Central Alaska Network

Vital Signs Monitoring Plan
Phase 2 Report

Denali National Park and Preserve
Yukon - Charley Rivers National Preserve
Wrangell - St. Elias National Park and Preserve

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Vital Signs Monitoring Plan

Phase II Report

By

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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.

- Each network must develop a detailed monitoring plan prior to commencement of monitoring. Development of monitoring plans occurs over several years and is required to occur in three phases. At the end of each phase, a report is written to provide opportunity for review and revision.

- This Phase II report updates introductory and background material presented in the Phase I report. The key addition in the Phase II report is the description of initial Vital Signs chosen by the network.

- The Alaska National Interest Lands Conservation Act of 1980 (ANILCA) created 2 of the 3 parks in CAKN and added significant acreage to the third. ANILCA firmly establishes the importance of maintaining natural ecological processes in the vast areas of CAKN parks (Chapter 1).

- Although each CAKN park preserves unique areas, these parks share common purposes of protecting fish and wildlife habitat and populations and other aquatic resources, 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, providing a solid foundation for "thinking like a network" (Chapter 1).

- 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 to detect change in its ecological components and to detect change in the relationships among the components.

- Major milestones of CAKN monitoring program development include: establishment of a Board of Directors and Technical Committee; hiring of the Network Coordinator and Data Manager; setting of initial goals and objectives; organization of a Scoping Workshop; writing of the initial chapters of the monitoring plan (this report), and determining the initial set of vital signs for the network.

- Denali has been the site of a prototype Long-term Ecological Monitoring (LTEM) Program since 1992. The Denali LTEM program has been formally integrated into the CAKN to avoid duplication of effort and enhance the overall monitoring effort. In 2003, reports summarizing the previous monitoring efforts at Denali were prepared as a foundation for decisions about future monitoring at Denali under the network paradigm.

- Natural resources of the three parks in the Central Alaska Network are similar in many respects. Important resources are mountains and geological processes, including glaciers; a diverse flora revealing landscape history; rivers, including significant salmon rivers; wildlife; and designation as international biosphere reserves. What is most important about the natural resources of these parks is that they exist together in an ecological system with its integrity largely intact.

- Resource protection concerns of the three parks relate to far-field and near-field human activities.

- Current monitoring in the network includes monitoring of the water resources, weather, air quality, ultraviolet radiation, glaciers, and monitoring of bird and mammal populations.

Chapter 2. Conceptual Models

- Development of conceptual models is required to guide the process of selecting vital signs. Conceptual models help capture viewpoints of people with different expertise and foster communication.

- The process of development models for CAKN has been iterative. Our initial models focused on describing the ecological context of the CAKN parks and on understanding the most important resource protection concerns.

- An important focus of our modeling has been to develop a unifying framework for integrated, interdisciplinary monitoring.

- Development of the models has allowed us to identify the most important natural and anthropogenic drivers of change in CAKN park ecosystems.

- A simplified ecosystem model including habitat change as a unifying theme was chosen.

- A holistic model combining our model of the resource protection concerns and our ecosystem model was developed as the unifying framework for selection of vital signs.

Chapter 3. Vital Signs

- The process of choosing and prioritizing vital signs for CAKN began with brainstorming sessions in each park during 2001.

- Monitoring strategies for physical environment, flora, fauna, and aquatic systems were developed for the Scoping Workshop held in 2002. These strategies were used to develop an initial list of 36 Vital Signs, nested within the Holistic Model that is the unifying framework for the monitoring program.

- The CAKN Technical Committee used a modified-Delphi web-based process to prioritize Vital Signs within each major footing of the Holistic Model. The prioritization question was "Which Vital Signs Should the Network Work on First?" This question combined the criteria of relevance to models, feasibility, and relevance to park concerns. The prioritization process was used to avoid group-think and to generate further discussion of the proposed Vital Signs.

- During follow-up discussions stimulated by the initial ranking process, an additional footing was added to the Holistic Model to emphasize the importance of Near-field Human Drivers. An initial list of 8 Vital Signs for this footing of the model was developed, but has not yet been ranked.

- The current list of proposed Vital Signs for the CAKN includes 36 Vital Signs: 9 Physical Drivers, 9 Vegetation, 5 Fauna, 5 Habitat, and 8 Near-field Human Drivers.

- One more round of prioritization will occur during fall 2003 to select the initial Vital Signs of the CAKN.

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Preface

This document concerns 3 national parks in central Alaska: Denali National Park and Preserve, Wrangell-St. Elias National Park and Preserve, and Yukon-Charley Rivers National Preserve. These parks have recently been organized into a network—the Central Alaska Network (CAKN)—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. The steps to follow in establishing the monitoring portion of the CAKN program have been set by national-level guidance and culminate in the publication of a peer-reviewed monitoring plan. The monitoring plans are to be written in three phases, corresponding to three phases of program development, over a period of roughly 3-4 years.

The first report, called a Phase I report, is intended as a preliminary look at the initial chapters of the monitoring plan by describing the parks within the network and the resources therein. The Phase II report picks up where the Phase I reports ends by outlining an initial list of prioritized Vital Signs chosen by the network. Completion of the Phase III report will constitute completion of the monitoring plan for the Central Alaska Network.

This document is the Phase II report for the Central Alaska Network.

Chapter 1. Introduction and Background

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 justification 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 track 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 Service'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 multi-agency, 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 further needed because no single spatial or temporal scale is appropriate for all system components and processes; the appropriate scale for understanding and effectively managing 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 change 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 track a subset of park resources and processes, known as "vital signs", that are determined to be the most significant indicators of ecological condition of those 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 Laws, Policies, and Guidance). The mission of the National Park Service (National Park Service Organic Act, 1916) is:

> "*...to promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental purposes of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations*".

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

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

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

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

> *scientific activities, that is regularly updated to ensure that the Service makes sound resource decisions based on sound scientific data."*

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

> *"Natural systems in the national park system, and the human influences upon them, will be monitored to detect change. The Service will use the results of monitoring and research to understand the detected change and to develop appropriate management actions"*.
>
> Further, *"The Service will:*

- *Identify, acquire, and interpret needed inventory, monitoring, and research, including applicable traditional knowledge, to obtain information and data that will help park managers accomplish park management objectives provided for in law and planning documents.*

- *Define, assemble, and synthesize comprehensive baseline inventory data describing the natural resources under its stewardship, and identify the processes that influence those resources.*

- *Use qualitative and quantitative techniques to monitor key aspects of resources and processes at regular intervals.*

- *Analyze the resulting information to detect or predict changes, including interrelationships with visitor carrying capacities, that may require management intervention, and to provide reference points for comparison with other environments and time frames.*

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

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

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

- Federal Cave Resources Protection Act 1988;
- Clean Air Act, amended 1990;

(see Appendix A).

1.1.3 CAKN Parks Legislation and Guidance

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 4 networks in Alaska (Fig. 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% of the land in the National Park System.

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 Claims Land 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. Though ANILCA was passed prior to 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' affect on management of Alaskan 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, preserv-

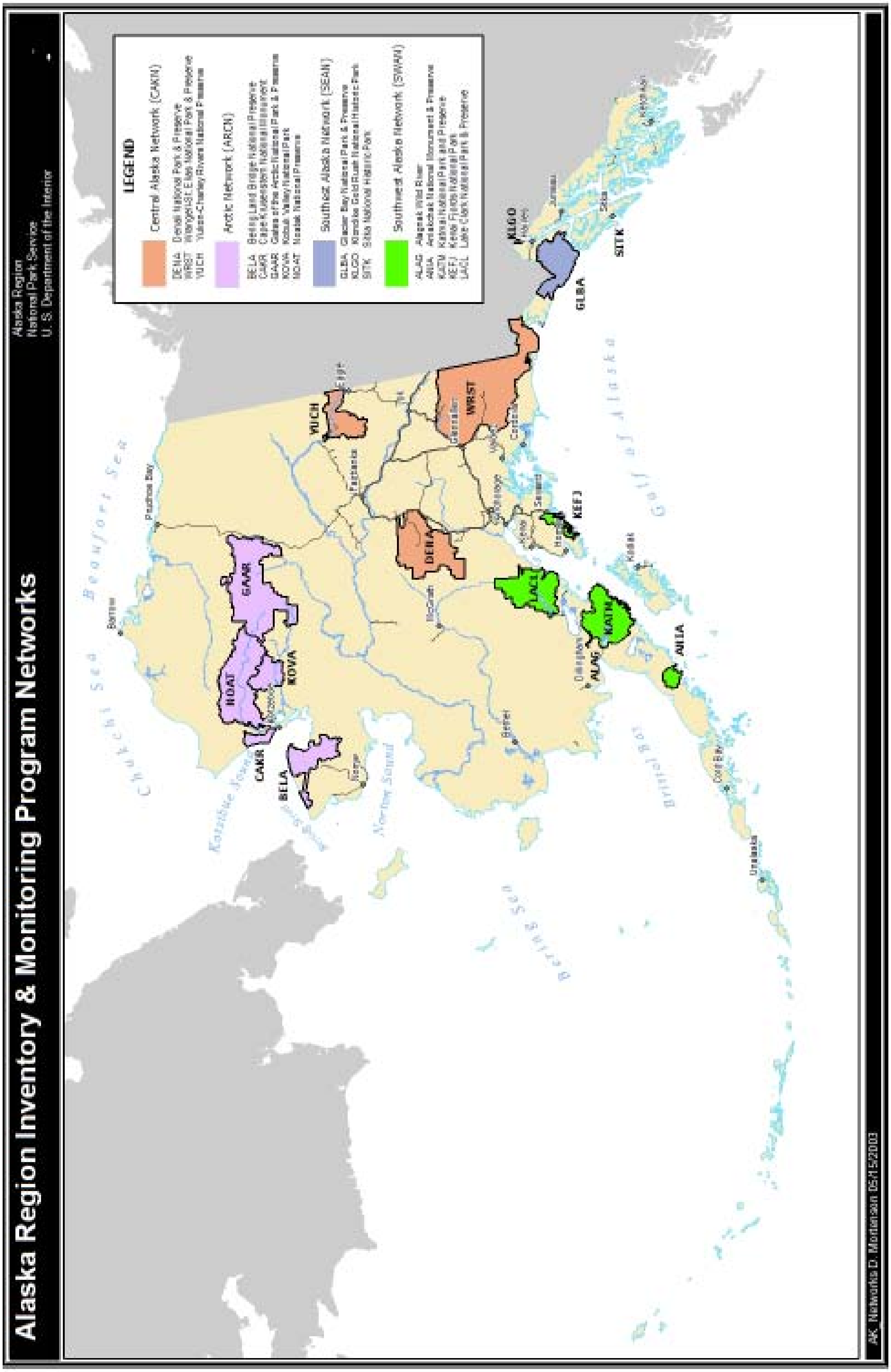

Figure 1. Location of Central Alaska Network and other Alaskan networks.

