossible to measure directly and can be well represented by glacier dynamics. Glaciers provide significant hydrologic base flow to major rivers in CAKN parks. Because glaciers are an important driver tied to climate, hydrology, and landform change, CAKN has identified change in glacier extent as a Vital Sign. In general, the CAKN wants to know where glaciers are and to monitor annual changes in their size, as indicated by mass balance, to have early warning of advancing and retreating trends.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The specific monitoring objectives of the Glacier Vital Sign Protocol are:

1. Monitor long-term changes in the location and extent of glaciers in DENA and WRST using aerial photography, satellite imagery, landscape profiling, and field surveys.
2. Monitor mass balance of selected glaciers in DENA and WRST on an annual basis.

Basic Approach

The basic approach will be to continue mass balance measurements at index sites established on glaciers in DENA during the DENA Long-term Ecological Monitoring Program, and to add similar index sites in WRST. Protocol development will continue to determine the best method of monitoring changes in glacial extent. Photographic methods, including use of satellite

imagery, are recognized as a simple but effective method for documenting changes in glacier extent.

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Development Schedule, Budget, and Expected Interim Products

The protocol for monitoring mass balance of glaciers at DENA will be revised to meet NPS requirements (Oakley et al. 2003) and to incorporate new index sites in WRST. A draft protocol for monitoring changes in glacial extent using various photographic methods will be developed.

Fiscal Year	Expected Interim Products
FY 2005	Revise mass balance protocol (December 1, 2004)
FY 2006	Draft glacier extent protocol and implement monitoring

Central Alaska Network
Protocol Development Summary

Disturbance—Volcanoes and Tectonics

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and
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Protocol: Monitoring the Occurrence of Landscape Disturbances Due to Volcanoes and Tectonics

Parks Where Protocol will be Implemented: DENA, WRST, YUCH

Justification/Issues Being Addressed

The Central Alaska Monitoring Network (CAKN) is located in a tectonically active region with major active and dormant volcanoes nearby. DENA and WRST are the most affected, due to their proximity to the fault zones and to the subduction zone for the Pacific Plate. The mountains of WRST include volcanoes (e.g., Mt. Sanford, Mt. Blackburn, Mt. Drum, and Wrangell Mt.). Eruptions of volcanoes (especially those in the Aleutian Arc) can send ash clouds over CAKN parks. Major earthquakes have occurred, including the November 3, 2002, Denali fault earthquake of magnitude 7.9, which was the largest on-land earthquake in North America in 150 years. This earthquake caused significant landscape disturbance in both WRST and DENA, including landslides, along the fault line. The CAKN recognized disturbances from major tectonic and volcanic events as important to montior as part of the Vital Signs program.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The Tectonics and Volcanoes monitoring component of the CAKN Vital Signs monitoring program will use existing sources of information to monitor the occurrence of major earthquakes and volcanic eruptions affecting CAKN parks. The specific monitoring objective is:

1. Monitor the occurrence of major earthquakes centered in the CAKN region using data provided by the USGS-Alaska Science Center, Hazards Office, to provide an annual summary of the number and location of earthquakes for the annual Network report.
2. Monitor the occurrence, timing, and duration of ash clouds from volcanic eruptions passing over CAKN parks using remote-sensed imagery (i.e., MODIS), and air quality data from the DENA air quality monitoring station to provide an annual summary on volcanic inputs for the annual Network report.

Basic Approach

On an annual basis the CAKN will acquire data from the USGS-Alaska Science Center, Hazards Office, to provide an annual summary of the number and location of earthquakes.

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Development Schedule, Budget, and Expected Interim Products

Fiscal Year	Expected Interim Products
FY 2005	
FY 2006	
FY 2007	Protocol development
FY 2008	Protocol development
FY 2009	Draft protocol completed
FY 2010	Implement monitoring

Central Alaska Network
Protocol Development Summary

Permafrost and Thermokarst

Guy Adema, Physical Scientist
Denali National Park and Preserve

Protocol: Monitoring Permafrost and Thermokarst Changes in Central Alaska Parks

Parks Where Protocol will be Implemented: DENA, WRST, YUCH

Justification/Issues Being Addressed

The CAKN has adopted a holistic view of network ecosystems and will monitor the major physical drivers of ecosystem change and responses of the two major components of the biota: plants and animals. An important characteristic of the physical environment of Alaska, including the CAKN parks, is permafrost—soil which remains frozen throughout the year. The three CAKN parks are primarily underlain by warm discontinuous permafrost (in contrast to the deep, continuous permafrost found further north). These parks contain some of the southernmost warm (fragile) permafrost in North America. This permafrost is typically within a few degrees of thawing, and recent measurements show that it has warmed significantly since the late 1980s (Osterkamp, 2003). Thawing permafrost and thermokarst terrain (an irregular topography resulting from thawing of excess ground ice) have also been observed near these parks (Jorgenson et al, 2000; Osterkamp et al, 2000). The predicted climatic warming of the 21st century and observations of currently thawing permafrost near national parks suggest that CAKN park ecosystems may currently be on the cusp of widespread changes. Permafrost is the physical foundation on which the ecosystems in these parks rest. Thawing of ice-rich permafrost changes this foundation. The formation of thermokarst terrain has the potential to partially or completely alter ecosystems. In lowlands, a shift from boreal forests to shrubby wetlands or grasslands often occurs with concurrent changes in bird and animal populations (Jorgenson et al, 2003; Osterkamp, 2003). Monitoring the spatial extent and condition of permafrost and thermokarst in network parks will provide information about what may be one of the most important drivers of landscape change in the next century.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The specific monitoring objectives of the Permafrost Vital Sign are to:

1. Detect broad-scale trends in permafrost condition across the landscape of CAKN parks by monitoring the abundance and distribution of thermokarst and other permafrost-related terrain features in index areas. ***Justification:*** *Permafrost is a condition widespread in CAKN parks, and through interaction with wildland fires, fluvial processes, and vegetation succession, there is a continual flux in the distribution of permafrost. More or less area affected by thermokarst features indicates a change in overall permafrost condition. By monitoring the terrain features related to permafrost condition in index areas in each park, the network will have information on trends in permafrost.*
2. Detect broad-scale trends in permafrost condition across the landscape of CAKN parks by monitoring temperatures in existing boreholes in and near CAKN parks. ***Justification:*** *Permafrost is defined by its temperature and is most often monitored by monitoring temperatures in boreholes. Several existing boreholes are present in the vicinity of CAKN parks, and some prior measurements have been made. Monitoring the temperatures in these boreholes can provide a direct measure of permafrost condition.*

Basic Approach

The basic approach to monitoring permafrost condition will be two-fold: (1) use of aerial photographs of index areas to monitor the number and distribution of thermokarst and permafrost terrain features over time, and (2) use of direct measurements of permafrost temperatures in existing boreholes in and near CAKN parks.

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Development Schedule, Budget, and Expected Interim Products

Existing permafrost monitoring methods and options for monitoring permafrost by the CAKN were evaluated by Karle and Jorgenson (2004), leading to the recommended use of aerial photography for monitoring permafrost terrain features in index areas. A protocol detailing the specific procedures will now need to be developed. In 2005, temperatures will be measured in the existing borehole near Denali to test the feasibility of the using direct temperature measurements.

Fiscal Year	Expected Interim Products
FY 2005	Draft protocol for aerial photo interpretation of permafrost terrain features. Measure temperatures in Denali borehole.
FY 2006	Develop protocol
FY 2007	Implement monitoring

Central Alaska Network
Protocol Development Summary

River and Stream Flow

Karen Oakley, Ecologist
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Protocol: Monitoring Long-term Changes in Amount and Timing of River and Stream Flow

Parks Where Protocol will be Implemented: DENA, WRST, YUCH

Justification/Issues Being Addressed

The CAKN has adopted a holistic view of network ecosystems and will monitor the major physical drivers of ecosystem change and responses of the two major components of the biota: plants and animals. The hydrological cycle is the dominating physical driver, and the network has included several Vital Signs that will monitor the distribution and abundance of water in CAKN ecosystems. These include monitoring of climate (to monitor temperature and precipitation regimes), snowpack, glaciers and permafrost, all of which drive the flow and therefore fate of water on the landscape. Monitoring stream flow will also allow the network to monitor changes in stream flow that result from changes in glacial dynamics and permafrost in the network. Lentic (non-moving) freshwater ecosystems will be monitored through the Shallow Lakes and Ponds Vital Sign. Lotic (moving water) ecosystems will also be monitored, and monitoring of long-term changes in the amount and timing of river and stream flows will be a component of this lotic ecosystem protocol. Monitoring stream flow will allow the network to monitor the environments' ability to store and release water, which may provide important clues to the effect climate change has on park ecosystems. Extreme flooding events are an important disturbance factor in CAKN riparian ecosystems, and an aspect of this protocol will be to monitor the occurrence of major floods. Included with this protocol is the monitoring of the biota in river and stream ecosystems, which are directly affected by all facets of water flow.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The objectives for the CAKN river/stream protocol are:

1. To detect changes in the hydrologic regime; timing of spring-melt, velocity, and extreme high and low water level of CAKN rivers and streams.
2. Determine the composition and spatial distribution of aquatic organisms within rivers/streams selected for sampling.
3. Detect changes in indices of stream productivity.

Basic Approach

The CAKN strategy for river and stream flow monitoring will be to incorporate hydrological monitoring into the overall aquatic monitoring protocol for moving water (lotic) systems. The CAKN is currently in the process of hiring a term Aquatic Ecologist to lead development of the moving water monitoring protocol. This will require additional scoping to finalize objectives and pilot field studies to test sampling methods leading to completion of the protocol by FY2009. A major factor in stream flow monitoring is the cost to install and operate stream gauges, and alternative methods (e.g., pressure transducers, continuous recorders) will be investigated as part of protocol development.

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Development Schedule, Budget, and Expected Interim Products

Fiscal Year	Expected Interim Products
FY 2005	
FY 2006	Protocol development
FY 2007	Protocol development
FY 2008	Draft protocol completed.
FY 2009	Implement monitoring

Central Alaska Network
Protocol Development Summary

Water Quality/Quantity/Macroinvertebrates

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Protocol: Detecting Trends in the Abundance, Size, Distribution, Water Quality, and Biological Communities of Shallow Lake and Pond Systems in the Central Alaska Network

Parks Where Protocol will be Implemented: DENA, WRST, YUCH

Justification/Issues Being Addressed

The CAKN has adopted a holistic view of network ecosystems and will monitor the major physical drivers of ecosystem change and responses of the two major components of the biota: plants and animals. For any ecosystem, the abundance and distribution of water is probably one of the strongest driving forces of ecological change. In this context, the network has decided to approach monitoring water quality by focusing not just on the chemical nature of the water but on the abundance and distribution of water in the landscape. Shallow lakes support abundant growth of lake-bottom and lake-edge plants. The high rates of primary production and the structure and nutrients provided by lake-edge plants provide habitat for macroinvertebrates and rearing areas for waterfowl, shorebirds, and fishes. Thus, the network is interested in the biota living in, near, and dependent on water-dominated parts of the landscape.

The hydrological cycle in the CAKN region involves seasonal snow cover and permafrost, which interact with topography and geology to create vast wetlands characterized by the presence of shallow lake and pond systems. Over the past 20 years much concern has been raised regarding the drying of the shallow lake systems in CAKN parks because they often provide critical wildlife habitat. The natural processes of formation and filling of shallow lake systems is closely tied to permafrost dynamics, and extensive permafrost degradation associated with anthropogenic climate change has been documented in western Canada (Bielman et. al, 2001), Russia (Pavlov, 1994), China (Ding, 1998), Mongolia (Shakuruu, 1998) and interior Alaska (Ostercamp et. al, 2000). Anthropogenic global climate change and the subsequent effects on fire frequency and intensity as well as potential changes in the distribution of permafrost and hydrologic regime may lead to more rapid changes in the size, abundance, or distribution of aquatic resources on the landscape.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The fundamental question to be addressed by this protocol is: Is the surface area, number, and distribution of shallow lake and pond systems changing, and if so, what is happening to the biota that depend on them?

The specific monitoring objectives of the Water Quality Vital Sign are:

1. Detect decadal-scale trends in the size, distribution, and number of shallow lakes and ponds in Central Alaska Network Parks. ***Justification:*** *Shallow lakes and ponds represent a significant proportion of the non-flowing waterbodies in CAKN parks, and they are a dominant feature of vast wetland and river bottom acreages in these parks. They provide important habitats for wetland plants, wildlife, and fish. Detecting a trend in their sizes, distribution and numbers across the landscape will provide the network with critical information about trends in water quantity and on overall wetlands habitat condition.*
2. Detect decadal-scale trends in the water quality (chemistry) of shallow lakes and ponds in Central Alaska Network Parks. This objective includes monitoring four core variables as directed by the NPS Water Resources Division, including including temperature, turbidity, pH and dissolved oxygen. ***Justification:*** *Knowing the quality of water is a fundamental goal of the Vital Signs monitoring program. Water chemistry provides important information on the condition of shallow lakes and ponds. Such data may indicate if change is taking place at local or larger spatial scales.*
3. Detect decadal-scale trends in the structure and composition of vegetation in shallow lake and pond margins in Central Alaska Network Parks. ***Justification:*** *Because they are shallow, shallow lakes and ponds provide habitat for submerged and emergent plants. These plants provide physical habitat structure for pond communities, as well as food. Monitoring changes in plant communities of shallow lakes and ponds is important to understanding how changes in the physical environment affect biological communities.*
4. Detect decadal-scale trends in species richness and abundance of macroinvertebrate taxa in shallow lake and pond ecosystems in Central Alaska Network Parks. ***Justification:*** *Macroinvertebrate communities of flowing and non-flowing waters are excellent indicators of waterbody type and condition and are used worldwide as water quality indicators. The macroinvertebrates of shallow lakes and ponds of CAKN are an important food source for mammals and birds. Monitoring changes in these communities will provide information about the biotic responses to changes in these important freshwater habitats.*

Basic Approach

The basic approach the network will take is to use some form of remote imagery to monitor the number, size, and distribution of shallow lakes and ponds on a landscape scale (Objective

1), and to conduct on-the-ground field sampling at a subset of lakes to monitor water quality and macroinvertebrate and plant communities (Objectives 2, 3, and 4). This network-wide sampling scheme will be allow us detect changes in 1) the quantity of water by measuring size, number, and distribution, and 2) the quality of water by measuring water chemistry and biotic indicators.

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Development Schedule, Budget, and Expected Interim Products

We have set up a cooperative agreement with Dr. Dave Verbyla at the University of Alaska Fairbanks to determine the appropriate sampling regime for remotely monitoring lake ecosystem dynamics. We are currently experimenting with using RADARSAT images to measure water quantity across the landscape. We have also set up a cooperative agreement with HartCrowser Inc. to determine appropriate sampling protocols for monitoring water chemistry, water level, vegetation, and macroinvertebrates in shallow lake ecosystems.