ing 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 multi-park 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. Because the CAKN is still early in the process of objective setting, this section will continue to evolve with the monitoring program. 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 resource inventories and research, provides the information needed for effective, science-based managerial decision-making and resource protection (Fig. 2; see also Appendix B). The NPS strategy to institutionalize inventory and monitoring throughout the agency consists

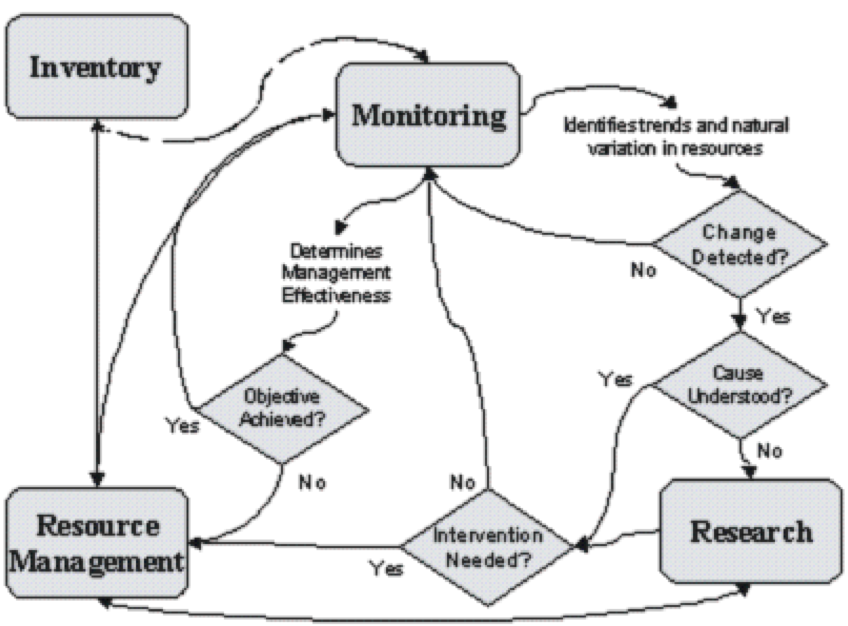

Figure 2. Relationships between monitoring, inventories, research, and natural resource management activities in national parks (modifed from Jenkins et al. 2002).

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 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. Eleven 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 is the prototype for the subarctic biome (see Appendix C).

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 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 section). 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 CAKN provide important baselines to measure and evaluate the direction and magnitude of changes brought about by human influences on regional, national, and global scales.

1.2.4 The Integration of Water Quality with Monitoring

In establishing the biological inventories for the CAKN, the network took the approach of combining the freshwater fish inventory with water quality efforts. The reasons for doing so are compelling when the size of the network is considered (21.5 million acres) along with the associated logistical costs of conducting fieldwork in the three parks. Due to the integration of the freshwater fish inventory with water quality work, a continued integration of water quality monitoring with the monitoring program has been fully incorporated into our planning process.

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 B). The CAKN contains only two streams in Tier 2 (see Appendix D for description) and will report on those streams.

During FY 2003, the network recognized that we needed to initiate a transition from the fish/water inventory work to implementation of the water quality monitoring portion of our program. Our Technical Committee has remained committed to a holistic view of our ecosystems in which we view a continuum of land to water, rather than a line of demarcation. We believe this important so that we do not subscribe to a fractured view of our ecosystems. Therefore, we conducted some pilot work for water quality monitoring in 2003 (For full pilot work study plan see http://www.nature.nps.gov/im/units/nw03/TC_login.cfm). Slightly less than half of the funds from the Water Resources Division in FY2003 were spent to assess the feasibility of conducting surveys to determine key factors affecting community structure and productivity of ponds and streams at an extensive landscape scale, as well as collecting data on the four mandatory water quality parameters. The work was conducted at Yukon-Charley Rivers National Preserve as an initial sampling location. This objective is consistent with the strategy developed by the Aquatic Work Group. The data from this project will be analyzed during fall and winter 2003-2004 and will be used to help the Technical Committee work on further developing and integrating the water quality monitoring work.

1.2.5 Focus of the Central Alaska Network

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 its 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 design of our program must by such that it minimizes bias in our 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 related to future issues, including ones that we cannot foresee.

At present, the focus of our program development remains broad as we continue to develop our thinking on the monitoring program. Our direction of thought since the writing of the Phase I Report and how we will proceed with the program is described in the following section.

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 such that we will evaluate the results of our monitoring at regular intervals (e.g. annually, 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, Physical Environment) that each developed a ‘strategy’ of how to approach the monitoring program for that ecosystem component. These strategies served as starting points for discussion during the Scoping Workshop as well as fitting the components of the ecosystem monitoring program together. Table 1 lists the objectives as detailed by each Work Group.

Table 1. Objectives as presented in subject-area “strategies” prepared for the CAKN Scoping Workshop.

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 our network parks.		
9		Monitor the annual area burned by fire in our 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.		

Table 1, continued. Objectives as presented in subject-area “strategies.”

Objective	Physical Environment	Flora	Aquatic	Fauna
12		Monitor changes in the relative forage quality of selected species of plants over time and space.		
13		Achieve various ‘intensive’ objectives.		

The full text of each ‘strategy’ appears in the CAKN Scoping Workshop Notebook (Full text appears on the netowrk webpage at http://www.nature.nps.gov/im/units/nw03/TC_login.cfm)

At the conclusion of our Scoping Workshop in April 2002, several conceptual developments regarding the monitoring program emerged. Several of the invited workshop participants had experience in designing and developing long-term ecological monitoring programs via the National Science Foundation or other federal and state agencies. Therefore we asked for their input on the challenges to designing our program. Probably the most important feedback we received was that if our goal was to be integrated across disciplines and attain a large scale picture of ecosystem function, we needed to design the monitoring program as such from the start with that concept being a focal point of the program.

Another development was with regard to the review of the Work Group strategies and on how to approach the challenges of developing the program holistically. In general, the invited workshop participants found the vital signs and measures proposed in the strategies are appropriately linked. One realization from our discussion was that including a scale component to objectives (e.g. being “extensive”- park or network wide, and “intensive”) a helpful progression of thought. “Intensive” objectives are those that are logistically infeasible to look at network-wide, or are area-specific in their interest/concern. Additionally, we recognized the 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, we will be able to appropriately link spatial scales of monitoring components for extensive and intensive objectives. This is crucial in attaining the holistic ecosystem picture that is primary in our network goal.

Given the above, we focused our work during 2003 on developing the framework to 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 the Interdisciplinary Team went through while Figure 3 illustrates the process portion of the work.

Figure 3. Program development for the CAKN 2001-2003.

Overview of CAKN Program Development March 2001 - August 2003

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 2. 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 and 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 is formalized.
July	Intensive work begins to prepare Phase I Report.
September	Phase I Report is completed.
October	Annual Work Plan for 2003 is determined, Interdisciplinary Team begins to meet to develop conceptual framework to program..
December	Study plans for pilot 2003 are written.
2003	
February	Conceptual framework for network is developed
March	Progress report on conceptual framework is written and circulated to Technical Committee.
July	Prioritization process of vital signs is initiated and drafting of the Phase II report.
August	Prioritization process is finalized and Phase II report is written.

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' of how to approach 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 3 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.

April 2002. The Scoping Workshop was held and helpful input was received from invited guests 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 importance of a common sample design for the program was agreed upon by the Technical Committee and invited experts. During this workshop it was also recognized that the planning process CAKN was going through was very similar to re-prioritization of the Denali LTEM program. 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 discusses the list of Vital Signs and puts them into initial prioritized order. The conceptual framework to the program with a prioritized list of vital signs will be presented to the Board of Directors for approval. The Phase II will be finished and submitted to the Alaska Regional Inventory and Monitoring Coordinator for review. The Annual Administrative Report and Work Plan for 2004 will be drafted.

1.2.7 The Role of the Denali Long-term Ecological Monitoring Program in the CAKN

In 1991, the NPS selected several parks representing different biogeographic provinces, to serve as prototypes for development of Long-term Ecological Monitoring programs. Denali National Park and Preserve was one of these prototypes, chosen to test methods for monitoring in subarctic parks. In developing its program over the last 11 years, Denali has worked closely with the U.S. Geological Survey-Alaska Science Center, on both the conceptual framework and specific protocols. As a member of the Central Alaska Network, Denali National Park and Preserve plays a unique role in its membership in the network.

To date, discussions of the structure of the CAKN monitoring program fully integrate Denali as a part of the network. We will define the nature of the intensive work that takes place in Denali and explain how it compliments and fits with the efforts in the rest of the network in the Annual Administrative Report and Workplan for 2003.

Recent efforts of the Denali Long-term Ecological Monitoring program (Denali LTEM) have focused on reframing the objectives of the program. Included in this effort has been the exploration of the feasibility of probability-based sampling designs that include the entire park in the sampling frame. This reprioritization was initiated after a program review in 1997 that revealed the program was not meeting the monitoring needs of the park. In 2000, a new conceptual document was published outlining the new direction of the program (Oakley and Boudreau 2000). Since the inception of the CAKN, the staff of the network parks have striven to integrate the Denali LTEM program with the CAKN program, however exactly what the nature of the integration would entail was unclear.

During the CAKN Scoping Workshop in April 2002 the advantages of complete integration of Denali into the CAKN program became clear, as well as how that integration might be accomplished. Due to the stage of development of the Denali LTEM program, the reassessment of the program, and the staff participation in the network it was logical to fit the Denali LTEM program with the network organization. The documents required for the Denali review were essentially the same documents needed by CAKN, but completing them for Denali alone would short-circuit the development of CAKN goals and objectives. These factors led to a convergence of thought that developing a plan for fully integrating the Denali LTEM program into the CAKN would benefit both Denali and the network. The key advantages would be to:

- avoid staging duplicative and possibly confounding conceptual planning efforts at the same time;
- to bring Denali's data management effort up to required standards following the guidance of the CAKN Data Manager;
- avoid the alternative of completely severing the Denali program from the network, in which case the network loses significant participation by key Denali LTEM staff in the areas of physical sciences, vegetation and wildlife.

During 2003, 3 reports were prepared to provide a foundation for decisions about the future of monitoring at Denali now that it is part of the CAKN. These reports included a synthesis covering the history of the LTEM program from 1991-2002 (Boudreau 2003), a database management report (Paynter and Boudreau 2003), and a report evaluating a study design for detecting ecological change in the park at multiple spatial scales (Roland et al. 2003). These reports describe the current status of monitoring at Denali and will provide the basis for network decisions about what monitoring should continue at Denali now that it is in the network.

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 F 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;
- recognition as international biosphere reserves.

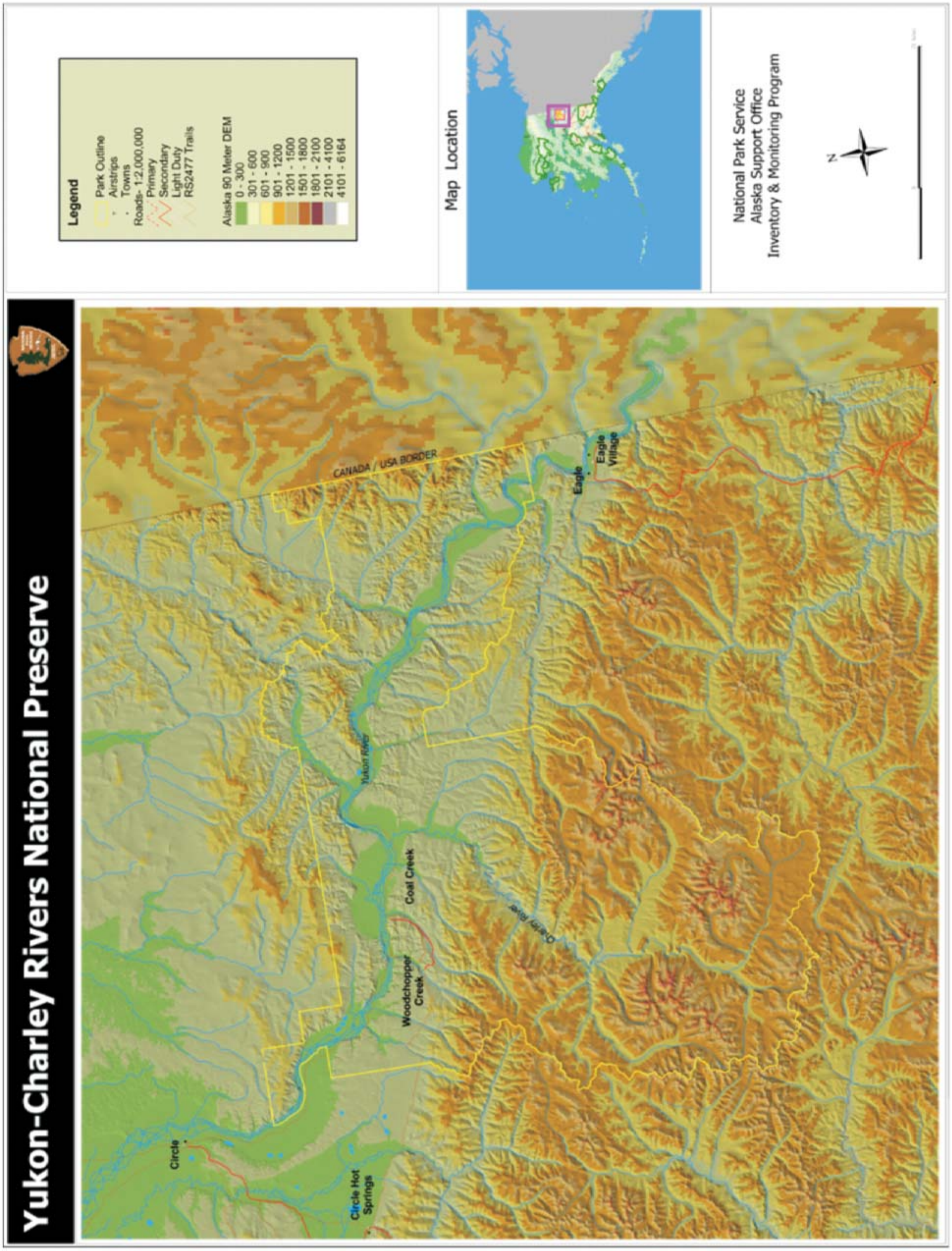

Figure 4. Yukon-Charley National Preserve, AK.

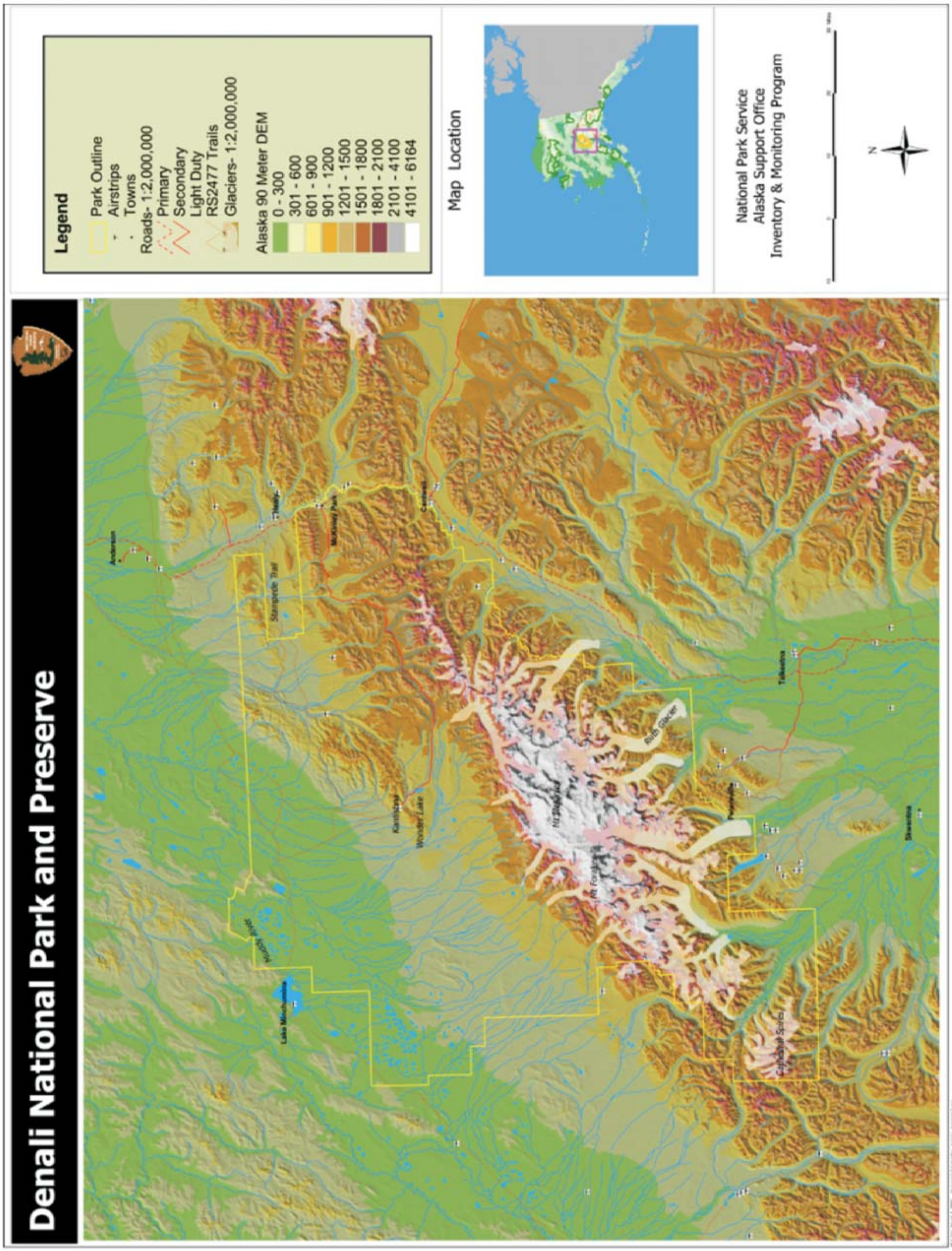

Figure 5. Denali National Park and Preserve, AK.