The protocol will be developed on the following schedule:

Fiscal Year	Expected Interim Products
FY 2005	Protocol completed. Contract report on use of RADARSAT. Contract report on water quality, vegetation, macroinvertebrates sampling protocols. Initiate field sampling at 2 network sampling panels
FY 2006	Implement monitoring

Central Alaska Network
Protocol Development Summary

Exotic Species

Karen Oakley, Ecologist
Biological Resrouces Division, USGS

Protocol: Detecting Presence of Exotic Plant and Animal Species in Central Alaska Network Parks

Parks Where Protocol will be Implemented: DENA, WRST, YUCH

Justification/Issues Being Addressed

The Central Alaska Monitoring Network (CAKN) identified global industrialization and regional and local human activities in and near parks as important stressors affecting park ecosystems. One of the most significant threats to park resources due to these pressures is introduction of exotic species, both plant and animal, through global commerce and travel. Although Alaska seems remote, the potential for exotic species introductions is there and may be increasing due to a warming climate. Preliminary surveys for exotic plants in Alaska parks, including WRST, have been conducted recently, finding several weed species (Densmore et al. 2001). Disturbed areas (such as roadsides and airstrips) have high potential for initial establishment of exotic plants, and river corridors, which are naturally disturbed, may provide avenues for spreading. Animal introductions are also a concern, especially the potential for Atlantic salmon introduction into the Copper River system of WRST. All exotic introductions are of concern for their potential to disrupt natural communities and ecosystem structure and function.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The Exotic Species monitoring component of the CAKN Vital Signs monitoring program is focused on providing early warning of the presence of exotic species so park managers can implement management strategies to eradicate or minimize their effects. Specific monitoring objectives are:

1. Detect the presence of exotic plant species in CAKN parks through regular surveys in areas of high human or natural disturbance or areas of known potential for supporting exotic species. ***Justification:*** *The Vegetation Structure and Composition Vital Sign will collect data on the flora of CAKN parks in a randomized design that will emphasize common species. This approach will build knowledge about the overall composition and distribution of the flora. Targeted surveys will be needed to detect*

the presence of exotic plant species to provide early warning of their occurrence.

2. Maintain awareness of the range extensions for exotic terrestrial and aquatic vertebrate species in CAKN parks through annual coordination with existing state and federal monitoring programs. ***Justification:*** *The State of Alaska Department of Fish and Game is concerned with exotic animal introductions and is the primary source of information on the status of exotic animals in marine and terrestrial habitats of Alaska. Annual communication with the ADF&G and other entities about the status of exotic and introduced species ranges in Alaska will be maintained to learn of imminent threats to CAKN parks.*

Basic Approach

The general strategy the network will use to monitor the Exotic Species Vital Sign will be two-fold. For exotic plants, regular surveys in targeted habitats will be conducted to augment the vegetation sampling that will occur in the Vegetation Structure and Composition Vital Sign. For exotic animals, the main strategy will be to rely on the Alaska Department of Fish and Game and other sources for general information about range changes and introductions of animal species. The annual network report will include updated information on exotic animals of potential concern to CAKN parks. When information from the ADF&G suggests that an exotic animal species may be extending its range into a CAKN park, park managers will be alerted so that appropriate action can be taken.

Principal Investigators and NPS Lead

Exotic Plants
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Exotic Animals
To be determined.

Development Schedule, Budget, and Expected Interim Products

Fiscal Year	Expected Interim Products
FY 2005	
FY 2006	
FY 2007	Protocol development.
FY 2008	Draft protocol completed.
FY 2009	Implementation

Central Alaska Network
Protocol Development Summary

Forest Insect Outbreaks

Jennifer Allen, Regional Fire Ecologist
Alaska Region, National Park Service
and
Karen Oakley, Ecologist
Biological Resources Division, USGS

Protocol: Disturbance Monitoring: Monitor Location and Duration of Tree and Shrub Mortality and Defoliation from Major Insect Outbreaks in Central Alaska Network Parks

Parks Where Protocol will be Implemented: **DENA, WRST, YUCH**

Justification/Issues Being Addressed

The CAKN has adopted a holistic view of network ecosystems and will monitor the major physical drivers of ecosystem change and responses of the two major components of the biota: plants and animals. In addition, the network is interested in biotic interactions (i.e., relationships between plants and animals) that have widespread ecosystem-level effects. Insect outbreaks in the forested portions of CAKN parks are such a biotic interaction. Boreal forests are subject to a variety of natural insect disturbances, including mortality events caused by spruce bark (*Dendroctonus rufipennis*) and engraver (*Ips perturbatus*) beetle outbreaks, as well as defoliation events from larch sawfly, aspen leaf miners, birch leaf roller, and willow leaf blotch miner. All of these insects are known to occur within the Central Alaska Network (CAKN) parks, and recent epidemic levels of spruce bark beetle in south-central Alaska, including WRST, have caused large-scale mortality of white spruce (*Picea glauca*) over the past decade. At a stand level, bark beetles have a substantial effect on stand structure and composition and possibly increase fire hazards due to changes in fuel loading. Spruce bark beetle epidemics can influence the distribution and heterogeneity of vegetation at a landscape level and may affect wildlife habitat and use. Defoliator outbreaks can occur on vast acreages with nearly every tree in a stand affected to varying degrees. In interior Alaska, including DENA, large areas of larch (*Larix laricina*) died due to heavy defoliation by larch sawflies over the past four years. Defoliators are ecologically important because larvae provide a food source for some bird species, although the loss of canopy cover may increase bird predation; the loss of overstory can increase sunlight exposure to streams, affecting the aquatic environment.

Forest insects respond quickly to changes in climate. Major changes in the distribution and abundance of insect species may occur in the CAKN with changes in climate. In addition, several species of invasive (non-native) forest insects have become established in Alaska. Baseline monitoring of insect disturbances in the Central Alaska Network is important to understand landscape and stand level changes in the vegetation and fuels structure due to insect disturbances.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The basic monitoring question we would like to address with this protocol is: what type, extent, and frequency of forest insect outbreaks occur within the three parks?

The following objective is proposed for the forest insect monitoring protocol: determine the annual variation and long-term trends in the extent (acreage) and frequency (return interval) of forest insect outbreaks within the three network parks.

Basic Approach

Broad-scale mapping of insect disturbances can be used to monitor the distribution and extent of insect disturbances in the CAKN parks. The USDA Forest Service-Alaska Region and State of Alaska conduct aerial detection mapping annually to document the extent and intensity of active forest insects and disease throughout large areas of the state (USDA 2004). Mapping is done through aerial sketch mapping from a fixed wing aircraft, usually at a 1:250,000 scale. Insect or disease type is identified, and a level of intensity is applied. Polygon-based GIS map products are produced annually, along with an annual Forest Health Condition Report. Currently, the following portions of the CAKN are mapped: WRST: Copper River, Chitina River, and McCarthy Corridor; YUCH: Yukon River, Charley River, Nation River, Kandik and Tatonduk Rivers; DENA: Kantishna-Minchumina Basin area. Requests can be made to map additional areas or specific areas of interest. It is recommended that the survey areas be assessed to determine if there are additional areas that should be mapped within the parks. This data can be used to summarize the total acres affected by specific insects or disease within the surveyed areas of the parks, trends or differences can be detected among parks or areas within the parks.

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Development Schedule, Budget, and Expected Interim Products

Fiscal Year	Expected Interim Products
FY 2005	Develop protocol
FY 2006	Write protocol
FY 2007	Implement monitoring

Central Alaska Network
Protocol Development Summary

Freshwater Fish

Karen Oakley, Ecologist
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Protocol: Monitoring the Distribution and Abundance of Freshwater Fish including Salmon

Parks Where Protocol will be Implemented: DENA, WRST, YUCH

Justification/Issues Being Addressed

The CAKN has adopted a holistic view of network ecosystems and will monitor the major physical drivers of ecosystem change and responses of the two major components of the biota: plants and animals. Thus, the CAKN has identified *Fauna Distribution and Abundance* as one of its top three Vital Signs. In general, the CAKN wants to know where fauna are distributed across the landscape and to monitor changes in both their distribution and abundance. For terrestrial species, the *Fauna Distribution and Abundance* Vital Sign comprises monitoring efforts for a suite of vertebrate species spanning the significant elevation gradient found in CAKN parks and also including species of particular interest within each park. For aquatic species, the *Fauna Distribution and Abundance* Vital Sign comprises monitoring efforts for freshwater (including anadromous) fishes. Freshwater fish are important members of aquatic communities in CAKN parks. Anadromous fish (salmon) are especially important, occurring in all three parks, where they migrate, spawn, and rear young. Salmon, by bringing marine-derived nutrients into the terrestrial environment (Cedarholm et al. 1999, Gende et al. 2002), are considered a keystone species in the network, although the specific role of salmon in each park is somewhat different (YUCH: mainly a migration corridor; DENA: late fall spawning chum salmon provide critical wildlife food; WRST: critical for subsistence fisheries and ecosystem food chains). The CAKN is interested in developing monitoring protocols concerning freshwater fishes, including salmon, because they are important indicators of change in aquatic systems and valuable resources to be protected and managed by parks.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The CAKN is still scoping the specific monitoring objectives to be achieved by this protocol (see below).

Basic Approach

The CAKN strategy for fish monitoring will be to incorporate fish sampling into the overall aquatic monitoring protocol for moving water (lotic) systems. The CAKN is currently in the process of hiring a term Aquatic Ecologist to lead development of the moving water monitoring protocol. This will require additional scoping to finalize objectives and pilot field studies to test sampling methods, leading to completion of the protocol by FY2009.

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Development Schedule, Budget, and Expected Interim Products

Fiscal Year	Expected Interim Products
FY 2005	
FY 2006	Protocol development
FY 2007	Protocol development
FY 2008	Complete protocol .
FY 2009	Implement monitoring.

Central Alaska Network
Protocol Development Summary

Bald Eagles

Carol McIntyre, Wildlife Biologist
Denali National Park and Preserve

Protocol: Monitoring the Spatial and Temporal Trends of the Breeding Population of Bald Eagles (*Haliaeetus leucocephalus*) in Wrangell-St. Elias National Park and Preserve, Alaska.

Parks Where Protocol will be Implemented: WRST

Justification/Issues Being Addressed

The CAKN has adopted a holistic view of network ecosystems and will monitor the major physical drivers of ecosystem change and responses of the two major components of the biota: plants and animals. Thus, the CAKN has identified *Fauna Distribution and Abundance* as one of its top three Vital Signs. In general, the CAKN wants to know where fauna are distributed across the landscape and to monitor changes in both their distribution and abundance. The *Fauna Distribution and Abundance* Vital Sign comprises monitoring efforts for a suite of vertebrate species spanning the significant elevation gradient found in CAKN parks and also including species of particular interest within each park. The Copper River in WRST contains a high density of nesting bald eagles in interior Alaska; accordingly, the CAKN technical committee identified bald eagles as a focal faunal species to monitor in Wrangell-St. Elias National Park and Preserve (WRST). Bald eagles in WRST are a high profile species that are dependent upon many resources along the Copper River and are ecologically interesting because they nest at the northern edge of the species range. Bald eagles are top-trophic level predators, and they often respond quickly to changes in their environment by changing their breeding activities. Further, bald eagles nesting along the Copper River in WRST may face increasing disturbance due to forestry activities and increased human visitation.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

Our primary interest in monitoring bald eagles is to know if the number of nesting birds or their demography is changing. We also are interested in contaminant levels in eggs and eggshell thickness.

The specific monitoring objectives are:

1. Determine annual levels of nesting territory occupancy, nesting success, and overall population productivity of bald eagles in WRST. ***Justification:*** *Occupancy of nesting territories is an index of population stability. Nesting success and productivity are important measures of population health and indicators of density*

dependent responses to increases in population size and nearest-neighbor distances.

2. Describe historic levels and monitor current levels of environmental contaminants (including mercury) and eggshell thickness every five years for bald eagles in WRST. ***Justification:*** *The continual introduction of anthropogenic chemicals into the environment far outpaces research on their effects on bald eagles and other wildlife and therefore warrants continued monitoring in WRST.*

Basic Approach

The main objectives of our monitoring plan are to detect changes in nesting territory occupancy, nesting success, mean brood size, and overall population productivity and to monitor the levels of environmental contaminants (organochlorine chemicals and mercury) and eggshell thickness. Our goal is to obtain population estimates, demographic parameter estimates, and contaminants analysis with low (or no) bias and high precision using cost-effective and logistically feasible methods (Thompson et al. 1998).

Sampling area: The sampling area will be the Copper River from Copper and Tanada lakes south to Miles Lake. Based on physiographic differences, the Copper River basin will be divided into three sub-basins: the Upper, Middle, and Lower Copper Rivers (following Steidl et al. 1997).

Data collection: We will use two aerial surveys each year to assess nesting territory occupancy, nesting success, and productivity. An experienced wildlife pilot and an experienced observer will conduct the aerial surveys using a small fixed-wing aircraft. Occupancy and breeding activity surveys will be flown in mid-May to determine which territories are occupied and which contain breeding pairs. The productivity survey will be conducted in late July or early August to determine the number of occupied territories with fledglings. The timing of the surveys follows Steidl et al. (1997). Contaminants levels will be assessed using feather, blood, and egg samples on a five year interval.

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Development Schedule, Budget, and Expected Interim Products

National-, regional-, and local-level protocols already exist for documenting nesting territory occupancy, nesting success and productivity, and for quantifying environmental contaminants and eggshell thickness. Additional protocol development will consist of writing a protocol that meets NPS standards (Oakley et al. 2003) and developing a protocol for database management and data analysis. We will need to write new sections in the protocol to meet any sampling requirements and to make the standard protocol specific to WRST including database management, data analysis, and reporting. This includes describing sampling locations and documenting how the data are entered in NPS computerized databases, how data are analyzed, and what is expected in annual and contaminant-related reports. The principal investigators will produce a draft bald eagle monitoring protocol ready for external review by November 1, 2004. After peer review, revision, and approval, we hope to implement this as our second raptor monitoring protocol in spring 2006.

Fiscal Year	Expected Interim Products
FY 2005	Begin development of protocol. Assessment of parameter variation from historical data (determines sampling interval) (Feb. 2005)
FY 2006	Complete protocol
FY 2007	Implement monitoring in WRST

Central Alaska Network
Protocol Development Summary

Golden Eagles

Carol McIntyre, Wildlife Biologist
Denali National Park and Preserve

Protocol: Monitoring the Spatial and Temporal Trends of the Breeding Golden Eagle (*Aquila chrysaetos*) in Denali National Park and Preserve, Alaska.

Parks Where Protocol will be Implemented: DENA

Justification/Issues Being Addressed

The conceptual model of the CAKN is based on a holistic view of network ecosystems and the desire to know where fauna are distributed across the landscape and the abundance of those fauna. This primary interest by parks in fauna is reflected in networks' selection of *Fauna Distribution and Abundance* as one of its top three Vital Signs. The *Fauna Distribution and Abundance* Vital Sign comprises monitoring efforts for a suite of vertebrate species at low and high elevations while also including species of particular interest within each park. Golden eagles are a focal species of interest for Denali National Park and Preserve (DENA) because the park contains the highest reported density of nesting golden eagles in North America. As with the other raptor species identified under this Vital Sign, golden eagles are top trophic-level predators, and they respond quickly to changes in their environment by changing their breeding activities. Long-term studies in DENA (1987–present) provide the only contemporary data on reproductive characteristics of a large migratory population of this species in northern North America. Data collected in DENA is directly comparable to the only other long-term data set for this species in North America, collected in the Snake River Birds of Prey National Conservation Area. Park management issues require contemporary information on location and status of nesting territories and nest sites. Golden eagles are on Audubon Alaska's Watchlist due to vulnerability of winter range due to loss of habitat and small population size.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

Monitoring questions we would like to address with the protocol include:
Is occupancy of nesting territories or their productivity changing? Is the timing of nesting changing? Do sympatrically nesting gyrfalcons (*Falco rusticolus*) exhibit similar reproductive characteristics as golden eagles?