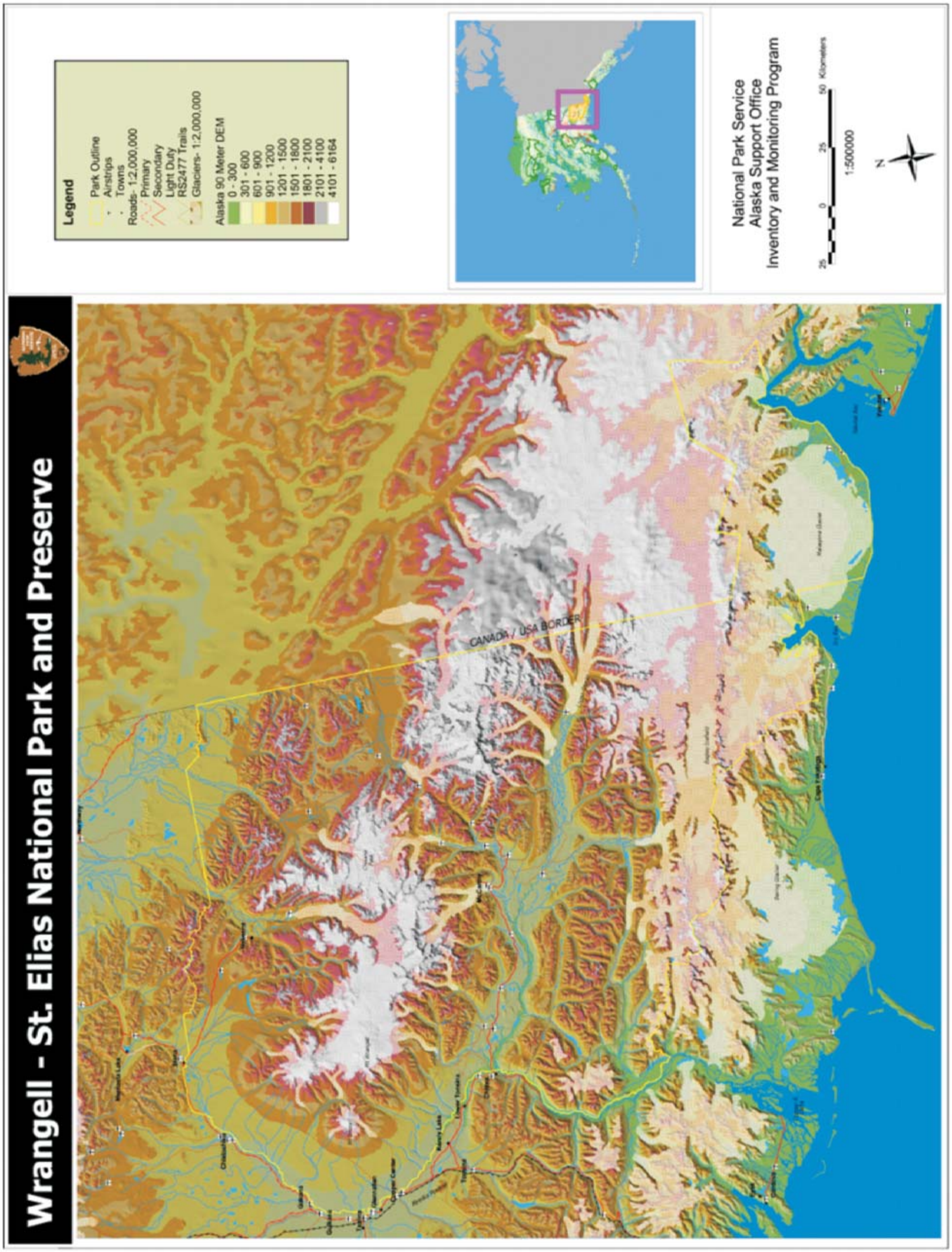

Figure 6. Wrangell-St. Elias National Park and Preserve.

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 3 parks provide for subsistence uses by local rural residents. Two of the 3 parks (Wrangell-St. Elias and Denali) have extremely tall mountains and extensive glaciers, which are remnants of the last glaciation. The 3rd park (Yukon-Charley) is entirely located in the unglaciated corridor known as Beringia. The network parks are therefore linked by Pleistocene history of the region.

The parks are also similar in having intact predator-prey systems involving wolves and 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 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. Some concerns were park-specific, and we then present these unique 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' 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 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 three categories: climate change, air pollution, 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 melting 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, 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 layer 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, Alaska Regional Assessment Group 1999). 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 within Interior Alaska. Alaska currently utilizes Canadian fire behavior models to determine the intensity and conditions under which the 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 2nd 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. Arctic Haze is 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. commun.). Ecological effects of these particular air pollutants in Alaskan 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 non-federally 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 information 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 concern 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 non-harvested 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. Among the network parks, 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 Alaskan 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 both 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 winged 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 G.

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, not be underestimated (M. Walker, University of Alaska Fairbanks, pers. commun.). 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 is a work in progress, reflecting 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. We include Tables 3 and 4 show monitoring efforts we are aware of but for which we did not have time to include brief descriptions for this report.

The focus of our initial search effort was monitoring conducted by the parks; we are presently conducting a comprehensive search of efforts by other agencies. However, in our search of existing efforts by parks, we found many efforts by other agencies that are integral to natural resource management in Central Alaska Network parks, and these are included here.

We describe in detail the monitoring efforts for the physical environment, aquatic resources, vegetation, birds, and mammals in Appendix H. We first review historic efforts, then describe current monitoring. To comprehensively show the monitoring efforts in each park, Figures 7-9 illustrates by park (Yukon-Charley, Denali, and Wrangell-St. Elias, respectively) where efforts have taken place.

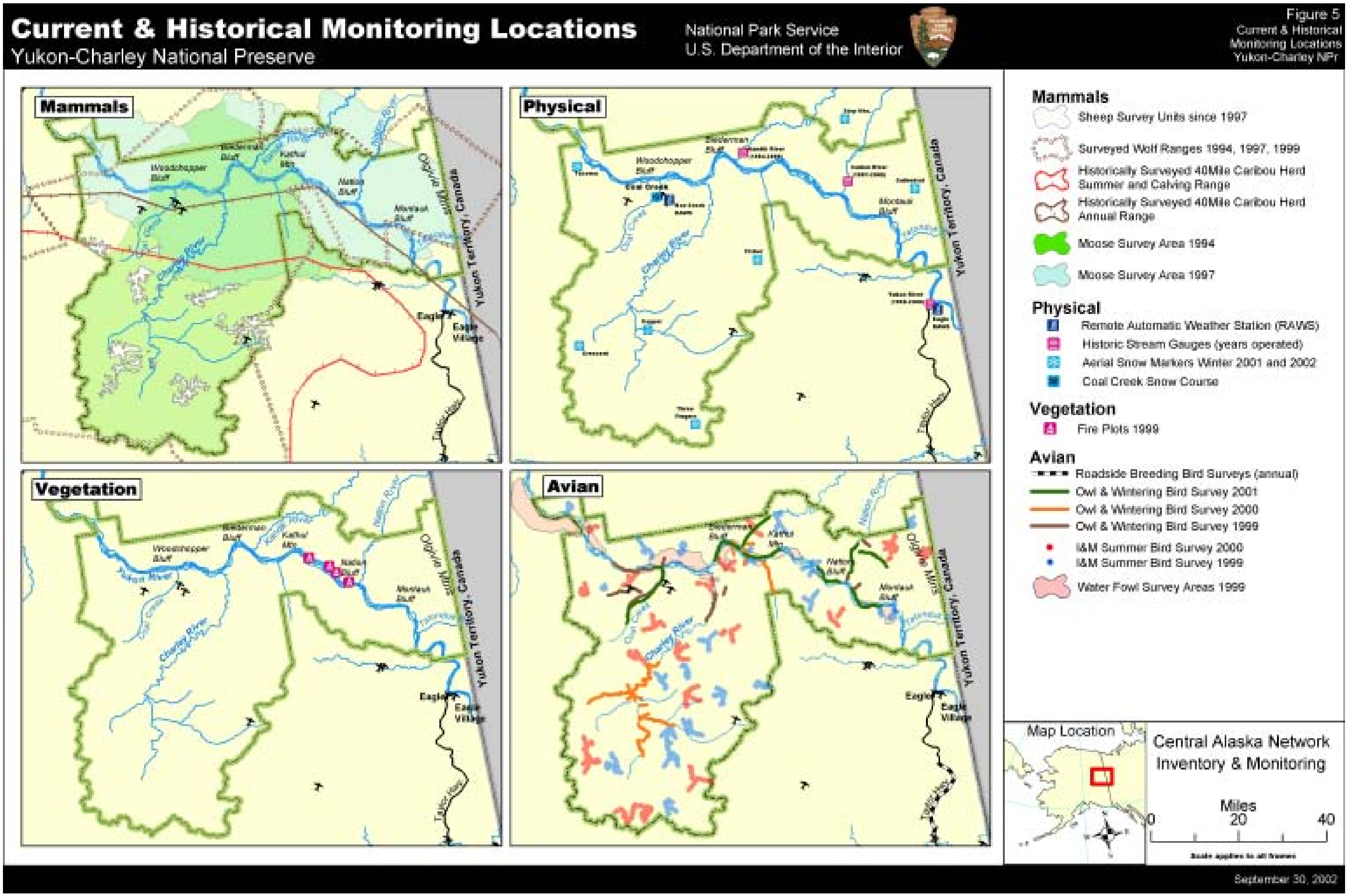

Figure 7. Current and historic monitoring locations for Yukon-Charley National Preserve