Our objectives are to:

1. Measure annual occupancy of nesting territories and reproductive success (laying rate, success rate, mean brood size, and overall population productivity) of golden eagles in the northeastern portion of Denali and a comparison study area 80 km east of Denali. ***Justification:*** *Nesting territory occupancy provides an index of population stability. Measures of reproductive success provide insight into changes in breeding area including prey abundance and availability and habitat change. Additional research questions include identifying the factors that influence these trends.*
2. Measure annual occupancy of nesting territories and reproductive success (laying rate, success rate, and overall population productivity) of gyrfalcons in the northeastern portion of Denali. ***Justification:*** *Many gyrfalcons nest in proximity to golden eagles and monitoring reproductive success of this species can be accomplished with little added cost. Gyrfalcons are currently a species of conservation concern in Alaska (Boreal Partners in Flight) because Alaska contains the only breeding populations of this species in the United States.*

Basic Approach

Measuring occupancy of nesting territories and reproductive success of golden eagles and gyrfalcons will involve two annual aerial surveys conducted by a small helicopter (McIntyre and Adams 1999). The first survey will be conducted in late April to determine occupancy of nesting territories and document breeding activities at all known nesting territories within the sampling area. The second aerial survey will be conducted in late July to determine nesting success and document fledgling production. The sampling area will be the northeastern portion of DENA where monitoring of these species has occurred annually since 1987.

Assessing sources of variation: As part of developing the monitoring protocol for golden eagles in DENA, we will address sources of variation that affect our monitoring effort including sampling variation, temporal variation, and spatial variation (Thompson et al. 1998). These efforts will include quantifying the temporal variation in the population and the range of variation in nesting territory occupancy, nesting success, and productivity.

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Development Schedule, Budget, and Expected Interim Products

Methodology for determining nesting territory occupancy and reproductive success already exist (Swem et al. 1994, Steenhof et al. 1997, McIntyre and Adams 1999). Therefore, no additional field work is necessary to develop methods to determine nesting territory occupancy and reproductive success. Protocol development will consist primarily of writing a protocol that meets NPS standards (Oakley et al. 2003) and incorporates standard protocols. Additional work is needed for developing relational databases and assessing analytical techniques for determining long-term trends. Additional field work is necessary to quantify sampling error. The principal investigators will produce a draft golden eagle monitoring protocol ready for external review by November 1, 2004.

Fiscal Year	Expected Interim Products
FY 2005	Assessment of parameter variation from historical data (determines sampling interval) (Oct. 2004)
	Golden eagle protocol complete (Nov. 2004)
FY 2006	Conduct golden eagle monitoring in DENA

Central Alaska Network
Protocol Development Summary

Peregrines

Carol McIntyre, Wildlife Biologist
Denali National Park and Preserve

Protocol: Population Trends of Nesting Peregrine Falcons (*Falco peregrinus anatum*) in Yukon-Charley Rivers National Preserve, Alaska.

Parks Where Protocol will be Implemented: YUCH

Justification/Issues Being Addressed

The CAKN has adopted a holistic view of network ecosystems and will monitor the major physical drivers of ecosystem change and responses of the two major components of the biota: plants and animals. Thus, the CAKN has identified *Fauna Distribution and Abundance* as one of its top three Vital Signs. In general, the CAKN wants to know where fauna are distributed across the landscape and to monitor changes in both their distribution and abundance. The *Fauna Distribution and Abundance* Vital Sign comprises monitoring efforts for a suite of vertebrate species spanning the significant elevation gradient found in CAKN parks and also including species of particular interest within each park. The Yukon-Charley National Preserve (YUGA) was created by the Alaska National Interest Lands Conservation Act in 1980 in part because of its population of nesting peregrine falcons (*Falco peregrinus anatum*), making them a high priority focal species for monitoring. Focal raptor species will also be monitored in the other network parks (golden eagles in DENA and bald eagles in WRST; please see Protocol Development Summaries for those species). Besides monitoring the species because of enabling legislation, it makes ecological sense to monitor this species because peregrines are a top trophic-level predator that responds quickly to changes in the environment as well as being highly sensitive to environmental contaminants and habitat alteration. Moreover, the peregrine population of YUCH is the focus of one of the longest term population dynamics studies of this species in the world.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

Fundamentally our question is to know if the number of peregrines nesting in YUCH is changing and if their demographics are changing. Based on historic contaminant issues with the species, we also want to know if contaminant levels in eggs or eggshell thickness is changing.

Our objectives are to:

1. Determine annual levels of nesting territory occupancy, nesting success, and overall population productivity. ***Justification:*** *Occupancy of nesting territories is an index of population stability. Nesting success and productivity are important measures of population health and indicators of density dependent responses to increases in population size and nearest-neighbor distances.*
2. Determine variation in nesting territory occupancy, nesting success, and productivity during the last decade. ***Justification:*** *Quantification of variation in these parameters is needed to develop realistic monitoring goals for the future.*
3. Describe historic levels of environmental contaminants and eggshell thickness. Determine levels of organochlorine pesticides, mercury, and eggshell thickness every five years. ***Justification:*** *Current levels of organochlorine pesticides and their residuals in peregrine falcons in Alaska are low enough to allow for successful reproduction and expansion of the populations (US Fish and Wildlife Service 2003). However, current levels of mercury in peregrine falcons in YUCH can affect reproduction and may have increased over time (Ambrose et al. 2000). The continual introduction of anthropogenic chemicals into the environment far outpaces research on their effects on peregrines and other wildlife and therefore warrants continued monitoring in YUCH (U.S. Fish and Wildlife Service 2003).*
4. Measure changes in habitat on the breeding ranges. ***Justification:*** *Peregrine falcons are very adaptable to changes in their habitat (U.S. Fish and Wildlife Service 2003); however, large-scale changes in their breeding habitat could negatively affect the individual pairs and/or portions of the breeding population.*

Basic Approach

Our basic approach for monitoring the population dynamics and environmental contaminants will follow guidelines established in the monitoring plan for the American peregrine falcon (U.S. Fish and Wildlife Service 2003). However, for population dynamics, we recommend a sampling interval of every year instead of every three years to maintain the consistency of the existing long-term data set. In addition, annual surveys provide more accurate data than intermittent (once every three years) surveys (S. Ambrose, personal communication). Collecting data on nesting territory occupancy, nesting success, and productivity would require two annual surveys conducted via boat on the upper Yukon River. Collecting data on environmental contaminants would require visiting nests to collect blood samples, feather samples, and eggs at a sample of occupied nesting territories and the required analysis of those samples.

Assessing sources of variation: As part of developing the monitoring protocol for peregrine falcons in YUCH, we must address sources

of variation including sampling variation, temporal variation, and spatial variation (Thompson et al. 1998). For instance, the national monitoring plan for peregrine falcons is designed to achieve an 80% probability (ß = 0.20) of detecting a decline of 12.5 percentage points in territory occupancy and nest success after the first sampling occasion with a Type I error of 10% (α = 10; i.e., there is a 100% chance that the data will indicate a declining trend in nest success or territory occupancy > 12.5 percentage points when, in fact, there is no such decline occurring). Before adopting this national standard, we suggest that we assess the variation in the known peregrine falcon population for the past ten years. To determine the level of change in population size that should receive our attention and suggest management action, first we need to quantify the temporal variation in the population.

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Development Schedule, Budget, and Expected Interim Products

National-, regional-, and local-level protocols already exist for documenting nesting territory occupancy, nesting success and productivity and for quantifying environmental contaminants and eggshell thickness. However, protocol development will include assessment and quantification of variation of nesting territory occupancy, nesting success, and productivity (see above) and description of known and expected levels of environmental contaminants and eggshell thickness before setting the long-term monitoring objectives. This will require additional analysis of the historical data set and some new fieldwork to assess sightability probabilities and precision of estimates of nesting territory occupancy, nesting success, and productivity. Additional protocol development will consist of writing a protocol that meets NPS standards (Oakley et al. 2003) and developing a protocol for database management and data analysis. We will need to write new sections in the protocol to meet any sampling requirements and to make the standard protocol specific to YUCH including data base management, data analysis, and reporting. This includes describing sampling locations and documenting how the data are entered in NPS computerized databases, how data are analyzed, and what is expected in annual and contaminant-related reports.

Fiscal Year	Expected Interim Products
FY 2005	Peregrine protocol complete (Dec. 2004). Assessment of parameter variation from historical data (determines sampling interval) (Feb. 2005)
FY 2006	Initiate peregrine monitoring in YUCH

Central Alaska Network
Protocol Development Summary

Passerine Birds

Carol McIntyre, Wildlife Biologist
Denali National Park and Preserve

Protocol: Monitoring Landbirds in CAKN: Population Trends of Common Species, Community Structure and Distribution, and Ecology of Species of Conservation Concern

Parks Where Protocol will be Implemented: **DENA, WRST, YUCH**

Justification/Issues Being Addressed

The Central Alaska Monitoring Network (CAKN) selected *Fauna Distribution and Abundance* as one of its top three Vital Signs. The *Fauna Distribution and Abundance* Vital Sign comprises monitoring efforts for a suite of vertebrate species at low and high elevations and includes passerine birds at both elevations. Passerine birds comprise more than 50% of the bird species in the CAKN. Passerines are an important component of park ecosystems, and their high body temperature, rapid metabolism, and high ecological position in most food webs make them a good indicator of the effects of local and regional changes in ecosystems (Fancy and Sauer 2000). Of all the vertebrates that occur in CAKN, passerines are easy and economical to detect (easy to identify and locate), and a single survey can cover many species. Passerines include a wide variety of species that occupy many habitats over many environmental gradients and may represent unique response variables relative to changes in vegetation. Park managers continually need information on wildlife and wildlife habitat in response to increasing pressures to develop more visitor services or to protect existing undeveloped areas from future impacts. Passerines come under the legal mandate related to the Migratory Bird Treaty Act, and many are key species for education and public awareness. By monitoring passerine species, the CAKN can contribute to park-related, statewide, national, and international programs to understand changes due to global industrialization and other factors.

In 2001, the passerine monitoring program of the Denali Long-term Ecological Monitoring Program (Denali LTEM) began a pilot study to assess the feasibility of integrating passerine monitoring with vegetation monitoring in Denali (Roland et al. 2003). The integrated programs used a probability based sampling design with permanently marked sampling points co-located for both vegetation and passerine sampling. Based on the apparent success of our pilot study, we are proposing to integrate the passerine monitoring

program with the vegetation monitoring program in the CAKN. Examining changes in the structure of passerine communities or changes in passerine demography in relation to changes in vegetation structure and composition provides us with a unique opportunity to examine ecological patterns and processes in CAKN.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The landbird monitoring component of the CAKN Vital Signs monitoring program has four objectives:

1. Population Trends of Common Species. Monitor population trends of common passerine species during the breeding season in each network park with methods that also allow the data to contribute to detection of statewide trends.
2. Community Composition and Distribution. Detect long-term changes in the distribution and composition of breeding passerine bird communities in each network park in relation to changes in their habitats.
3. Integration. Using data from the vegetation and other components of the CAKN Vital Signs monitoring program, develop and update habitat models for common passerine species and for species of conservation concern. Link changes in passerine abundance and distribution to changes in vegetation and other environmental attributes. These linkages will provide insight into the relationships among ecosystem components.
4. Ecology of Species of Conservation Concern. For passerine bird species of conservation concern (due to declining population trends) within Alaska/western Canada, provide demographic information and detect changes in demographic parameters for selected populations within CAKN parks. Current species of conservation concern include olive-sided flycatcher, gray-cheeked thrush, arctic warbler, blackpoll warbler, and rusty blackbird.

Basic Approach

The basic approach of the CAKN landbird monitoring effort will be to integrate Objectives 1-3 with vegetation monitoring by co-locating sampling points using the minigrid sampling design (Roland et al. 2003) because these are extensive scale objectives where the inference scale is the entire park landscape. The minigrid sample design consists of a grid of plots spaced at 20 km intervals across a park landscape. Each plot is composed of 25 individual sampling points spaced 500 m apart. Because this is a random sampling design, we can make inferences to the entire sampling universe. To meet Objective 4, we will monitor the targeted species in a more intensive type of effort.

We will use variable circular points (VCPs) with distance sampling to describe overall distribution and relative abundance. We will also continue to contribute to the National Breeding Bird Survey (BBS) program by conducting the BBS routes established in DENA/WRST/YUCH.

To meet Objective #4, different methods will be required. Species presence or relative abundance may not be accurate measures of long-term persistence or viability (Perkins et al. 2003). Demographic information can be useful for identifying mechanisms associated with changes in density and estimating and predicting trends in the numbers and status of passerine birds (McEachern 2000). To provide estimates of demographic parameters, we will use mist-netting and banding/color-banding, nest searching, territory mapping, and nesting success studies. Many of these techniques already exist and are easily transferable to studies in the CAKN. We recommend using constant-effort mist netting for capture-recapture studies, but we caution against using a standard MAPS protocol in CAKN because sample sizes obtained through this methodology may not be adequate to estimate or detect changes in demographic parameters (DeSante et al. 2003).

Additionally, the sampling frame for specific species of conservation concern will include specific habitats where these species occur (i.e., alpine tundra, boreal wetlands, and boreal forests). Within these habitats, we will employ a probability-based sampling design for sampling populations and measuring demographic parameters of individual species.

Frequency of sampling: We are recommending a rotating panel design for sampling VCPs. A subset of VCPs will be sampled every year to obtain enough data to develop a temporal trend. Another subset of VCPs will be sampled on a longer interval to continue to establish a database on the distribution of passerines within the sampling universe. We recommend annual sampling for estimating and detecting trends in demographic parameters.

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Development Schedule, Budget, and Expected Interim Products

Regional- and national-level protocols already exist for estimating abundance, describing distribution, developing habitat association models, and assessing population demographics and trends. Regional programs are also available for training surveyors in identification of Alaska passerines by sight and sound and distance sampling.

Fiscal Year	Expected Interim Products
FY 2005	Passerine protocol complete (Dec. 2004). Assessment of interseasonal variation across habitat (determines temporal sampling interval) (Feb. 2005)
FY 2006	Initiate passerine monitoring in YUCH
FY 2007	
FY 2008	Initiate passerine monitoring in WRST

Central Alaska Network
Protocol Development Summary

Ptarmigan

Karen Oakley, Ecologist
Biological Resources Division, USGS

Protocol: Ptarmigan Population Trends

Parks Where Protocol will be Implemented: DENA, YUCH, WRST

Justification/Issues Being Addressed

The Central Alaska Network has selected Fauna Distribution and Abundance as one of its top three Vital Signs (along with Climate and Vegetation Structure and Composition). Fauna species to be monitored include a suite of bird and mammal species, in addition to fish. Terrestrial species to be monitored as part of the Fauna Vital Sign were selected to include both high and low elevation species and both herbivores and predators. This protocol addresses ptarmigan. Ptarmigan are grouse-like birds that reside permanently in network parks. There are three ptarmigan species: the willow ptarmigan (*Lagopus lagopus*), rock ptarmigan (*L. mutus*) and white-tailed ptarmigan (*L. leucurus*). Willow ptarmigan is the most numerous and widespread of these species and during winter eats mainly willows (*Salix* spp.). They are common in the subalpine and shrubby habitats of all three network parks. The other ptarmigan species (rock ptarmigan and white-tailed ptarmigan) occur in rocky habitats and generally higher elevations.

Ptarmigan are of interest to the network because they play an intermediary role in the food webs of Central Alaska Network park ecosystems. They are herbivorous, eating mainly willows (*Salix* spp.), and adults, eggs and chicks are eaten by a wide variety of predators. These predators include: golden eagles (*Aquila chrysaetos*), gyrfalcons (*Falco rusticolus*) and other raptors; wolverines (*Gulo gulo*), wolves (*Canis lupus*), red fox (*Vulpes vulpes*), and lynx (*Felis lynx*). The eggs and chicks are eaten by a wider variety of predators including smaller avian and mammalian predators (e.g., black-billed magpies, least weasel). Willow ptarmigan populations fluctuate, and periods between population highs range from eight to 11 years (Mossop 1994, Hannon et al. 1998). Their populations appear to rise and fall in synchrony with snowshoe hares (Hannon et al. 1998, McIntyre and Adams 1999). The mechanism for this cycling is not known—the leading hypothesis is that predators dependent on snowshoe hare switch to alternative prey, such as willow ptarmigan, as hare populations crash (Hannon et al. 1998). Monitoring the general trend of the ptarmigan populations

provides important information about a major part of the terrestrial ecosystem of Central Alaska Network parks.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The objective of this protocol is to annually determine the general population trend (high, low, declining, or increasing) of willow ptarmigan throughout the Central Alaska Network parks.