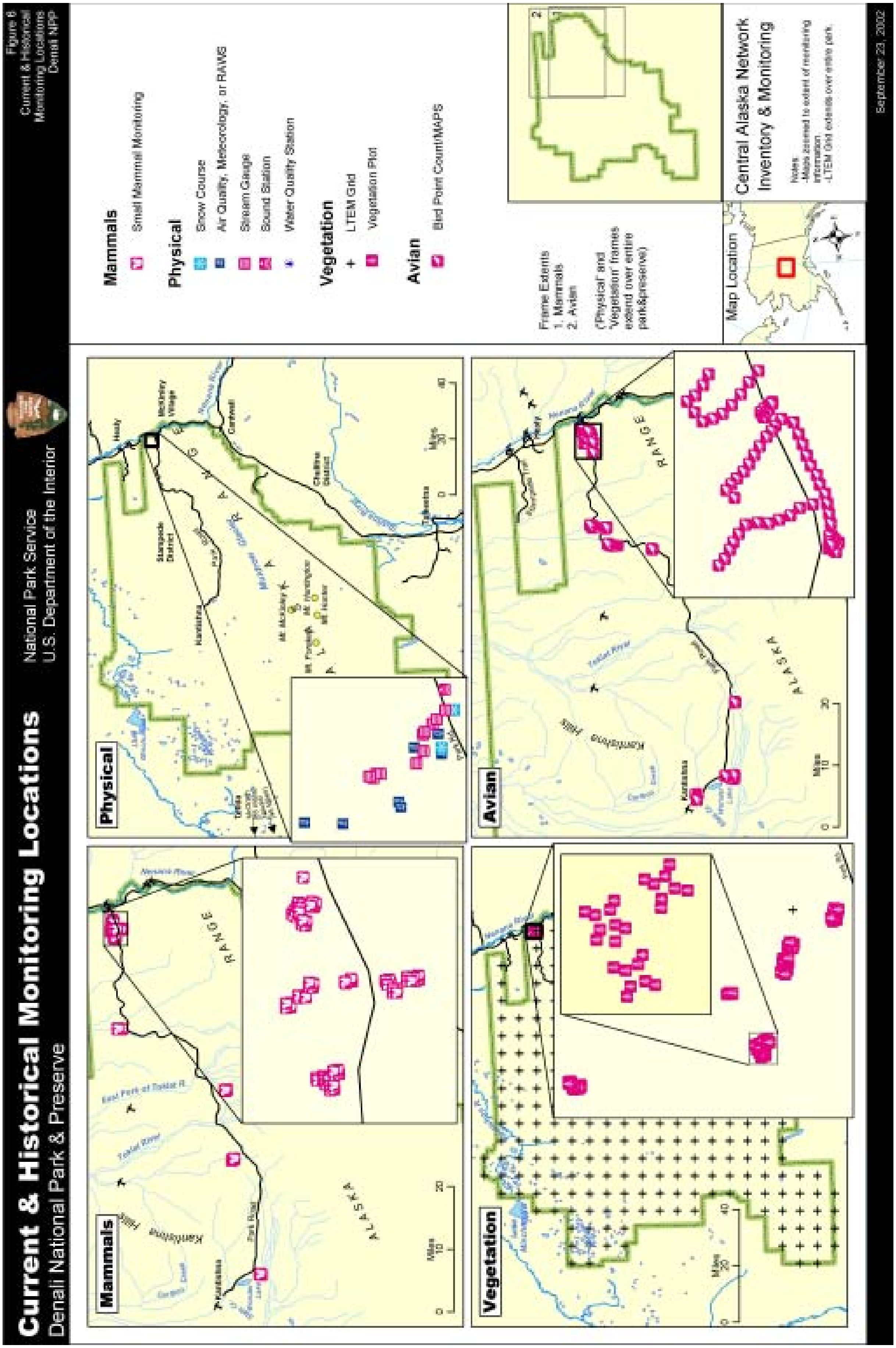

Figure 8. Current and historic monitoring at Denali National Park and Preserve.

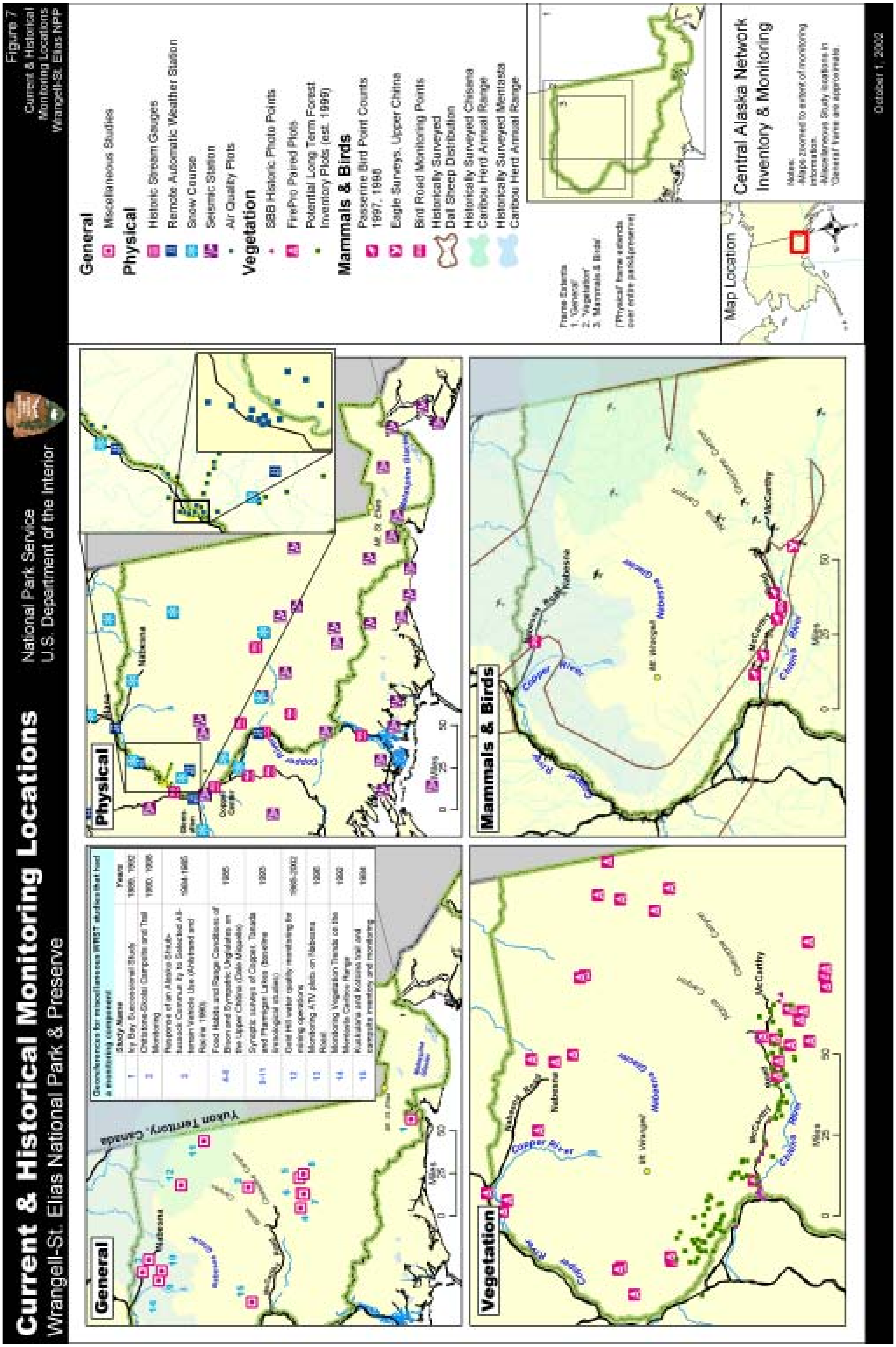

Figure 9. Current and historic monitoring locations for Wrangell-St. Elias National Park and Preserve

Information Still Being Gathered

At the time of writing of this report, there are current and historic monitoring projects of which we are aware, but still need to collect pertinent information on. The following table indicates those efforts for which documentation efforts are ongoing.

Table 3. Current and historic monitoring in Denali National Park and Preserve for which documentation efforts are ongoing.

Monitoring Project	Current	Historic
Grizzly bears	X	
Spawning salmon	X	
Dall sheep		X
Succession of the Muldrow Glacier		X
North American passerine migration count		X
Merlin productivity		X
Fire Pro paired vegetation plots		X
Vegetation succession after fire		X
Tanana Valley vegetation succession		X
Riparian zone vegetation structure		X
Assessment of exotic plant distribution along the park road corridor		X
Reclamation and restoration of riparian areas after mining		X
Production and availability of berries		X

Table 4. Current and historic monitoring in Wrangell-St. Elias National Park and Preserve for which documentation efforts are ongoing.

Monitoring Project	Current	Historic
Food habits and range condition of bison and sympatric ungulates on the upper Chitina River		X
Alaska shrub-tussock community response to selected all-terrain vehicle use		X
Fire Pro paired plots, 1982-86		X
Vegetation trends on the Mentasta Caribou Range		X
Inventory of vascular flora of the Bagley Icefield		X
Element concentrations of baselines for moss, lichen, spruce and surface soils in and near WRST		X

Chapter 2 Conceptual Models

2.1 Introduction

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, and 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).

Chapter 2 of the Central Alaska Network Monitoring Plan presents and discusses the conceptual models we develop to guide design of the program. We first provide a short background on conceptual modeling as an integral aspect of ecological monitoring and our general approach to modeling in the Central Alaska Network. We then describe the conceptual models. Earlier iterations of the models created during the modeling process are found on the network website as appendices to this Phase II report.

2.1.1. Reasons for Development of Conceptual Models as Part of Monitoring

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;
- 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 <u>different points of view</u> (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 has 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 is 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 can be evaluated. Knowing what changes it is desired to detect is the foundation for the selection of vital signs.

2.1.2. 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 calls for a unifying framework of some type. The modeling effort of the network up to now has largely focused on defining this unifying framework. The process has 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 has 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 does 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 seek to build a holistic picture of change in our ecosystems; thus, we are looking for holistic models that integrate knowledge about the ecosystems of the Central Alaska Network parks. We primarily desire a landscape level of inference from our observations This focus of the network is 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 provides an opportunity to understand these influences as they change through time.

We are also looking for models that can 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) are among the most important we have to grapple with (Dayton and Tegner 1984), and which our models must address. We recognize there are some attributes we want to measure that cannot be measured at the landscape scale due to park-specific or feasibility issues. Therefore we have 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 are focusing on a holistic view of our ecosystems, we must initiate the program from a discipline-integrated view now, and not later. Therefore, integration of information becomes an important feature of the program framework, as well 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.[1]

Publication of this report constitutes a second iteration of conceptual models for the Central Alaska Network program. If the modeling process continues to work as we intend, the models will generate further discussion among network program managers and scientists. These discussions, and external review of this Phase II report, 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 4 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 identified 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. The ecoregions analysis and the protection concerns models were presented in the Phase I report. They 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 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: our initial attempt to create a 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 I 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 (Figure 10). These ecoregions span a gradient from maritime to continental climate regimes, and include a mountainous transition zone between them. This mountainous transition zone contains extremely tall mountains with polar climate.