Basic Approach

The basic approach will be to adapt aerial line transect survey methods developed in Yukon Territory, Canada, by Pelletier and Krebs (1997) for use in the Central Alaska Network. Historically, ptarmigan have been censused (counted) in small areas, but due to great variation in ptarmigan populations among locales, counts based on surveys in small areas do not reflect the true status of populations in the larger area. Pelletier and Krebs (1997) experimented with aerial line transect methods for monitoring ptarmigan populations in extensive areas. They concluded this methodology was appropriate and useful for estimating breeding density of male ptarmigan.

In CAKN, ptarmigan surveys would be flown using fixed-wing aircraft during spring, mostly likely between late April and early June, when males return to their breeding areas. Pilot studies will be required to determine appropriate timing, detection functions, and spatial extent of surveys in network parks. The pilot studies will also generate data to help determine the frequency of surveys (i.e., annual, biennial, etc.) needed to monitor general population trends. Our intent is to develop cost-effective and efficient survey methodology to provide estimates with little (or no) bias. We expect that ptarmigan surveys will require a similar in level of effort to the snow course surveys.

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Development Schedule, Budget, and Expected Interim Products

Protocol development for ptarmigan population trend monitoring will require two to three years of pilot study. The startup date for commencement of work on this protocol has not been established yet.

Central Alaska Network
Protocol Development Summary

Arctic Ground Squirrels

Carol McIntyre, Wildlife Biologist
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Protocol: Monitoring the Population Trends of Arctic Ground Squirrels (*Spermophilus parryii*) in Denali National Park and Preserve and Wrangel-St. Elias National Park and Preserve, Alaska

Parks Where Protocol will be Implemented: DENA/WRST

Justification/Issues Being Addressed

The CAKN has adopted a holistic view of network ecosystems and will monitor the major physical drivers of ecosystem change and responses of the two major components of the biota: plants and animals. Thus, the CAKN has identified Fauna Distribution and Abundance as one of its top three Vital Signs. In general, the CAKN wants to know where fauna are distributed across the landscape and to monitor changes in both their distribution and abundance. The Fauna Distribution and Abundance Vital Sign comprises monitoring efforts for a suite of vertebrate species spanning the significant elevation gradient found in CAKN parks and also including species of particular interest within each park. Arctic ground squirrels (*Spermophilus parryii*) are included as a species to monitor from high elevations. Arctic ground squirrels are medium-sized, diurnal, colonial, burrowing omnivores. As a common and abundant member of the subarctic faunal community, their abundance may influence the reproductive success of the species that rely on them as a food source, including terrestrial predators such as wolves, grizzly bears, and red fox, and aerial predators such as golden eagles and gyrfalcons. They also affect the trophic level below them because there may be as much as a 70% difference in floral composition between their core use areas and surrounding areas. Although arctic ground squirrels are ubiquitous in many areas and serve as an important food resource for many terrestrial and aerial predators in DENA and WRST, little is known about their distribution, abundance, and population trends in Alaska. These reasons taken together warranted their inclusion with the high elevation species for monitoring.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

Monitoring the long-term abundance and distribution of arctic ground squirrels is the primary goal for this protocol. These monitoring data could provide a base of information to later address related questions such as how arctic ground squirrels respond to changes in the snowshoe hare (*Lepus americanus*) cycle,

determining the habitat associations of arctic ground squirrels, the effect arctic ground squirrels have on vegetation and soil characteristics, and how arctic ground squirrels respond to changes in climate and habitat.

Specific objectives for this monitoring are to:

1. Determine the distribution and abundance of arctic ground squirrels in alpine areas in DENA and WRST. ***Justification:*** *The CAKN determined that abundance and distribution would be the primary measurements of monitored faunal species.*
2. Monitor population trends of arctic ground squirrels in conjunction with monitoring population trends of snowshoe hare and other herbivores including willow ptarmigan. ***Justification:*** *In the boreal forest of western Canada, arctic ground squirrel populations fluctuated in close synchrony with snowshoe hare populations. Does this relationship exist in DENA and WRST?*
3. Monitor changes in vegetation composition in relation to arctic ground squirrel colonies. ***Justification:*** *This is part of an Integrated effort with the vegetation monitoring program.*

Basic Approach

Sampling areas: The sampling areas will correspond to the minigrid sampling design used for the integrated landscape monitoring (Roland et al. 2003) and will be within walking distance of the Denali Park road and the road system within WRST. Arctic ground squirrels concentrate their activity around burrows that serve as hibernacula in winter and as nurseries in summer. Therefore, we will focus our sampling efforts on locating active burrows, which usually occur in colonies. A series of transects (1000–2500 m long) will be established in a sample of minigrids. Each year, two observers will walk the transects to locate and mark the active ground squirrel colonies located within 100 m of each side of the transect. We propose to use live trapping and mark-recapture to estimate density and abundance and to monitor the population demography and population trends of arctic ground squirrels. Mark-recapture surveys provide one of the more reliable approaches to estimating population size of mammals (Drennan et al. 1998, Thompson et al. 1998).

Principal Investigators and NPS Lead

We propose that the National Park Service and the Institute of Arctic Biology would accomplish protocol development.

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Development Schedule, Budget, and Expected Interim Products

Most field studies of arctic ground squirrels address the physiological aspects of this species. Little work has been done on estimating abundance and distribution of this species in Alaska or Canada. Extensive and intensive fieldwork is required to develop methods for estimating and monitoring changes in the abundance of arctic ground squirrels in DENA and WRST. Additional work is needed to determine sample sizes and sampling intervals necessary for developing trend data. We suggest that graduate students working under the guidance of Dr. Eric Rexstad or other appropriate investigators conduct much of the work associated with developing these methods.

Fiscal Year	Expected Interim Products
FY 2004	
FY 2005	
FY 2006	
FY 2007	Establish cooperative agreement for protocol development
FY 2008	Conduct protocol development in DENA and WRST
FY 2009	Write protocol and submit for peer review
FY 2010	Implement monitoring

Central Alaska Network
Protocol Development Summary

Snowshoe Hare

Mason Reid, Wildlife Biologist
Wrangell-St. Elias National Park and Preserve

Protocol: **Snowshoe Hare Population Trends**

Parks Where Protocol will be Implemented: **WRST, DENA, YUCH**

Justification/Issues Being Addressed

The CAKN has adopted a holistic view of network ecosystems and will monitor the major physical drivers of ecosystem change and responses of the two major components of the biota: plants and animals. Thus, the CAKN has identified *Fauna Distribution and Abundance* as one of its top three Vital Signs. In general, the CAKN wants to know where fauna are distributed across the landscape and to monitor changes in both their distribution and abundance. The *Fauna Distribution and Abundance* Vital Sign comprises monitoring efforts for a suite of vertebrate species spanning the significant elevation gradient found in CAKN parks and also including species of particular interest within each park. Snowshoe hares were included as a member of the low elevation suite of species and because they are typically the dominant herbivores in the boreal forest throughout Alaska and Canada. Their populations experience 8–11 year cyclic fluctuations over very large geographic areas, and densities may vary 5–25 fold. These large scale changes have widespread effects on the shrubs and trees on which they forage, on both avian and mammalian predators that eat them, and on other herbivores which compete for the same food. Populations of predatory species (including lynx, coyote, fox, wolverine, marten, fisher, goshawk, and great horned owl), and small herbivores (spruce and ruffed grouse) have been found to vary synchronously with hare populations (see Hodges 1999 for a review). In DENA, golden eagle populations were found to be correlated with hare populations (McIntyre and Adams 1999). Changes in hare populations also affect other prey species by providing a highly variable food source to predators. Coyote predation rates on white-tailed deer have been correlated with hare abundance (Patterson and Messier 2000). Coyotes are important predators of Dall's sheep in the Alaska Range (Scotton 1998), and thus sheep and hare populations may be linked. The linkage between hare and lynx populations is such that Alaska Department of Fish and Game (ADF&G) manages lynx in interior Alaska using a "tracking harvest strategy" where seasons and bag limits are adjusted based on hare cycles (Golden 1999).

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The monitoring questions regarding this species center on knowing the status and trends of the species across all three network parks.

Our specific objectives is to:

1. Determine annual trends in abundance of snowshoe hares on the park-wide sampling grid used for vegetation monitoring. ***Justification:*** *Snowshoe hares comprise approximately half of the herbivore biomass in the boreal forest. Monitoring the trends in abundance of this species will provide information on general function of the network boreal forest ecosystems.*

Basic Approach

Estimates of snowshoe hare density can be effectively determined using hare pellet transects (Krebs et al. 1987, Krebs et al. 2001, Murray et al. 2002). Ten permanent transects will be established in predicted snowshoe habitat and will be dispersed throughout each park unit. Each transect will consist of 50–80 plots, either 0.155 m^2 perpendicular linear plots (Krebs et al. 1987, 2001) or 1.0 m^2 circular plots (Murray et al. 2002). Sites will be visited annually in late June–early July, and hare pellets falling within the transect boundaries will be counted and then removed. Although Krebs et al. (1987, 2001) could obtain a population density estimate based on the density of pellets on the transects, the same mathematical relationship may not hold for other geographical areas due to the different digestibility (and hence rate of defecation) of different forage species. Thus, these efforts will provide an index of hare populations rather than an actual density.

Recent work under Dr. Eric Rexstad, University of Alaska Fairbanks, has further investigated these methods, and the results of this work are forthcoming. In addition, YUCH (with ADF&G, USGS) is in the process of developing aerial videography methodology which may provide additional information on hare populations. Results from these two studies will be evaluated for applicability in addressing Vital Signs needs. If aerial videography provides the best methodology for assessing hare abundance, then base-funded pellet counts in WRST will continue for a limited time to allow appropriate comparisons to be made to historical data.

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Development Schedule, Budget, and Expected Interim Products

WRST has been utilizing the proposed methods since 1991, so all transects have been developed. Neither DENA or YUCH have developed similar protocols (DENA monitors hares based on incidental observations ["hares/field day"]). For FY05, investigation on recent pellet transect research will continue, and the aerial videography methodology will be evaluated for its applicability. A finalized protocol can be developed in FY05 in preparation for implementation in FY06. No additional funds are needed for methodology development.

Fiscal Year	Expected Interim Products
FY 2005	Pellet transect evaluation as protocol. Evaluation of videography to monitor hares
FY 2006	Continue protocol development
FY2007	Continue protocol development
FY 2008	Complete protocol
FY 2009	Implement monitoring

Central Alaska Network
Protocol Development Summary

Small Mammals

Maggie MacCluskie, Coordinator
Central Alaska Network

Protocol: Distribution and Abundance of Small Mammals

Parks Where Protocol will be Implemented: DENA

Justification/Issues Being Addressed

The Central Alaska Network has identified the vital sign of Fauna distribution and abundance as one of high priority. Under this broad vital sign, the network has delineated species based on elevation gradients and has sought to include suites of species that may be monitored together, as opposed to those species that require focal measurements. Mice and vole species have been included by the network as members of the lower elevation suite of species to monitor.

Mice and voles (*Microtus* spp. and *Clethrionomys* spp.), by virtue of their morphology and daily habits, are not highly visible members of the faunal community in the boreal forest. Yet these species represent a larger proportion of biomass on the landscape than brown bears (*Ursus arctos horribilus*) (Krebs et al. 2001). Within the ecosystems encompassed by the Central Alaska Network, mice and voles consume seeds, fungi, and invertebrates and provide a key prey source for raptor species and carnivorous mammals. As a result of their pivotal position in the ecosystem, mice and voles have the ability to influence species both above and below them in the food chain.

Since 1991, mice and voles populations have been monitored in Denali National Park and Preserve as part of the previous Long-term Ecological Monitoring program. From these data (Rexstad and Debevec 2002) and other studies (Krebs et al. 2001), we know that populations of mice and voles vary over space and time. Data from Denali suggests that annual fluctuations in small mammal populations are strongly related to abiotic factors (Rexstad and Debevec 2002). Additionally, the relative abundance of small mammal species is directly related to vegetation composition, so any changes in vegetation composition will likely affect small mammal distribution and patterns of abundance. Thus by monitoring populations of mice and voles, we may detect evidence of effects from human induced change (like global warming) in our ecosystems. These combined characters led the network to identify mice and vole species as a logical group to include in the program.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The objective of this monitoring is to determine the long-term trends in abundance and spatial distribution trends of mice and vole species in DENA.

Basic Approach

Historically the Denali LTEM program monitored small mammals to estimate animal abundance on ~1 hectare study plots clustered within watersheds in the Denali road corridor. However, the ability to extrapolate these findings to larger spatial scales has been unsuccessful because of the small-scale variability in the Denali landscape. We believe this same circumstance will apply to the landscapes of the other two network parks. Therefore our approach for small mammal monitoring will be to collocate sampling with the spatially extensive grid-based sample design used for the vegetation and passerine bird monitoring (please see respective protocol development summaries) (Roland et al. 2003). This will allow the large scale level of inference we wish for small mammals.

Using the grid-based system for sampling will shift the parameter of interest from a ~1 hectare sample to 500 m^2 grids spaced at intervals ranging from 20–30 km across the landscape of the park. Rather than estimate absolute abundance, we will estimate absolute density of small mammals on the grids using mark-recapture methods via live-trapping techniques.

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Development Schedule, Budget, and Expected Interim Products

A full protocol that describes estimation of small mammal abundance will be developed during FY 2005.

Fiscal Year	Expected Interim Products
FY 2004	
FY 2005	Complete protocol
FY 2006	Implement monitoring

Central Alaska Network
Protocol Development Summary

Caribou

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Denali National Park and Preserve

Mason Reid, Wildlife Biologist
Wrangell-St. Elias National Park and Preserve
and
John Burch, Wildlife Biologist
Yukon-Charley Rivers National Preserve

Protocol: Caribou—Abundance, Distribution, and Demography

Parks Where Protocol will be Implemented: WRST, DENA, YUCH

Justification/Issues Being Addressed

The CAKN has adopted a holistic view of network ecosystems and will monitor the major physical drivers of ecosystem change and responses of the two major components of the biota: plants and animals. Thus, the CAKN has identified *Fauna Distribution and Abundance* as one of its top three Vital Signs. In general, the CAKN wants to know where fauna are distributed across the landscape and to monitor changes in both their distribution and abundance. The *Fauna Distribution and Abundance* Vital Sign comprises monitoring efforts for a suite of vertebrate species spanning the significant elevation gradient found in CAKN parks and also including species of particular interest within each park. Caribou occur in all three network parks and are of interest to the network from several perspectives. They are one of six keystone large mammal species in interior Alaska that are of great importance to the ecosystem as a whole and to people from both consumptive and non-consumptive viewpoints: (1) Three of four herds have experienced significant recent declines; (2) Subsistence harvest on two herds has been curtailed due to conservation concerns, and providing for the opportunity for subsistence uses is a directive for NPS lands in Alaska; (3) One herd is the subject of intensive interagency management, including the control of predators; (4) One herd is the subject of an international captive rearing conservation program which has significant long-term implications; and (5) Long-term research and monitoring on caribou on CAKN lands provide a background against which future patterns may be compared (Mech et al. 1998, Farnell and Gardner 2002).