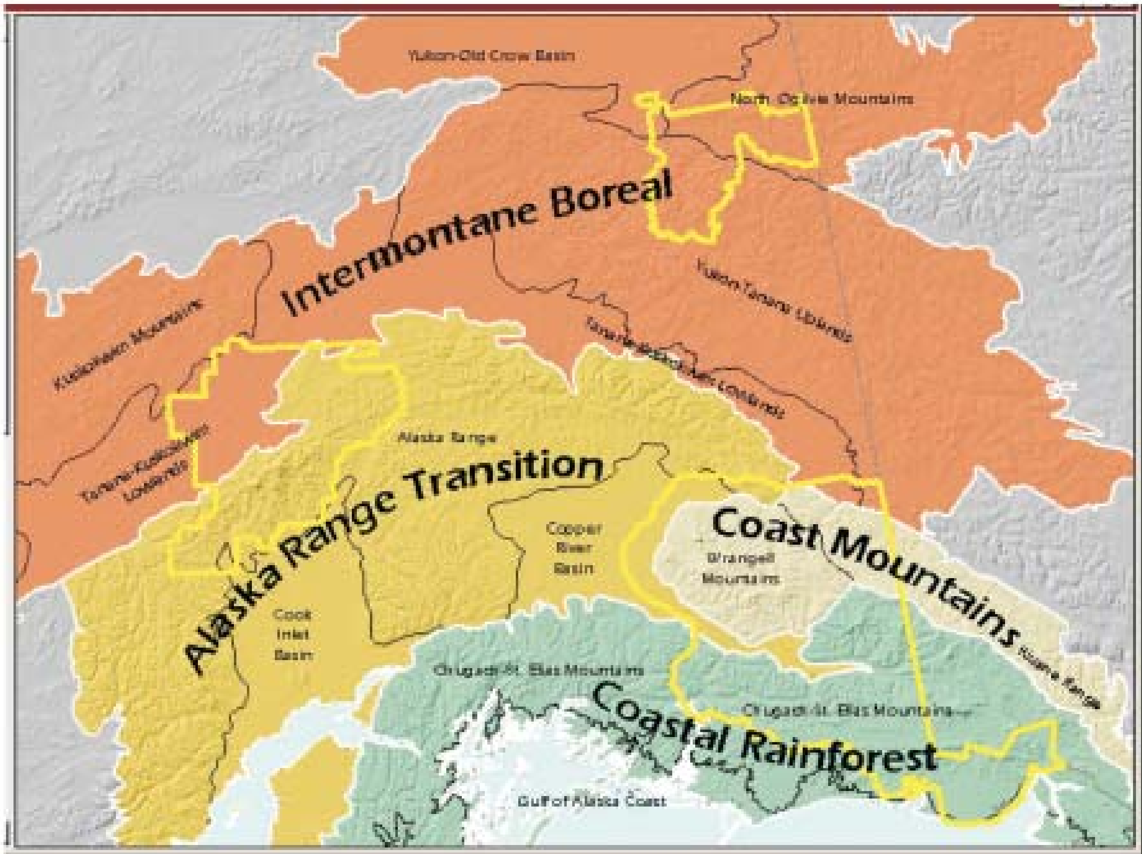

Figure 10. Ecoregions. Location of Central Alaska Network parks relative to ecoregion regime boundaries, based on ecoregions mapping for Alaska by Nowacki et al. (2002).

The ecoregions analysis provided a useful perspective on a number of topics important in the design of a long-term ecological monitoring program for Central Alaska Network parks, including:

- understanding how the three parks are both ecologically similar and different, and how they relate to each other and the lands between them;
- understanding the most important drivers of change within network ecosystems;
- offering a holistic paradigm for considering aquatic resources;
- changing our perspective on the significance of marine influences (e.g., El Nino/ Southern Oscillation) within what we have considered to be a largely terrestrial setting;
- challenging us to develop a broader understanding of the role of fauna, including humans, in ecosystem processes; and,
- suggesting several potential organizing questions for further discussion.

One of the most fruitful discussions that emerged from the ecoregions analysis concerned the range of gradients encompassed by our network (Figure 11). The major gradients within the Central

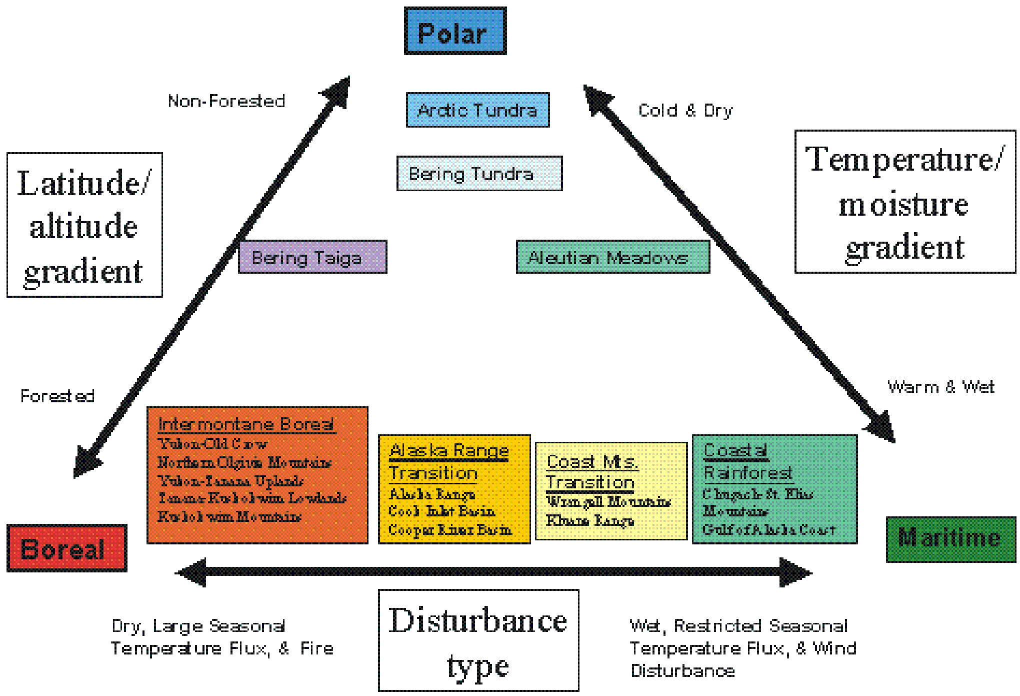

Figure 11. ***Ecological Gradients in Alaska****. Climatic and environmental relationships among ecoregions in Alaska (from Nowacki et al. 2002). Ecoregions found in Central Alaska Network parks are arrayed along the gradient between boreal and maritime climate.*

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 2 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 affects of variation in disturbance regimes on the distribution of resources in the network?

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 would not address all our modeling needs.

2.2.2 Resource Preservation Concerns Model

In this section, we pick up where we left off in Section 1.4, 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 Figure 12, 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 is also expected to help us identify what monitoring attributes will be most informative to preservation of the park ecosystems.

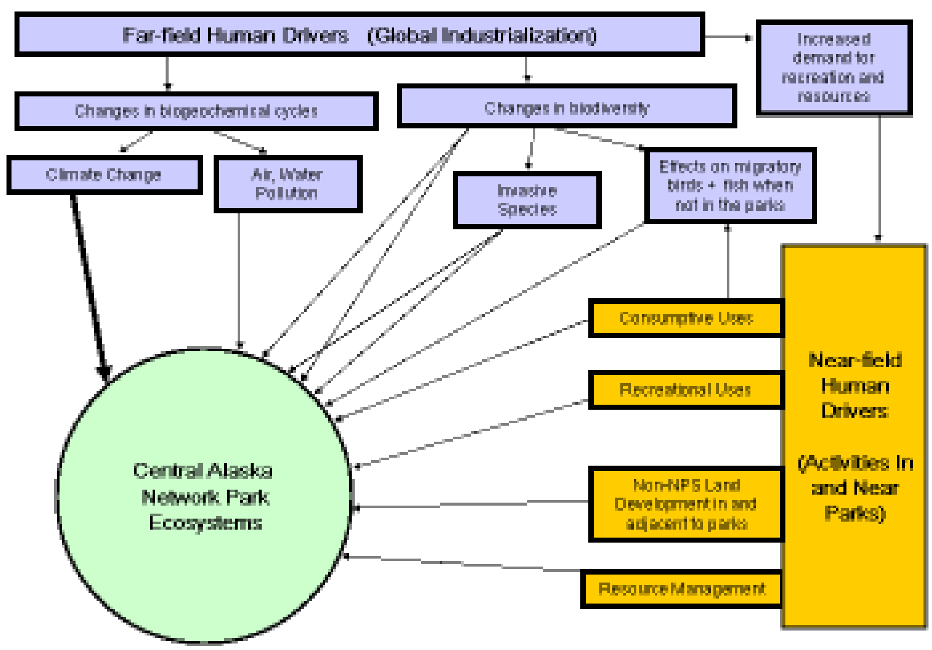

Figure 12. Resource Protection Concerns Model. Preliminary conceptual model of relationships among resources preservation concerns of Central Alaska Network parks. Regional scale concerns shown in orange. Global industrialization aspects shown in blue.

[1] The disciplinary committees that had been formed earlier to develop monitoring strategies for physical drivers, vegetation, fauna and aquatic systems were temporarily disbanded. These committees will be called back into action once vital signs in those disciplines have been identified.

Human population growth and resulting industrialization drives all the concerns facing network parks. Global growth is the driver for climate change, the main source of long distance air pollution, and for 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 industrialization— 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 strategically deploy monitoring effort, a sense of the relative importance or level of concern the parks have about these issues is 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 of the NPS and neighboring entities. Park management decisions also have a high probability to influence these concerns. Because of their potential to significantly impact park ecosystems, and because park decisions can reasonably be expected to prevent or reduce those impacts, the suite of issues related to near-field human drivers rank 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 of the high potential for warming 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 encounter 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 should help the monitoring program develop to address concerns we are aware of now while being robust to 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 have come up with is a very simple ecosystem model that has habitat change as a unifying theme.

We found that "habitat change" is a unifying theme for the network because we want to know how our landscape is changing. For example, is 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 are melting, this melting will *change river and stream characteristics (therefore river/stream habitats) as well as landform characteristics. These changes 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, and to highlight the unifying role of habitat change (Figure 13).

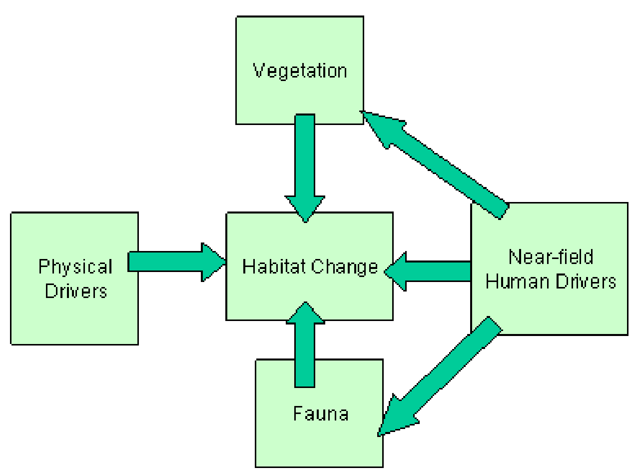

Figure 13. Conceptual ecosystem model for Central Alaska Network monitoring program in which changes in habitat provide a unifying theme across aquatic and terrestrial boundaries and across scales of interest.

Below, we explore each part of this habitat change model, highlighting our previous discussions about each topic. Focusing on *habitat change* makes clear what needs to be emphasized in each layer 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 plays critical role in the hydrological cycle because of the set 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. The "hydrological cycle and disturbance" provide a unifying theme for the physical drivers portion of the program.

In the CAKN Technical Committee meeting of Dec. 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 is that, while those parameters may be "socially" easier to discuss and decide upon (we could all easily agree that physical processes are highly important and drive our ecosystems), they will not, by themselves, provide us with information on how our ecosystems are functioning. For example, knowing that average annual temperature increased by 1º C, will not tell us how that change affected park ecosystems.

Another important point to consider about physical drivers is this: many entities are 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. Perhaps network effort at this time would best be spent carefully evaluating existing physical data streams and their applicability to our network questions. The network could 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.

This idea runs somewhat counter to the network's initial enthusiasm for monitoring physical parameters. Prudence suggests that the adequacy of existing data streams should be thoroughly examined prior to investing heavily in physical driver monitoring. Physical data are noisy, and their analysis is not as straightforward as it might at first seem. If the network can rely on other sources to meet our data needs about drivers, this will free up resources for other aspects of the program.

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. 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 has 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, is highly desirable. Trying to choose which species or species groups are the most deserving of monitoring has led to a quagmire where almost any choice could be defended, and is a direct function of who is making the choice.

Focusing on habitat change appears to offer at least a partial way out of our fauna conundrum. The habitat change focus will move our faunal work in the direction of modeling their habitat relationships. The theme of animal distributions relative to habitat is a major concern of wildlife ecologists and conservation biology (Verner et al. 1986, Scott, J.M. 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 will mean broadening our definitions of which taxa are of interest. The habitat focus will allow the network to move in the most forward-looking direction with its faunal work.

Choosing which species or species groups to start with will still be difficult. With this approach, we recognize that our knowledge will accumulate over time, and improve as our skill with modeling fauna-habitat relationships improve.

This approach, focusing on habitat relationships, is different from most fauna monitoring programs, which typically focus on estimating animal abundance for specific species. Documenting and detecting changes in the distribution of many species of animals within a broad landscape is population question of a different type.

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 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* (Figure 14). 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 five footings: (1) Physical Drivers, (2) Vegetation, (3) Fauna, (4) Habitat, (5) Near-field Human Drivers.

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

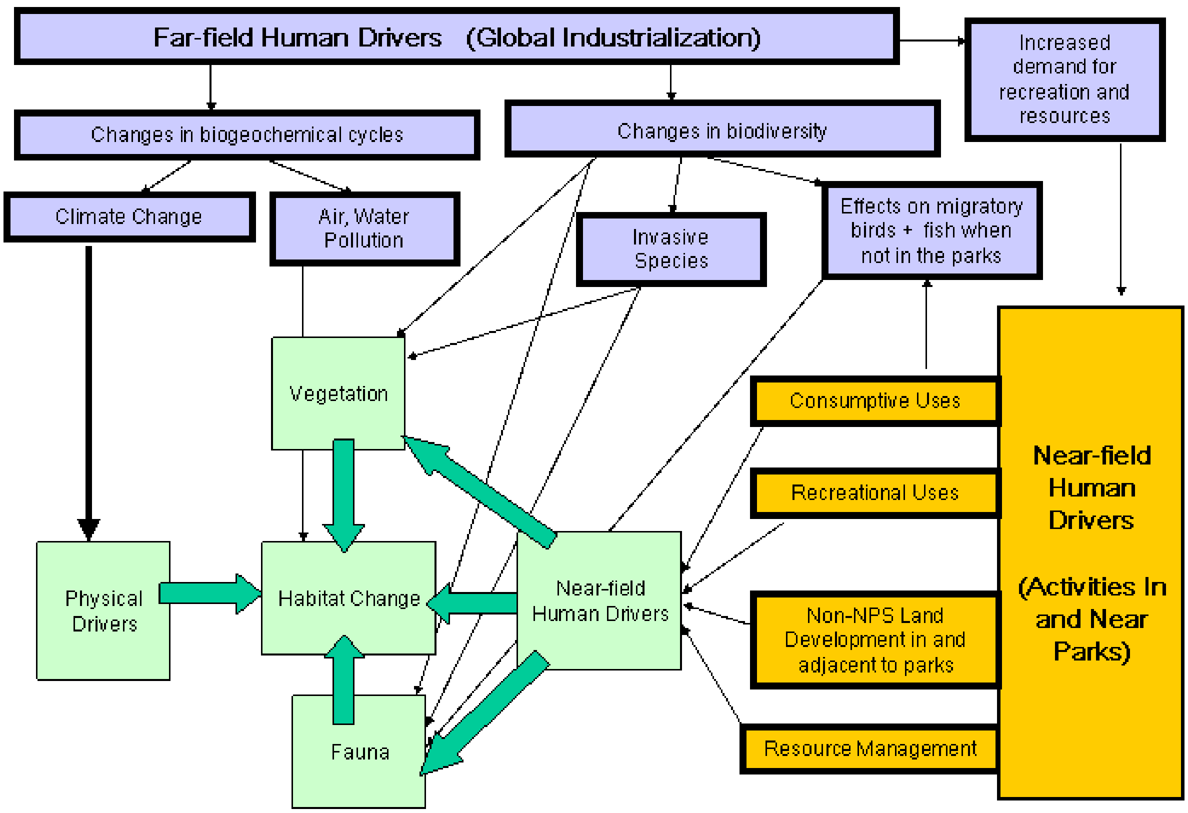

Figure 14. Holistic Model. Putting the Resource Protection Concerns Model and the Habitat Change Model together creates a Holistic Model.

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

During Phase II of monitoring program development, Vital Signs for each network are selected and prioritized. In this chapter, we describe the current list of 36 Vital Signs proposed by the Central Alaska Network. We also describe the process the network has used to select and prioritize these Vital Signs. Relationships of the proposed Vital Signs to the conceptual models that provide the overall framework for the Central Alaska Network monitoring program are explained.

In summary, the Central Alaska Network has identified 36 Vital Signs, and these have been prioritized within the major footings of the program's conceptual framework. These footings include Physical Drivers (9 Vital Signs), Vegetation (12 Vital Signs), Habitat (5 Vital Signs), Fauna (6 Vital Signs), and Near-Field Human Drivers (8 Vital Signs). The Technical Committee made the initial rankings using a web-based Delphi process, which facilitated further discussion of vital signs. Next steps in our process include explicit input from the Board of Directors and we plan to have our list finalized by January 2004.

3.1 Process for Choosing and Prioritizing Vital Signs

The process for choosing and prioritizing Vital Signs has been ongoing within the Central Alaska Network since the fall of 2001. The process began with individual park meetings to brainstorm wide-ranging lists of potential Vital Signs. Over the last 2 years we have narrowed the list and build a framework in which the Vital Signs are nested. Table 5 summarizes the major steps in the CAKN process. Note that the process is not yet complete. The final selection of Vital Signs will be made following review and discussion of this report.

Table 5. Summary of the process 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 J.
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).
Fall 2003	Discussion and Review	Upcoming Technical Committee and Board of Directors meetings.	
December 2003	Final Selection		

To initiate discussion of Vital Signs, we held park-level brainstorm session 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 J). 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 list of what 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.

The next stage of Vital Signs refinement was the 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 2 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 will require 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 will be 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 deter-

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[1] Thanks go to Doug Wilder, CAKN Data Manager, and Dorothy Mortenson, Southwest Alaska Network Data Manager, for quickly setting up the website.

[2] It strikes us that a useful process for prioritizing or making decisions generally should involve alternating opportunities for group discussion and for individual input made outside the group context.

mined that human affects 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, however those vital signs have not yet been prioritized. During this meeting we were also able to appropriately link some vital signs that had been listed separately. However, the Technical Committee will continue to work on the list of vital signs and their measures. We recognize that there still remain some "apples and oranges" in our list of vital signs. Further definition of the proposed Vital Signs will help resolve this problem.