CAKN contains four separate caribou herds: Denali (DENA), Mentasta (WRST), Chisana (WRST) and Fortymile (YUCH). The

Fortymile herd is currently monitored by ADF&G, and these efforts should meet CAKN objectives with little required from CAKN (although if the status of ADF&G efforts changes, then CAKN involvement may need to be reevaluated). Therefore, the network efforts will focus on the Denali, Mentasta, and Chisana herds.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The monitoring questions regarding this species center on knowing the status and trends of the herds in the network parks, including the composition of the herds. The specific objectives for this monitoring are:

1. Determine changes in abundance, distribution and demographics of caribou in the CAKN. ***Justification:*** *Abundance, distribution, and demographics of caribou herds are the fundamental parameters of interest for managing this species. Collecting only one or two of these parameters for monitoring could result in erroneous conclusions regarding herd status.*
2. Estimate calf survival and recruitment in CAKN. ***Justification:*** *Low calf recruitment is the primary mechanism of the observed declines in small caribou herds (Adams et al. 1995, Mech et al. 1998, Farnell and Gardner 2002, Schaefer et al. 1999).*
3. Estimate mortality of caribou in and around CAKN. ***Justification:*** *Mortality of marked animals is an important demographic parameter in understanding population change.*

Basic Approach

Monitoring of caribou populations in CAKN will employ the use of radiocollars and radiotelemetry to locate groups and to provide a mark-recapture estimate of population size. The use of radiotelemetry is standard throughout Alaska and parts of Canada for monitoring caribou populations; methodology for population assessment, however, varies (e.g. aerial photocensus [Fancy et al. 1994], stratified random block [Gasaway et al. 1986, Kuzyk and Farnell 1997], and mark-recapture [Adams 1997]). Aerial photocensus is applied only to larger (>5000) herds, and is not an effective method for the three smaller herds in CAKN, which number less than 2000. A sample of 30–40 radiocollared cows per herd will be maintained for population assessment. At present all three herds have 30–40 radiocollared cows. Our goal will be to maintain these sample sizes during the program. This will require the addition of about 10–15 radiocollars annually per herd.

Population assessment will be made in two efforts: a post-calving (June) census, when cows are grouped and calf production can be assessed, and a fall (Sept.-Oct.) composition count, when bulls associate with cows during the rut. With the mark-recapture estimate of cows from the spring census, and the herd composition obtained from the fall count, herd size, composition, and calf recruitment can be estimated.

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Development Schedule, Budget, and Expected Interim Products

Regional protocols already exist for monitoring caribou populations. Therefore, protocol development will not require field research and will consist primarily of writing a protocol that meets NPS standards (Oakley et al. 2003) and incorporates existing standard protocols. We will need to write new sections in the protocol narrative and SOPs to make the existing protocols specific to CAKN parks, such as describing survey area locations and documenting how data will be entered into NPS computers, analyzed, and reported. We will continue to review pertinent literature and ongoing research to ensure that proposed methodology is consistent with CAKN goals. The protocol should be ready for review by June 2005.

Fiscal Year	Expected Interim Products
FY 2005	Begin protocol development. Assessment of parameter variation from historical data (determines sampling interval) (Feb. 2005)
FY 2006	Complete protocol and submit for peer review
FY 2007	Implement monitoring

Central Alaska Network
Protocol Development Summary

Moose

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Yukon-Charley Rivers National Preserve

Tom Meier, Wildlife Biologist
Denali National Park and Preserve
and
Mason Reid, Wildlife Biologist
Wrangell-St. Elias National Park and Preserve

Protocol: Moose—Abundance, Distribution, and Composition.

Parks Where Protocol will be Implemented: YUCH, DENA, and WRST

Justification/Issues Being Addressed

The CAKN has adopted a holistic view of network ecosystems and will monitor the major physical drivers of ecosystem change and responses of the two major components of the biota: plants and animals. Thus, the CAKN has identified *Fauna Distribution and Abundance* as one of its top three Vital Signs. In general, the CAKN wants to know where fauna are distributed across the landscape and to monitor changes in both their distribution and abundance. The *Fauna Distribution and Abundance* Vital Sign comprises monitoring efforts for a suite of vertebrate species spanning the significant elevation gradient found in CAKN parks and also including species of particular interest within each park. Moose (*Alces alces*) are one such species for the CAKN, in part because moose are found in each network park. Moose are considered good indicators of long-term habitat change within park ecosystems because they require large quantities of resources from their habitat year round, and populations have the potential to respond dramatically to long-term changes in resource conditions. They are crucial to many subsistence communities as a primary source of food throughout most of NPS land in Alaska, in addition to being harvested by the general public on NPS Preserve lands.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The essential question we want to answer with this work concerns the long-term trends in the abundance, distribution, and sex/age composition of moose. In concordance with the Consumptive Use Protocol, we want to know the long-term trend in the number and composition of harvested moose from park lands. In addition to answering our monitoring questions on moose, we also anticipate the data will provide insight into research questions we are interested in, such as how change in plant communities affect the

abundance, distribution, and composition of the moose population; if there are correlations among wolf and/or bear population change and the abundance, distribution, and composition of moose populations; and what are the primary variables affecting moose population change.

Our specific objectives for monitoring moose are to:

1. Determine changes in abundance, distribution and composition of moose in CAKN via surveys conducted once every three years in each park. ***Justification:*** *The CAKN determined that abundance and distribution would be the primary measurements of monitored faunal species. Sex and age composition are important variables to any evaluation of population change and will be collected during the abundance/distribution surveys.*
2. Estimate calf survival and recruitment success for moose every three years for each network park. ***Justification:*** *Reproductive success is a primary demographic parameter that provides critical information for understanding patterns of population change. Hence, these data can be used to understand trends, focus management action and money, and identify hypotheses for further evaluation.*
3. Estimate annual human harvest of moose in CAKN. ***Justification:*** *Monitoring annual human harvest is an important demographic parameter in understanding population change; population trends can thus be better understood from monitoring the interaction of these demographic parameters.*

Basic Approach

Monitoring moose populations in CAKN will employ the use of an aerial survey method developed by Bill Gasaway (Gasaway et al. 1986) and modified by Jay Ver Hoef (Ver Hoef 2001, 2002) both of the Alaska Department of Fish and Game (ADF&G). The initial methodology using a stratified random design was developed in the early 1980s, published in 1986, and has been used by most agencies in Alaska and the Yukon as the standard for estimating moose populations over the past 20 years. The modifications mean that moose surveys are more likely to be successful, more precise, and less expensive, allowing larger areas to be surveyed more consistently.

Survey areas are already defined for YUCH, DENA, and WRST and these areas have been surveyed periodically since 1987. These survey areas may need to be modified depending on network ecological goals or budgetary constraints. The survey areas should be chosen to be as ecologically representative of each park as possible, balanced with the management needs of each park unit and budget constraints of CAKN. Surveys will take place as soon as adequate snow conditions exist in the fall, usually late October for DENA and WRST and early to mid-November for YUCH. Surveys will occur once every three years for each park on a rotational schedule.

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Development Schedule, Budget, and Expected Interim Products

Regional protocols already exist for conducting moose surveys. Therefore, protocol development will not require field research and will consist primarily of writing a protocol that meets NPS standards (Oakley et al. 2003) and incorporates existing standard protocols. We will need to write new sections in the protocol narrative and SOPs to make the existing protocols specific to CAKN parks, such as describing survey area locations and documenting how data will be entered into NPS computers, analyzed, and reported.

The principal investigators will produce a draft moose survey protocol ready for external peer review by November 1, 2004. After peer review, revision, and approval, we hope to implement the protocol in November 2005. No funds are budgeted for development or testing of this protocol.

Fiscal Year	Expected Interim Products
FY 2004	Full protocol submitted for review
FY 2005	Initiate survey in WRST
FY 2006	Initiate survey in DENA
FY 2007	Initiate survey in YUCH

Central Alaska Network
Protocol Development Summary

Dall's Sheep

Protocol: **Dall's Sheep Monitoring**

Parks where this would be implemented: **WRST**

Justification/Issues Being Addressed

The CAKN has adopted a holistic view of network ecosystems and will monitor the major physical drivers of ecosystem change and responses of the two major components of the biota: plants and animals. Thus, the CAKN has identified *Fauna Distribution and Abundance* as one of its top three Vital Signs. In general, the CAKN wants to know where fauna are distributed across the landscape and to monitor changes in both their distribution and abundance. The *Fauna Distribution and Abundance* Vital Sign comprises monitoring efforts for a suite of vertebrate species spanning the significant elevation gradient found in CAKN parks and also including species of particular interest within each park. We are including Dall's sheep (*Ovis dalli)* as one of the suite of high elevation species to monitor. They are year-round residents of alpine areas and are one of the six keystone large mammal species (moose, caribou, sheep, black bear, brown bear, wolf) of interior Alaska. Dall's sheep can be legally hunted on park and preserve lands in the Central Alaska Network by subsistence users and on preserve lands by sport hunters, yet recent evidence suggests that dramatic changes observed in population size of Dall's sheep are due to changes in environmental conditions (Lawler 2004). Part of the interest in monitoring sheep populations relates to where they are found elevationally in the network; monitoring population size and sex and age structure of this species will also contribute to establishing and maintaining appropriate harvest levels that protect sheep populations as well as their natural behavior and social structure. In 1990, the world estimate of Dall's sheep was 100,000 animals (Valdez and Krausman 1999). Strickland et al. (1993) estimated a sheep population in WRST of 17,455 animals. Singer (1984) estimated approximately 2,476 sheep in DENA. An estimated 355 sheep occurred in YUCH in 2002 (Burch and Lawler 2001, Lawler in press). Given that approximately 20% of the world's Dall's sheep population occurs in the CAKN, it is an additionally compelling reason to monitor the species in this network.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

Determining the long-term trends in abundance, distribution, and sex and age composition of Dall's sheep in the Central Alaska Network is the primary goal for this protocol. This baseline information will provide an important foundation for research questions concerning the productivity (lamb survival and recruitment) of sheep in the CAKN parks relative to other populations of Dall's sheep; the relationship between Dall's sheep, other ungulates, and predators in the CAKN parks; the relationship between snow cover and Dall's sheep population trends; and the influence of local and global climate cycles on Dall's sheep populations

Our specific objectives are:

1. Detect changes in abundance, distribution, and sex and age composition of Dall's sheep in the Central Alaska Network. ***Justification:*** *The CAKN determined that abundance and distribution would be the primary measurements of monitored faunal species. Sex and age composition are important variables to any evaluation of population change and will be collected during the abundance/distribution surveys.*
2. Detect changes in the number and composition of harvested sheep from park lands. ***Justification:*** *Monitoring annual human harvest is an important demographic parameter in understanding population change; population trends can thus be understood better by monitoring the interaction of these demographic parameters.*
3. Estimate Dall's sheep productivity (lamb survival and recruitment) in the CAKN parks. ***Justification:*** *Reproductive success is a primary demographic parameter that provides critical information for understanding patterns of population change. Hence, these data can be used to understand trends, focus management action and money, and identify hypotheses for further evaluation.*
4. Integrate and collocate sheep monitoring with other monitoring efforts where practical including monitoring efforts directed at flora, fauna and physical resources. ***Justification:*** *Collocating monitoring activities provides a wider scope*

Basic Approach

We will survey Dall's sheep in the Central Alaska Network by counting sheep in representative units of each park area and then double sample subunits of some of these units (Strickland et al. 1993). The initial survey will be completed with a fixed wing aircraft (Piper PA-18 Super Cub with pilot and one observer). We will use survey units delineated by previous workers to facilitate comparison of results (DENA: Singer 1984, Taylor 1987; WRST: Singer 1984, Strickland 1993; YUCH: Singer 1984, Burch and Lawler 2001). These units provide an area that can be surveyed in a reasonable amount of time and yet are large enough that movement between units during surveys should be negligible.

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Development Schedule, Budget, and Expected Interim Products

Protocols for effective Dall's sheep monitoring will be developed by February 2005. Because aerial sheep surveys have been conducted for a number of years in Alaska, protocol development will consist of an extensive literature review to ensure the proposed methodology is statistically sound and fits the needs of the Central Alaska Network. No funds are being requested for protocol development.

Fiscal Year	Expected Interim Products
FY 2005	Begin protocol development
FY 2006	Complete protocol development
FY 2007	Implement monitoring

Central Alaska Network
Protocol Development Summary

Wolves

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Yukon-Charley Rivers National Preserve
and
Tom Meier, Wildlife Biologist
Denali National Park and Preserve

Protocol: **Wolves—Abundance, Distribution, and Demographics.**

Parks Where Protocol will be Implemented: YUCH, DENA, and WRST

Justification/Issues Being Addressed

The CAKN has adopted a holistic view of network ecosystems and will monitor the major physical drivers of ecosystem change and responses of the two major components of the biota: plants and animals. Thus, the CAKN has identified *Fauna Distribution and Abundance* as one of its top three Vital Signs. In general, the CAKN wants to know where fauna are distributed across the landscape and to monitor changes in both their distribution and abundance. The *Fauna Distribution and Abundance* Vital Sign comprises monitoring efforts for a suite of vertebrate species spanning the significant elevation gradient found in CAKN parks and also including species of particular interest within each park. Wolves (*Canis lupis*) occur in all three network parks and are one of six keystone large mammal species in interior Alaska that are of great importance to the ecosystem as a whole and to people from both consumptive and non-consumptive viewpoints. From a monitoring standpoint, wolves are considered to be good indicators of long-term habitat change within park ecosystems because they depend on healthy populations of large ungulate prey, which in turn respond to vegetation, weather, and other habitat patterns across the entire landscape (Mech and Peterson 2003, Fuller et al. 2003). As a top predator, wolves may play a key role in influencing ungulate populations and as a result influence vegetation patterns (Miller et al. 2001, Ripple and Beschta 2003). This ties to the subsistence issue for CAKN parks because the effects of wolves on ungulate populations may be important determinants of ungulate availability for subsistence harvest on NPS park and preserve lands in Alaska and harvest by the general public on NPS preserve lands (National Park Service 2003)

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The monitoring questions regarding this species center on knowing the status, trends, and demography of the packs in the network. If we collect these basic data on the species, we would also have the ability to collect other data that are of interest such as: patterns of pack structure and reproduction in wolves; patterns of phenotypic and genetic variability; disease exposure; location of active wolf den and rendezvous sites; and interrelationships in a complex multi-predator, multi-prey system.

Our specific objectives are to:

1. Determine changes in abundance, distribution, and population structure of wolves in CAKN annually. ***Justification:*** *The CAKN determined that abundance and distribution would be the primary measurements of monitored faunal species. Patterns of pack formation (population structure) are important variables in any evaluation of wolf population change and will be collected in the course of determining abundance and distribution).*
2. Estimate pup production and survival for wolves in CAKN annually. ***Justification:*** *Reproductive success is a primary demographic parameter that provides critical information for understanding patterns of population change. These data can be used to understand trends, focus management action and money, and identify hypotheses for further evaluation.*
3. Estimate mortality, including human harvest, of wolves in and around CAKN annually. ***Justification:*** *Mortality of marked animals is an important demographic parameter in understanding population change. Patterns of natural and human-caused mortality among wolf packs that live entirely or partly on CAKN lands will help in the understanding of changes in distribution and abundance of wolves in these areas.*

Basic Approach

Monitoring of wolf populations in CAKN will employ the use of radiocollars and radiotelemetry to monitor a sample of packs in each park/preserve unit. The use of radiotelemetry is the standard method for monitoring wolf populations in a great variety of habitats worldwide (Boitani 2003, Mech and Barber 2003). It is especially useful in remote wilderness areas with highly variable terrain, vegetation, and snow cover, typified by the lands within CAKN. To the extent possible and practical, the areas of wolf monitoring will be co-located with areas of long-term monitoring of moose, caribou, Dall's sheep and grizzly bears.

Dominant/breeding wolves will be selected for collaring when possible, based on behavior and appearance. This will result in a biased sample of collared wolves for mortality and dispersal estimates but will greatly increase the efficiency of the project for maintaining collars in a pack and learning about reproduction and den locations. Aerial monitoring of collared wolves will depend on

budgetary constraints but at a minimum will concentrate on obtaining early-winter and late-winter population counts and evaluating pup production and den use in early summer. Because wolves are difficult to see without snow cover and because packs are less cohesive in summer, population estimates are not obtained in the snow-free months.

Advantages of the total-count radiotelemetry method of wolf population estimation include the benefits of animal capture and marking (genetic sampling, phenotypic, reproductive, and health measurements, maintenance of a marked sample for mortality and dispersal estimates), advantages to park management of accurate wolf pack territory and denning information, and the benefits of a whole-area count method as opposed to plot or transect sampling (less dependence on weather patterns, pilot expertise, and luck for a successful count; assurance of completeness by the development of a mosaic of wolf pack locations).

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Development Schedule, Budget, and Expected Interim Products

Regional and international protocols already exist for monitoring wolf populations. New technologies may allow monitoring to be done more economically and less intrusively. Approximately $60,000 will be spent in FY 2004 for protocol development, comparing the effectiveness of GPS/ARGOS satellite collars to conventional VHS collars for wolf monitoring.

The principal investigators will produce a draft wolf survey protocol ready for external peer review by November 1, 2004. After peer review, revision, and approval, we hope to implement the protocol in November 2005.

Fiscal Year	Expected Interim Products
FY 2005	Full protocol submitted for review
FY 2006	Initiate wolf monitoring in DENA and YUCH
FY 2007	Initiate wolf monitoring in WRST

Central Alaska Network
Protocol Development Summary

Brown Bears

Tom Meier, Wildlife Biologist
Denali National Park and Preserve

Protocol: Brown Bears—Abundance, Distribution, and Composition

Parks Where Protocol will be Implemented: YUCH, DENA, and WRST

Justification/Issues Being Addressed

The CAKN has adopted a holistic view of network ecosystems and will monitor the major physical drivers of ecosystem change and monitor of the two major components of the biota: plants and animals. Thus, the CAKN has identified *Fauna Distribution and Abundance* as one of its top three Vital Signs. In general, the CAKN wants to know where fauna are distributed across the landscape and to monitor changes in both their distribution and abundance. The *Fauna Distribution and Abundance* Vital Sign comprises monitoring efforts for a suite of vertebrate species spanning the significant elevation gradient found in CAKN parks and also including species of particular interest within each park. Brown bears (*Ursus arctos*) are considered good indicators of long-term habitat change within park ecosystems because they are a long-lived species, require large quantities of specific resources from their habitat, and populations have the potential to respond dramatically to long-term changes in resource conditions. The species is crucial to many rural Alaska communities with respect to cultural identity, and they are considered by many to be an important driving force in the regulation of moose and caribou populations, primarily by predation on calves.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The objectives for brown bear monitoring are to:

1. Determine changes in abundance, distribution, and composition of bears in CAKN every five years. ***Justification:*** *The CAKN determined that abundance and distribution would be the primary measurements of monitored faunal species. Sex and age composition are important variables to any evaluation of population change and will be collected during the abundance/distribution surveys.*
2. Estimate cub survival and recruitment success for bears in CAKN annually. ***Justification:*** *Reproductive success is a primary demographic parameter that provides critical information for understanding patterns of population change. Hence, these data can be used to understand trends, focus management action and money, and identify hypotheses for further evaluation.*

3. Estimate annual human harvest of bears in CAKN.
   Justification: *Monitoring annual human harvest is an important demographic parameter in understanding population change; population trends can thus be better understood from monitoring the interaction of these demographic parameters.*

These fundamental data on the species will provide a foundation for research to be conducted by others to answer such questions as

- What is the productivity (cub survival and recruitment) of brown bears in the parks relative to other areas in Alaska and Canada?
- Predator/prey relationships: is there a correlation between bear and/or wolf population change and the abundance, distribution, and composition of moose or caribou populations?
- What are the primary variables affecting bear population change, and how do those variables change over time and space? Or more simply put: Why do bear populations change?

Basic Approach

Monitoring of brown bear populations in CAKN will employ the use of an aerial survey method developed by Earl Becker and Harry Reynolds (Becker 2001) both of the Alaska Department of Fish and Game (ADF&G). The methodology uses a line transect sampling design developed in the early 1990s (Quang and Lanctot 1991, Quang and Becker 1996) coupled with a double count technique (Manly et al. 1996, Quang and Becker 1997, 1999) and has been used by most agencies in Alaska as the standard for estimating bear populations over the past five years. Both brown and black bear species can be surveyed simultaneously if sufficient numbers of both exist within the study area.

The survey areas would be chosen within each park unit to be as ecologically representative of each park as possible and co-located with as many other monitored species as possible but balanced with the management needs of each park unit and budget constraints of CAKN. Survey areas can be quite large, up to 25,000 km^2 or more, although approximately 10,000 km^2 is being proposed here.

Trends in human harvest of brown bears in CAKN will be monitored by annually summarizing ADF&G harvest data for each park unit (See Consumptive Harvest Protocol Development Summary).

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Development Schedule, Budget, and Expected Interim Products

Regional protocols already exist for conducting bear surveys. Therefore, protocol development will not require field research and will consist primarily of writing a protocol that meets NPS standards (Oakley et al. 2003) and incorporates existing standard protocols. We will need to write new sections in the protocol narrative and SOPs to make the existing protocols specific to CAKN parks, such as describing survey area locations and documenting how data will be entered into NPS computers, analyzed, and reported.

The principal investigators will produce a draft bear survey protocol ready for external peer review by November 1, 2006. After peer review, revision, and approval, we hope to implement the protocol in May 2008. No funds are budgeted for development or testing of this protocol. Cost of the surveys themselves will depend on the size of the survey area and the density of bears. Likely survey areas will be 10,000–15,000 km^2 for each park and cost about $40,000 per survey. Surveys could occur as infrequently as once every six years. If a survey is conducted in each park on a six year rotation, a survey would be required in one park every other year, and the cost to the Network would be about $40,000 once every two years. This assumes, however, that bear densities are high enough to observe at least 150 bear groups in one season, which is likely not the case for all three CAKN parks. In this circumstance three surveys in consecutive years in one park may be required to estimate population size with sufficient precision (±15–20%). Therefore, costs of $80,000 per estimate per park may be more realistic. More precise estimates of costs will need to wait until after the first surveys are completed.

Fiscal Year	Expected Interim Products
FY 2006	Write protocol
FY 2007	Complete protocol
FY 2008	Initiate survey in DENA
FY 2009	Initiate survey in YUCH
FY 2010	Initiate survey in WRST

Central Alaska Network
Protocol Development Summary

Forage quantity/quality

Jim Lawler, Wildlife Biologist
Yukon-Charley Rivers National Preserve

Protocol: Monitoring Changes in Forage Quantity/Quality of CAKN Parks

Parks where this would be implemented: DENA, WRST, and YUCH

Justification/Issues Being Addressed

The CAKN has adopted a holistic view of network ecosystems and will monitor the major physical drivers of ecosystem change and responses of the two major components of the biota: plants and animals. The CAKN has identified *Fauna Distribution and Abundance* as a Vital Sign along with *Vegetation Structure and Composition*. In general, the CAKN wants to know where fauna are distributed across the landscape and to monitor changes in both their distribution and abundance. This is an informative Vital Sign for this network because in Alaska, two explanations are commonly advanced regarding control of populations of large herbivorous mammals and game birds. Many Alaskan residents feel that mammalian predators control ungulate populations within the state, and proposals regarding predator control are common fare for the Alaska Board of Game. The alternative explanation for fluctuating game populations is the quality and quantity of forage. Although these two explanations are not mutually exclusive, the relative importance of each is difficult to ascertain because of a lack of long-term ecological studies on the interactions of mammalian herbivores and their forage base. Suggestions that high predator populations are depressing ungulate populations (e.g., the Chisana caribou herd, the Denali caribou herd, moose populations in interior Alaska) are difficult to dispute if there is no evidence to the contrary. Fluctuations in forage quantity and quality over time and space, however, have been suggested as factors responsible for fluctuations in population size for caribou (*Rangifer tarandus*; Bergerud 1980, Leader-Williams 1980, White 1983, Skogland 1985, Russell et al. 1993, Dale et al. 1994, Boerjte et al. 1996, Valkenburg et al. 1996, Lenart et al. 2002), moose (*Alces alces*; Gasaway et al. 1992, Kielland and Osborne 1998, Keech et al. 2000), Dall's sheep (*Ovis dalli*; Bunnel 1978, Hoefs and Cowan 1979, Nichols and Bunnel 1999) and snowshoe hare (*Lepus americanus*; Pease et al. 1979, Fox and Bryant 1984, Bryant et al. 1985, Sinclair et al. 1988, Smith et al. 1988, Hodges et al. 2001).

Factors that effect forage quality and availability would likely also affect herbivore populations. Resource availability as influenced by climatic factors (stochastic as well as long-term), disturbance history, and soil fertility affect not only the distribution of plant species and plant communities but would also vary the quality of forage available to herbivores because they control phenotypic expression of forage quality (Bryant et al. 1983). Quality of forage species on caribou ranges has been shown to vary by degree of shading (Chapin and Shaver 1985, Shaver et al. 1986, Chapin et al. 1995), air temperature (Jonasson et al. 1986), and soil moisture (Webber 1978, Chapin et al. 1988). Understanding factors responsible for changes in forage quality would provide insights into distribution and population fluctuations of herbivorous mammals as well as insights into the consequences of perturbations to the system.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The network wants to determine the long-term trends in forage quality and quantity in Central Alaska Network in addition to the patterns of forage utilization across the entire spatial scale of the Central Alaska Network. Additionally the pattern of forage quality and utilization in relation to abundance and distribution of herbivores is of interest along with the influence of local and global climate cycles on forage quality and quantity.

The specific objectives for this protocol are to:

1. Detect changes in forage quantity and quality across the entire network.
2. Describe the relationship of forage quality/utilization to vegetation characteristics, such as vegetation structure, across the network.
3. Monitor changes in forage quality and utilization in relation to abundance and distribution of herbivores.
4. Integrate monitoring of forage quality and quantity with other aspects of the monitoring program of the Central Alaska Network. It will be particularly important to integrate with other vegetation monitoring efforts taking place within the Central Alaska Network.

Basic Approach

Consumed plant species and quality of forage consumed by Dall's sheep, moose, and caribou will be investigated by examining fecal pellets using microhistological techniques. Fecal pellet samples be analyzed for plant species composition. Nitrogen content of fecal pellets (a measure of consumed forage quality) will be analyzed by the University of Alaska Fairbanks Chemical Nutritional Laboratory.

Forage utilization in open areas will be assessed by categorizing vegetation into one of five levels based on percent utilization (*Procedures for Environmental Monitoring in Range and Wildlife*

Habitat Management, Habitat Monitoring Committee 1990). Browse utilization will be measured by categorizing browse species based on plant architecture (Seton 2002). Percent utilization of current annual growth on browse species will be assessed by counting all current annual growth below 3 m and classifying it as browsed or unbrowsed. Diameter of twigs at point of browse will be measured.

Nutritional quality of forage plants will be assessed by gathering samples of forage species. Samples collected from browse species will be current annual growth and the diameter of twigs collected will approximate the diameter at which twigs in the vicinity are being browsed. All samples will be analyzed for *in vitro* digestibility and nitrogen.

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Development Schedule, Budget, and Expected Interim Products

Fiscal Year	Expected Interim Products
FY 2006	Investigate integrating methods with vegetation structure/composition vital sign
FY 2007	Develop protocol
FY 2008	Develop protocol
FY 2009	Complete protocol
FY 2010	Implement protocol

Central Alaska Network
Protocol Development Summary

Vegetation Structure and Composition

Carl Roland, Botanist
Denali National Park and Preserve

Protocol: Monitoring Structure and Composition of Vegetation in CAKN Parks at the Landscape Scale

Parks Where Protocol will be Implemented: DENA, WRST, YUCH

Justification/Issues Being Addressed

The CAKN has adopted a holistic view of network ecosystems and will monitor the major physical drivers of ecosystem change and responses of the two major components of the biota: plants and animals. Vegetation was chosen as a primary monitoring component because vegetation provides the energetic foundation for all ecosystem functions. Vegetation is also unique in that it defines the habitat structure for most other forms of life. Thus, the CAKN has identified *Vegetation Structure and Composition* as one of its top three Vital Signs. In general, the CAKN wants to know how dominant plant species of different structural types are distributed across the landscape and to monitor changes in both their distribution and abundance over time. The CAKN also wants to know how the diversity of plant species comprising the vegetation changes over time. The *Vegetation Structure and Composition* Vital Sign comprises monitoring efforts for a suite of vegetation characteristics and ecological attributes closely tied to vegetation (e.g., soil depth, duff layer). Changes in vegetation will have profound and far-reaching effects on other vital park resources, including wildlife populations, and interacting effects with disturbance processes such as fire, insects, and glaciers. To tie together changes in vegetation with changes in other components of the CAKN ecosystems, sampling points for vegetation, passerine birds, small mammals, and other components will be co-located in a probability based sampling design using permanently marked sampling points. This design is robust for detecting changes that cannot be predicted at this time and for developing integrated ecological information about long-term changes in CAKN parks.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The specific monitoring objectives of the *Vegetation Structure and Composition* Vital Sign are:

1. Detect changes in the absolute and relative abundance and distribution of the different growth-form classes that form the vegetation cover of CAKN parks. ***Justification:*** *At the landscape scale, the most important changes in vegetation affecting*

park ecosystems will come from large changes in the abundance and distribution of plants with different growth forms (e.g., a change from forest to non-forest or low shrub to tall shrub). Knowing whether the parks or certain areas of the parks are getting shrubbier or less forested or whether cover by mosses (which can reduce soil temperatures) is increasing is valuable information about overall ecosystem status. This objective targets overall vegetation structure, which is the most fundamental aspect of the vegetation that needs to be monitored.

2. Detect change in the abundance, distribution, and composition of the dominant species in the vegetation cover of CAKN parks. ***Justification:*** *The dominant species in the vegetation of CAKN parks are the ones that define the structure of the vegetation. Thus, monitoring their abundance and distribution is important to monitoring vegetation structure. The individual species that are dominant in the cover are important to determining how the vegetation functions ecologically. For example, it is important to know not just that the cover of trees (as a growth form class) has changed, but which trees comprise the cover—whether they are deciduous or evergreen has major ecological ramifications.*
3. Detect change in the distribution and abundance of discrete vegetation types on the landscape of the CAKN parks. ***Justification:*** *The strong gradients in CAKN parks related to topography, landscape history, and distance from the ocean result in many different recognizable vegetation types. Habitat associations of animals are typically described in relation to vegetation types. Monitoring changes in the broad patterns of the major vegetation types in CAKN parks will provide the level of detail about changes in vegetation structure needed to relate vegetation change to other elements of the ecosystem, especially fauna.*
4. Detect changes in the taxonomic composition and diversity characteristics of the vegetation cover of CAKN parks. ***Justification:*** *The vegetation cover of CAKN plants includes vascular plants, bryophytes (mosses and liverworts), and macrolichens. Along with vegetation structure, taxonomic composition is a basic element of the botanical resource. Changes in species composition are strongly correlated with other aspects of the ecosystem including forage quality, habitat use, nutrient cycling, and successional status. Specific management concerns such as the invasion of exotic plant species and conservation of rare native plants require knowledge of the general distribution of individual species within a landscape framework. Knowing the species that compose the vegetation also allows diversity measures to be calculated. Knowing which parts of the landscape have high species diversity is important for conservation planning and protection activities of park management.*
5. Detect changes in the absolute and relative densities and basal area of the selected tree species at a landscape scale in CAKN parks. ***Justification:*** *Where they occur, trees have a dominating influence on the characteristics of the vegetation and ecosystem function. This influence relates to their longevity, physical structure, and use of space and soil resources. Monitoring changes in the productivity (basal area) and population structure (number of individuals of different size classes) of the major tree species provides measures of how the tree component of the vegetation is changing.*

6. Detect changes in the mean depth of the active layer in CAKN parks. ***Justification:*** *The depth of seasonal thaw of the soil (active layer depth) is an important environmental characteristic affecting vegetation. Easily measured, monitoring active layer depth will provide correlative data for understanding changes in vegetation.*
7. Detect changes in the total amount, type, size, and position (vertical distribution) of fuels and the depth of the duff and litter layers on the landscape of CAKN parks. ***Justification:*** *Wildland fire is a dominant disturbance factor in major portions of the CAKN parks. Monitoring the specific aspects of the vegetation that relate to its characteristics as fuel for wildland fire (structure, duff, and litter) will provide useful information to fire program managers.*

Basic Approach

The basic approach we will take is to establish permanent vegetation monitoring plots throughout the CAKN parks for revisits at intervals of (most likely) ten or more years. Plots will be established following the multi-stage, systematic grid design developed for vegetation monitoring in the Denali Long-term Ecological Monitoring Program (Roland et al. 2003). At Denali, a grid spacing of 20 km has been established, and modeling to determine appropriate grid spacings for WRST and YUCH was recently completed. The use of the multi-stage design for vegetation monitoring provides a framework that will be used by other components of the monitoring program (e.g., songbirds, small mammals, snow cover) to promote integration of data sets.

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Development Schedule, Budget, and Expected Interim Products

Considerable work towards completing the Denali protocol for this vital sign following NPS guidelines (Oakley et al. 2003) has already been completed. The *Vegetation Structure and Function* protocol for the CAKN is currently being written and is targeted for completion in late 2004.

The protocol will be developed on the following schedule:

Fiscal Year	Expected Interim Products
FY 2005	Draft protocol completed (November 1, 2004)
FY 2006	Implement monitoring

Central Alaska Network
Protocol Development Summary

Subarctic Steppe

Carl Roland, Botanist
Denali National Park and Preserve

Protocol: Monitoring Subarctic Steppe Vegetation—Community of Special Concern

Parks: DENA, WRST, YUCH

Justification/Issues Being Addressed

Open, xeric subarctic steppe plant communities that occur on steep, south-facing river bluffs in interior Alaska (many of which are located in YUCH) harbor several very rare endemic vascular plant species. In addition, these sites are home to numerous taxa with disjunct geographic ranges that (aside from their Alaska localities) occur in northeastern Asia or in the Great Basin of western North America. Because of the high numbers of rare and endemic plants and the very limited spatial extent of these communities on the landscape, these plant communities are of special concern to managers of the preserve. This unique community is an important botanical resource and as such is considered a vital sign for this area. As a result, a monitoring strategy is needed that will allow us to monitor the status and health of these plant communities.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

1. Determine changes in the distribution and spatial extent of this community across the entire CAKN.
2. Detect directional changes in the population status of selected sensitive species.
3. Assess whether any adverse impacts to sites supporting this vegetation are occurring.

Basic Approach

Additional thought and discussion of the right approach to monitoring this plant community of special concern is needed. The hill slopes where subarctic steppe occurs are steep, erodible, and very easily disturbed. The costs and benefits of procuring data on the status of the community versus harming it through sampling must be weighed and considered. One suggestion has been to use photographic techniques to make periodic assessments of the extent of open habitat. Further scoping of the issues around monitoring steppe will be necessary prior to moving forward with protocol development.

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Development Schedule, Budget, and Expected Interim Products

The next step in the development of this protocol will be discussion among the technical committee and managers of YUCH and WRST (where this community occurs) to determine the data needs and how these can be met without adversely affecting the subarctic steppe communities.

Fiscal Year	Expected Interim Products
FY 2007	Begin protocol development
FY 2008	Develop protocol
FY 2009	Complete protocol
FY 2010	Implement monitoring

Central Alaska Network
Protocol Development Summary

Human Populations in the Central Alaska Network Region

Karen Oakley, Ecologist
Biological Resources Division, USGS

Protocol: Human Populations in the Central Alaska Network Region

Parks Where Protocol will be Implemented: DENA, YUCH, WRST

Justification/Issues Being Addressed

The Central Alaska Network has identified Human Populations of the network region as a Vital Sign. In the network's conceptual model, human populations are an important driver of ecological change. Globally, increasing human populations influence demand for resources, affect migratory birds and fish that breed in Central Alaska Network parks, and influence local and regional demand for recreational resources provide by network parks (i.e., tourism). Even though human populations in the network region are currently "low" (by lower 48 standards), the local and regional human populations are also of interest to the network. Local and regional residents comprise the majority of subsistence users of network park resources. As settlements along park borders grow, consumptive and nonconsumptive uses of park resources can grow along with habitat fragmentation concerns. Thus, monitoring of human population growth in the communities in and near the parks is important for the network. These human population data are an important part of the Human Driver Vital Sign Footing. The purpose of this protocol is to gather and report on existing demographic data on human populations in the network region cheaply and efficiently.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

1. Use state and federal census data to monitor trends in the number of people residing in communities in and near Central Alaska Network parks (see Table 1).

Basic Approach

The U.S. Census Bureau collects data on the characteristics of human population in the United States every decade. The Alaska Department of Labor and Workforce Development, Research and Analysis, Demographics Unit, also reports on demographic trends in the state as a whole and for selected communities. These data are currently made available on the Internet, and the Central Alaska Network will rely on these sources of data. To develop the protocol for monitoring human populations in the network region

and communities, methods for retrieving and formatting the data for inclusion in network reports on ecosystem trends will be tested. In this respect, this protocol will have a similar approach to other protocols where the primary data of interest to the network are collected by another federal or a state agency (e.g., animal harvest data collected by the Alaska Department of Fish and Game). The goal is to take data in one form and present it in a format that will best help the network see how the data relate to other network data sets. The expectation is that this data transfer process can be cheap and efficient, once a system for it is established.

Census data are reported by census area and by community. Central Alaska Network parks include all or part of seven of Alaska's Census Areas. The current number of communities in or bordering the parks is 38 (see attached list), all relatively small. Although the U.S. Census Bureau reports every decade, the State updates population information more frequently. Various options for how often to update the network's information on human population will be considered as part of protocol development. Our preliminary assessment is that the main attribute to be monitored by the network is simply the number of people residing in communities in and near the parks. A wide variety of socio-economic data are gathered as part of the census, however, and whether there are other data that would help the network assess human population trends will also be assessed.

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Development Schedule, Budget, and Expected Interim Products

This protocol will be developed by first producing a report on human population trends in the Central Alaska Network region based on 1990 and 2000 census data. By working with the existing data, the mechanisms for downloading and formatting the data will be tested, and feedback on the most useful ways to report the data will be obtained. A draft protocol will be written and review by a state demography will be sought. The protocol will be developed on the following schedule:

Fiscal Year	Expected Interim Products
FY 2004	Report on Human Population Change in the Central Alaska Network region, 1990-2000. Draft protocol for internal network review, October 31, 2004.
FY 2005	Draft protocol for regional review, December 15, 2004
FY 2006	Implement

No direct costs for developing this protocol are anticipated. Costs are mainly salary costs for Karen Oakley and Doug Wilder (CAKN Data Manager).

Table 1. List of census areas and communities in and near Central Alaska Network parks whose populations are monitored by the U.S. Census Bureau.

Denali National Park and Preserve
- Denali Borough
  - Anderson
  - Cantwell
  - Ferry
  - Healy
  - McKinley Park
- Yukon-Koyukuk Census Area
  - Lake Minchumina
  - Nikolai
- Matanuska-Susitna Borough
  - Chase
  - Petersville
  - Skwentna
  - Talkeetna
  - Trapper Creek

Yukon-Charley Rivers National Preserve
- Southeast Fairbanks Census Area
  - Chicken
  - Eagle
  - Eagle Village
- Yukon-Koyukuk Census Area
  - Central
  - Circle

Wrangell-St. Elias National Park and Preserve
- Yakutat Borough
  - Yakutat
- Valdez-Cordova Census Area
  - Chisana
  - Chistochina
  - Chitina
  - Copper Center
  - Copperville
  - Gakona
  - Glennallen
  - Gulkana
  - Kenny Lake
  - McCarthy
  - Mendeltna
  - Mentasta Lake
  - Nelchina
  - Paxson
  - Silver Springs
  - Slana
  - Tazlina
  - Tolsona
  - Tonsina
  - Willow Creek

Central Alaska Network
Protocol Development Summary

Consumptive Use

Maggie MacCluskie, Coordinator
Central Alaska Network

Protocol: Monitoring Consumptive Uses of Natural Resources in CAKN Parks

Parks Where Protocol will be Implemented: DENA, WRST, YUCH

Justification/Issues Being Addressed

The CAKN parks and preserves are mandated by their enabling legislation (ANILCA Public Law 96-487) to allow consumptive uses of natural resources by local rural residents. These resources include but are not limited to: fish, wildlife, timber resources (logs for subsistence cabins and firewood), water, and berries. In addition, some park resources may be used by park management for administrative purposes. (Gravel mining from park river floodplains to obtain gravel for park road maintenance is one example.) The CAKN identified consumptive uses of park resources as a potential near-field driver of ecological change (MacCluskie and Oakley 2003). The *Consumptive Use Vital Sign* will annually monitor the type, quantities, and locations of selected consumptive uses to detect long-term trends. Because parks may manage and regulate some aspects of consumptive use, this vital sign has a direct link to park resource protection.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The fundamental question to be addressed by this protocol is: What is the level of consumptive use and where do these uses occur? The underlying question of critical importance to management is: Are these consumptive uses sustainable? Monitoring alone cannot answer this question, but the monitoring data will provide the foundation for determining if the level of consumptive use is rising to the level of concern or damage.

The specific monitoring objectives are:

1. Using existing data collection systems of the Alaska Department of Fish and Game and the Federal Subsistence Board, monitor the number and locations of the annual sport and subsistence take of grizzly bear, black bear, moose, caribou, and Dall's sheep within the State Game Management Units within which the CAKN park and preserve lands occur.
2. Using existing data collection systems of the Alaska Department of Fish and Game, monitor the annual number and

locations of grizzly bears and black bears killed in Defense of Life and Property on CAKN park and preserve lands.
3. Using existing data collection systems of the Alaska Department of Fish and Game, monitor the annual number and location of mammals trapped.
4. Using existing data collection systems of the Alaska Department of Fish and Game, monitor waterfowl and upland bird harvest.
5. Using existing data collection systems of the Alaska Department of Fish and Game, monitor the annual harvest (sport, commercial, subsistence, personal use) of salmon from the Copper River.
6. Monitor the annual use (amount and location) of house logs and firewood by local rural residents using the permit databaess of network parks.
7. Monitor the annual use (amount and location) of gravel mining from WRST and DENA rivers for administrative uses.
8. Monitor the occurrence of new consumptive uses as they begin to occur.

Basic Approach

The basic approach of the Consumptive Use Vital Sign will be to focus on making existing data sources on consumptive uses more readily available to park managers wherever possible. Protocol development will be staged because consumptive uses span a wide variety of resources. As noted, for some consumptive uses, data are available, and the primary task of the network will be to facilitate the acquisition and formatting of the data for park managers' use. For other consumptive uses, quantitative data are not available, and protocols will need to be developed.

The first part of the protocol to be developed will address the utilization of fish and wildlife (Objectives #1-5). The Alaska Department of Fish and Game manages databases that provide considerable information about fish and wildlife harvest in CAKN parks. However, not all fish and wildlife is harvested under state regulations; there is a parallel set of federal fish and wildlife regulations that have a separate and different database. These databases need to be collected and templates for their use developed. The network has begin this work in a pilot study conducted during FY 2003 (cite 2003).

The second part of the protocol to be developed will address use of forest products (Objective #4). The ANILCA parks (WRST and YUCH) and the new portion of Denali must permit use of firewood by local residents without a permit (36 CFR §13.49 b). Dead and downed wood may be utilized. Monitoring amounts and impacts of firewood and house log use has proven to be difficult for parks.

The third part of the protocol to be developed will address the administrative use of park resources, focusing on gravel. Data on these uses are available from the maintenance division.

The fourth part of the protocol to be developed will address water and any other consumptive uses we overlooked.

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Development Schedule, Budget, and Expected Interim Products

The protocol will be developed on the following schedule:

Fiscal Year	Expected Interim Products
FY 2006	Begin protocol development
FY 2007	Develop protocol.
FY 2008	Complete protocol
FY 2009	Implement

Central Alaska Network
Protocol Development Summary

Human Presence

Karen Oakley, Ecologist
Biological Resources Division, USGS

Protocol: Monitoring Human Presence in Central Alaska Network Parks

Parks Where Protocol will be Implemented: DENA, WRST, YUCH

Justification/Issues Being Addressed

The Central Alaska Monitoring Network (CAKN) identified human activities in and near parks as an important driver affecting park ecosystems. These activities included consumptive uses, recreational uses, developments on private lands inside parks and on non-NPS lands adjacent to parks, and resource management activities. The Human Presence Vital Sign was selected to provide the network with critical information about human uses occurring within the parks. The Human Presence Vital Sign, in conjunction with the Human Population and Landcover-Landscape Dynamics Vital Signs, will help the network monitor the regional and local scale human activities that may be affecting park resources.

CAKN parks encompass a huge land area with limited access, and monitoring of human activities is difficult (Cessford and Muhar 2003). Generally, these parks include frontcountry areas where human activities are concentrated and backcountry areas where human activities are dispersed. Separate park management plans are typically developed for the frontcountry and backcountry areas, and the plans include monitoring of human activities and impacts to reach plan goals. Currently, only one park in Alaska, DENA, has developed a backcountry management plan, and that plan will be finalized in 2005. The other network parks will develop their plans in the next few years. The development of the Human Presence Vital Sign Monitoring Protocol for the CAKN will be conducted in partnership with park backcountry planning efforts and take into account current and planned methods used for monitoring human presence. The spatial distribution of human activities is one of the most important aspects of human presence to be monitored, in addition to seasonal patterns and levels and types of use.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The Human Presence monitoring component of the CAKN Vital Signs monitoring program seeks to monitor long-term trends in the spatial distribution of human presence in CAKN parks by season, intensity, and type of activity.

Basic Approach

The general strategy the network will use to monitor the Human Presence Vital Sign will be to work with planning teams in each park to develop metrics that will help the backcountry management plans be developed and implemented. As a start, the CAKN monitoring program will be able to contribute information on signs of human presence from visits to the permanent sampling points (minigrids) established for the Vegetation Structure and Composition and Passerine Bird Vital Signs. Additional metrics of human presence and use will be developed in conjunction with backcountry management plans. Costs of monitoring activities for monitoring long-term trends in human presence will be shared between the network and individual parks.

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Development Schedule, Budget, and Expected Interim Products

Fiscal Year	Expected Interim Products
FY 2005	Denali completes Backcountry Management Plan.
FY 2006	Scoping and evaluation of existing and planned data gathering by parks on human presence,
FY 2007	Protocol development to improve and refine existing data gathering and add new metrics, as needed.
FY 2008	Protocol completed.
FY 2009	Implementation

Central Alaska Network
Protocol Development Summary

Trails

Carl Roland, Botanist
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Protocol: Monitoring Impacts to Vegetation and Soil Resources from Social Trails and Trampling.

Parks: DENA, WRST, YUCH

Justification/Issues Being Addressed

Vegetation impacts from trampling, campsite formation, and related visitor uses have been identified as an important issue for backcountry management in the network. Because correcting these impacts once they have already occurred is a difficult, expensive, and time-consuming process, it is important to manage recreational use to avoid (to the greatest degree possible) such impacts to park resources. In order to set effective recreational use policies, it is necessary to monitor both the amount of and kinds of recreational use and the impacts to resources from such use. Data gathered from impacts monitoring can be used to inform managers charged with formulating park policy and direction for recreational use.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

1. Detect changes in the severity of impacts to park resources from recreational use of the landscape.
2. Detect changes in the spatial extent and distribution of trampling damage to vegetation and soils resources in regions of the network that are subject to these problems.

Basic Approach

We propose a three-tiered system for monitoring the impacts to vegetation resources in the network resulting from visitor use in the backcountry. The coarsest spatial scale on which impacts from recreational use would be quantified is the landscape-scale systematic mini-grid network of permanent plots. The next level of monitoring intensity would be annual reconnaissance forays aimed at identifying new or intensified impacts from these activities. The third, most intensive level of monitoring in this system would be periodic measurements made at a set of "index sites" installed in areas with known vegetation and soil impacts resulting from visitor use.

In each case, we plan to make measurements according to vegetation protocols developed for the monitoring program, to maximize

the ability to compare data from different areas where measurements are made.

There are several basic criteria that must be met to design an effective, affordable, and sustainable program for monitoring vegetation impacts. The first is that any measurements must be simple and highly repeatable, with the potential for observer-introduced error reduced to an absolute minimum. Secondly, the attributes chosen as indicators of human use must be clear and incontrovertible—metrics such as exposure of bare soil in camp sites and social trails and the compaction of soils are not likely to be caused by factors other than human activities. Similarly, the presence of exotic plant species in disturbed areas is a reliable metric of human-induced change. Thirdly, the program must be affordable and sustainable in the long term, even with the minimum anticipated crew and resources. Only if these three criteria are met—simple, reproducible measurements, reliable and incontrovertible metrics of human use, and a financially-sustainable commitment—will a monitoring strategy be successful.

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Development Schedule, Budget, and Expected Interim Products

Further work on development of the CAKN trail and impacts monitoring protocol will occur after the network completes and formalizes the landscape-scale vegetation structure and composition monitoring protocol (FY05). This is necessary because the two efforts will be complementary and, in several respects, overlapping. Thus the current proposal for trail monitoring protocol is predicated to some degree upon the vegetation structure and composition protocol. We anticipate relying on several of the techniques being developed and proposed for the larger vegetation monitoring protocol.

Fiscal Year	Expected Interim Products
FY 2006	Begin protocol development
FY 2007	Develop protocol
FY 2008	Complete protocol
FY 2009	Implement

Central Alaska Network
Protocol Development Summary

Wildland Fire

Jennifer Allen, Fire Ecologist
Alaska Region, National Park Service

Protocol: Disturbance Monitoring: Monitoring Trends in Extent, Severity, and Effects of Wildland Fire in Central Alaska Network Parks

Parks Where Protocol will be Implemented: DENA, WRST, YUCH

Justification/Issues Being Addressed

Wildland fire is one of the most influential disturbance processes in boreal ecosystems and has been identified as a vital sign for the Central Alaska Network (MacCluskie and Oakley 2003). Fire affects all of the parks in the Central Alaska Network—over 1.5 million acres have burned within the three parks in the past 50 years. Fire is the dominant ecological process in YUCH and in the northwestern regions of DENA. Fire is also important in the non-maritime portions of WRST, although fire return intervals there are generally much longer than in DENA and YUCH. Fire is an important monitoring variable because it not only influences vegetation succession and distribution but also wildlife habitat, soil parameters (e.g. permafrost and nutrient cycling), hydrology, water quality, and air quality. In addition, the natural fire regime (fire frequency, extent, and severity) is likely to respond to local and global climate changes. Baseline monitoring of fire parameters such as the number of fires, fire extent, and burn severity will provide explanatory variables for other ecological changes detected. Long-term monitoring of fire effects on vegetation will also provide a foundation to elucidate the complex relationship between fire and the landscape. Fire management in Alaska needs the ability to predict fire behavior and fire spread to evaluate the potential risk to infrastructure, cultural sites, or communities adjacent to the parks. Understanding the successional trends of fire and how the fuel complex (the structure and composition of combustible materials in a forest stand) changes as forests age will provide fire management with the information needed to predict fire behavior and fire potential in Alaska parks.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The specific objectives of the Wildlife Fire monitoring protocol are:

1. Work with the existing NPS Fire Management Program in the Alaska Region to annually monitor the location, extent, timing, and severity of wildland fires in CAKN parks to determine annual fire frequency, average fire size, average and variability

of burn severity, and total area affected by fire in each CAKN park. ***Justification:*** *Mapping the occurrence of wildland fires is the fundamental information needed to monitor effects of this major disturbance process in CAKN parks*.

2. Work with the existing NPS Fire Management Program in the Alaska Region to monitor successional effects of fire and burn severity on: the species composition and structure of vegetation; soil temperature and moisture; active layer depth; permafrost state; and animal community composition. ***Justification:*** As the importance of fire is recognized in the CAKN ecosystems, incorporating fire severity and extent from the NPS Fire Management Program will be a significant step to building a holistic monitoring program. As these data are already being collected by the NPS Fire Management Program this is an excellent example of a cooperative opportunity that will result in a better program.

Basic Approach

The basic approach of the Wildland Fire Vital Sign Protocol will be to work cooperatively with the existing Fire Management Program of the NPS-Alaska Region. The Fire Management Program is currently collecting the basic data on locations, extents, and severity of fires in CAKN parks. The Fire Management Program is also working on fire effects monitoring through establishment of new plots and use of historic fire effects plots. The CAKN approach will be to develop mechanisms for making data collected by the Fire Management Program available for network purposes, including reporting on ecological trends in network parks and correlating with other Vital Sign measures. The CAKN will also augment the existing fire effects monitoring conducted by the Fire Management Program using the minigrid plots established for the Landscape-Scale Vegetation Vital Sign (see Roland et al. 2003). When minigrid plots are burned, the network will re-measure them at more frequent intervals to monitor post-fire succession in vegetation and animal communities. In addition, the network will support the Fire Management Program in periodic re-measurement of the historic fire effects plots that were permanently marked in network parks (8 in YUCH, 5 in WRST, and 11 in DENA).

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Development Schedule, Budget, and Expected Interim Products

The NPS-Alaska Region Fire Management Program has already developed standard operating procedures (SOPs) for mapping fires and collecting data on burn severity. Protocol development will not require field research and will consist primarily of writing a protocol that meets NPS standards (Oakley et al. 2003) and incorporates existing standard protocols. We will need to write new sections in the protocol narrative and SOPs to make the existing protocols specific to CAKN parks, such as describing plot locations and documenting how data will be entered into NPS computers, analyzed, and reported. A draft protocol for the NPS Fire Plots for measuring fire effects has been completed, and pilot testing of these methods was conducted during 2003 in YUCH in areas where fires burned that season. Site selection of these fire effects plots and historic plots needs to be assessed statistically before this protocol is finalized. Protocols have been developed for the mini-grid sampling, but additional tree variables to be monitored will need to be added.

Fiscal Year	Expected Interim Products
FY 2005	Begin protocol development
FY 2006	Develop protocol
FY 2007	Complete protocol
FY 2008	Implement protocol

Central Alaska Network
Protocol Development Summary

Landcover

Karen Oakley, Ecologist
Biological Resources Division, USGS

Protocol: Monitoring Long-term Trends in Landcover Categories of CAKN Parks

Parks Where Protocol will be Implemented: DENA, WRST, YUCH

Justification/Issues Being Addressed

The Central Alaska Monitoring Network (CAKN) identified monitoring changes in the amount of area occupied by broad landcover categories in CAKN parks as an important Vital Sign. Broad landcover categories include several vegetated classes (i.e., forest, shrub, and alpine), and unvegetated classes such as glacier, rock, and floodplains. The network envisioned that remote sensing would be used at widely-spaced intervals (e.g., 10–20 years) to get a general sense of major directional changes in landcover, including the amount of area occupied by these broad landcover classes and also the amount of area covered by glaciers and the location of treeline. The network envisioned the Landcover Vital Sign producing a relatively cheap, low resolution snapshot of the general landcover situation at a given point in time. Trends in landcover at the scale of the entire network was considered important background for relating to trends in all other Vital Signs.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The Landcover monitoring component of the CAKN Vital Signs monitoring program is focused on park managers with general information about long-term trends in spatial extent and area occupied by major landcover classes. The specific monitoring objective is to monitor the long-term trends in the spatial extent and area occupied by broad landcover classes in CAKN parks using remotely-sensed imagery at 10–20 year intervals.

Basic Approach

The CAKN strategy for developing a protocol for the Landcover Vital Sign is to build on approaches being developed by other networks and to work in cooperation with other Alaska networks and the Alaska Regional GIS team. Almost all networks have expressed interest in using remote sensing to monitor landscape changes, and numerous protocol development efforts are ongoing, with some coordination by the National I&M office to avoid duplication of effort. The CAKN will follow these protocol development efforts and take them into account in FY 2007 when work on the CAKN protocol will begin.

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Development Schedule, Budget, and Expected Interim Products

Fiscal Year	Expected Interim Products
FY 2005	
FY 2006	Develop protocol
FY 2007	Complete protocol
FY 2008	Implement protocol

Central Alaska Network
Protocol Development Summary

Sound

Chad Hulz, Sound Specialist
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Protocol: Monitoring Changes in the Natural Soundscape in Central Alaska Parks

Parks Where Protocol will be Implemented: DENA, WRST, YUCH

Justification/Issues Being Addressed

The CAKN has adopted a holistic view of network ecosystems and will monitor the major physical drivers of ecosystem change and responses of the two major components of the biota: plants and animals. An important characteristic of the physical environment is the natural soundscape of an ecosystem. Soundscape is generally comprised of two main sound categories: biophony and geophony. Ecosystems have specific soundscape characteristics that are an important attribute of the natural system, as well as have a distinct impact on the human perception of the environment. In 2000, Director's Order 47 directed park managers to identify baseline soundscapes and related measures. Prior to the Director's Order, YUCH devoted significant resources to evaluating the potential effects military overflights have on Dall's sheep and peregrine falcon populations. While WRST and DENA do not experience military flight activity, soundscape disturbance due to helicopters, air taxis, and flightseeing is a topic of concern as the number of visitors continues to increase.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

The specific objectives to be addressed by this protocol are to:

1. Detect and monitor change in the natural soundscapes of the ecoregions of CAKN parks, including quantification of biophony and geophony.
2. Provide information to managers on changes to the soundscape, both natural and human-caused.
3. Provide a reliable data stream that will integrate with other monitoring efforts of the CAKN.

Basic Approach

Denali has been researching soundscape monitoring techniques and applications since 2001. Though this research has primarily been aimed at finding an effective way to develop baseline information that will allow management to protect sound resources, values intrinsic to soundscape and ecological monitoring have become evident. An extensive project in Yukon-Charley

has explored the effect of sound on raptors. These experiences, along with experiences from all other National Park units that are currently monitoring sound, will be explored in a scoping meeting in September 2004. Sound monitoring techniques, intrinsic values and ecological importance, and applications to other aspects of ecological monitoring will be main topics of the workshop. Park managers, resource specialists, and outside experts will work together to determine if soundscape monitoring should be a priority vital sign for the Central Alaska Network, and if so, what aspects are most important. If successful, protocol development will begin in FY2005. Many elements of the protocol are already available through research efforts at Denali, Yukon-Charley, and other western parks.

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Development Schedule, Budget, and Expected Interim Products

Pre-Scoping Information Report, Summer 2004 (review of monitoring programs, legislation, techniques, background, and applications)
Scoping Workshop, Fall 2004 ($6,000)
Scoping Workshop Report, Fall 2004

Fiscal Year	Expected Interim Products
FY 2004	Pre-scoping information report prepared. Scoping Workshop
FY 2005	Scoping Workshop Report
FY 2006	Develop protocol
FY 2007	Complete protocol
FY 2008	Implement protocol

Central Alaska Network
Protocol Development Summary

Landscape Phenology

Carl Roland, Botanist
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Protocol: Monitoring the Timing of Seasonal Snow Cover and Vegetation Green-up, Maximum Greenness, and Senescence in the CAKN Landscape

Parks Where Protocol will be Implemented: DENA, WRST, YUCH

Justification/Issues Being Addressed

A defining characteristic of CAKN ecosystems is extreme seasonality: the presence of seasonal snow cover (currently) for 8–9 months, and a compressed growing season of 3–4 months. Seasonal snow cover defines the length of the growing season, is a major determinant of the annual water cycle, and greatly affects the reproduction and survival of animals. Within the snow-free season, the progression of vegetative development depends on climatic parameters including temperature, precipitation, and cloudiness (solar radiation). The benchmarks in the annual development of seasonal snow cover and the vegetation canopy in CAKN parks are: (1) snow-free date, (2) date of onset of greenness ("green-up" date), (3) date of maximum greenness, (4) date of senescence of greenness, and (5) snow-cover date. Annual variation in the timing of these events may have profound effects upon a wide variety of ecosystem processes, including net primary productivity, and survival rates and reproductive success for both plants and animals. We expect that an initial effect of climate change would be changes in the timing of these events. Changes in the distribution and abundance of the biota would likely follow any significant and directional changes in the timing of seasonal snow cover and plant growth and senescence. Detecting trends in landscape phenology was selected as a Vital Sign for CAKN because of the fundamental importance of vegetation productivity and snow cover to ecosystem structure and function. The Landscape Phenology Vital Sign will provide an annual measure of key ecosystem processes across the entire network landscape. This vital sign will play an integrative role with other vital signs (especially Vegetation Structure and Function, Climate and Snow Cover, Permafrost, Glaciers, Disturbance Processes: Fire, and all faunal vital signs).

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

1. Using remote sensing techniques, monitor the annual dates and spatial extents of (1) snow-free, (2) onset of greenness, (3) maximum greenness, (4) senescence of greenness, and (5) snow

cover for CAKN parks to allow long-term trends in landscape phenology to be detected.

Basic Approach

The basic approach we will take to monitoring landscape phenology will be to use remote sensing techniques. We propose that satellite imagery, most likely MODIS or AVHRR, be used to determine snow cover dates and to calculate NDVI (Normalized Difference Vegetation Index) for sections of the three network parks on a specified schedule, beginning in March and ceasing in October. This would (potentially) enable us to make annual estimates of the critical points in the development of the vegetation canopy through the course of the growing season on a landscape scale. Data from successive years would then be compared to determine the spatial and temporal variation in these events.

The difficulty in successfully implementing this protocol will be in consistently acquiring imagery data of sufficient quality (cloud-free) and quantity (on a week to two-week basis throughout the growing season) to make the requisite calculations and make reliable estimates of the desired parameters. In addition, we will need to find and identify individuals with the skills and time to perform the imagery analysis, quality control, and presentation of this technical data.

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Development Schedule, Budget, and Expected Interim Products

The next step in the development of this protocol will occur in association with the development of other remote-sensing protocols for this and other networks. The USGS-National Park Monitoring Project is expected to fund a project in FY 2005 with the USGS-Earth Resources Observation Systems (EROS) Data Center to look at the use of MODIS imagery (Moderate Resolution Imaging Spectroradiometer) to meet similar objectives for the Southwest Alaska Network. We will monitor the progress of that project and look to the protocol developed for SWAN as the basis for the CAKN protocol.

The protocol will be developed on the following schedule:

Fiscal Year	Expected Interim Products
FY 2005	USGS-EROS Data Center report for SWAN on use of MODIS for monitoring landscape processes
FY 2006	Develop draft protocol based on SWAN project, test in CAKN
FY 2007	Implement full protocol.