The next steps in the selection and prioritization process are further discussion and refinement of the initial Vital Signs list by the Technical Committee and Board of Directors, and then selection of the final list. These steps will occur during the first quarter of FY 2004. The Technical Committee is meeting October 1-2, 2003, to discuss the Vital Signs and review the prioritization process used thus far. The Board of Directors has also reserved time for further discussion and consideration of the Vital Signs. Each Superintendent will meet with their park's staff to ensure that the network Vital Signs will meet their park's needs. The Board will then reconvene and provide formal guidance to the Network Coordinator and Technical Committee about the Vital Signs and program direction.

3.2 Proposed Vital Signs

The initial prioritized list of proposed Vital Signs for the Central Alaska Network includes 36 Vital Signs (Table 6). These include 9 related to Physical Drivers, 9 related to Vegetation, 5 related to Habitat, 5 related to Fauna, and 8 related to Near-field Human Drivers. These Vital Signs and their rankings, with the exception of the Near-field Human Drivers, were derived based on the process described in the previous section.

Table 6. Initial prioritized list of Proposed Vital Signs for the Central Alaska Network**.**

Ecological Footing and Rank	**Proposed Vital Sign**	**Potential Measures**
Physical Drivers		
1	Climate/Weather	Temperature, precipitation, wind
2	Snowpack	Total accumulation, timing, geographic extent
3	Water quality – ponds & streams temperature, alkalinity	pH, conductivity, total N, total P, turbidity,
4	Permafrost	Active layer depth, presence/absence
5	Disturbance regime	Fire frequency/intensity, wind, tectonics, geomorphology, volcanism
6	Ice phenology	On/off timing
7	River/stream flow	Flow rate, timing
8	Glaciers	Mass balance, movement
9	Air quality	Measures of existing NPS program

Table 6. Initial prioritized list of Proposed Vital Signs, continued.

Vegetative Characteristics		
1	Structure/Compostion	Cover by growth form class & species (aquatic/terrestrial), species and species area relationships
2	Plant phenology	Timing of leaf out
3	Fuels	Type, size and position and fuels
4	Pond primary production	Littoral vegetation extent/classification, species relative abundance, chlorophyll a
5	Density/basal area of whitespruce	Selected species at landscape scale
6	Special communities	Subarctic steppe communities, distribution and abundance of lichens, sensitive species and exotic plants
7	Chronosequences	Structure and composition
8	Stream vegetation	Riparian vegetation classification, percent overhead cover
9	Whitespruce growth/reproduction	Seed production, diameter breast height
Habitat Patterns		
1	Landcover change	Percent of land in specified categories, distribution of landcover types (including water bodies)
2	Pond characteristics	Distribution/abundance of ponds
3	Landscape appearance	Photograph points
4	Stream characteristics	Channel course maps, extent of pool/riffle habitat, channel width/depth, bed stability
5	Anecdotal observations	
Fauna Characteristics		
1	Animal distribution patterns	Presence/absence of selected species, geographic extent
2	Stream animals	Fish species richness, fish community composition, fish density/relative abundance
3	Pond animal productivity	Macroinvertebrate density, plankton composition, zooplankton density
4	Human presence	Presence/absence of human sign
5	Forage quality	Carbon:nitrogen
6	Insect damage	Presence/absence of insect damage in plots
Near-field Human Drivers		
1[1]	Consumptive use	Annual harvest of wildlife/fish, firewood, home logs, gravel
2[1]	Park resident and adjacent populations	Abundance estimate
3[1]	Human presence	Presence/absence of human sign
4[1]	Sound quality	Decibel level
5[1]	Water use (ground and surface)	Annual rate of use
6[1]	Trails (hiking/ATV), airstrips, snowmobiles	Number of miles of trails, number of airstrips, metric of snowmobile use
7[1]	Potential concerns	Number of ships in Icy Bay, RS2477 circumstances, navigable rivers, new roads
8[1]	Recreational visitor use	Number of visitors, campsite impacts

[1] The vital signs under this Ecological Footing have not yet been ranked by the CAKN Technical Committee.

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).

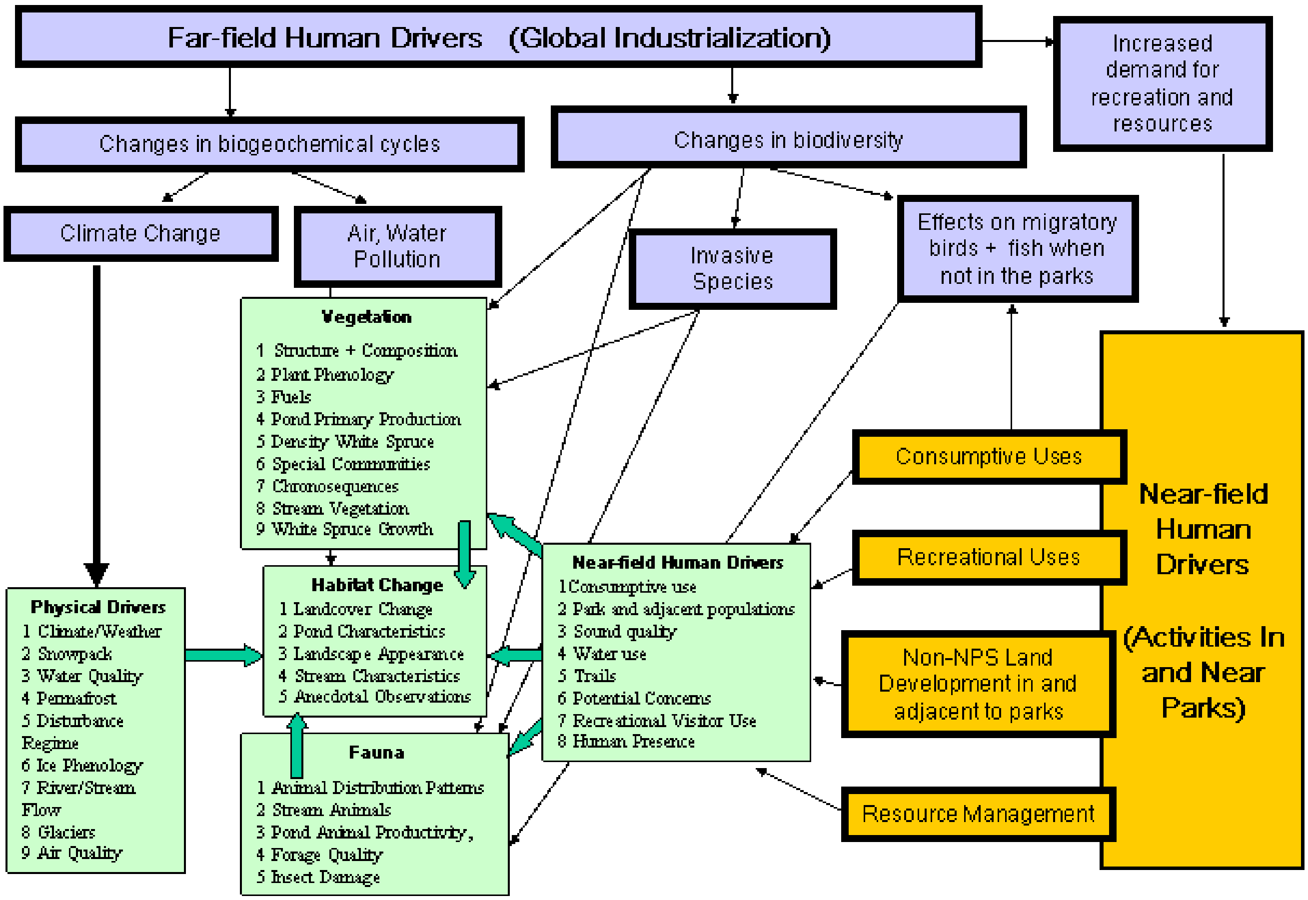

Figure 15. Proposed Vital Signs of the Central Alaska Network in relation to the Holistic Model that serves as the overall conceptual framework for the monitoring program. Vital Signs listed in the order ranked by the Technical Committee in August 2003 to show which Vital Signs should be investigated for feasibility first.

The Technical Committee will use Figure 15 as a basis for further vital signs discussion. During the first quarter of FY04, we will work 53***Vital Signs Monitoring Plan***53***Vital Signs Monitoring Plan***to clearly identify which attributes of each vital sign would inform us the most about each resource protection concern and our ecosystems. This will require us to further define each vital sign and a corresponding attribute. Once we complete this exercise for each vital sign we can then determine any further evaluation we need to conduct for protocol development and sample design.

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Appendices

Appendix A: Summary of Laws, Policies and Guidance

Legislation	Significance to Inventory and Monitoring
Management Policies 2001	*"The Service will: Identify, acquire, and interpret needed inventory, monitoring, and research, including applicabletraditional knowledge, to obtain information and data that will help park managers accomplish park management objectives provided for in law and planning documents.Define, assemble, and synthesize comprehensive baseline inventory data describing the natural resources under its stewardship, and identify the processes that influence those resources.Use qualitative and quantitative techniques to monitor key aspects of resources and processes at regular intervals. Analyze the resulting information to detect or predict changes, including interrelationships with visitor carrying capacities, that may require management intervention, and to provide reference points for comparison with other environments and time frames. Use the resulting information to maintain-and, where necessary, restore-the integrity of natural systems.*
NPS Management Policies 2001, related to Endangered Species Act,1973, amended 1988	*Undertake active management programs to inventory, monitor, restore, and maintain listed species' habitats, control detrimental non- native species, control detrimental visitor access, and re-establish extirpated populations as necessary to maintain the species and the habitats upon which they depend. Manage designated critical habitat, essential habitat, and recovery areas to maintain and enhance their value for the recovery of threatened and endangered species.Cooperate with other agencies to ensure that the delineation of critical habitat, essential habitat, and/ or recovery areas on park- managed lands provides needed conservation benefits to the total recovery efforts being conducted by all the participating agencies.The National Park Service will inventory, monitor, and manage state and locally listed species in a manner similar to its treatment of federally listed species, to the greatest extent possible. In addition, the Service will inventory other native species that are of special management concern to parks (such as rare, declining, sensitive, or unique species and their habitats) and will manage them to maintain their natural distribution and abundance.*
National Parks Omnibus Management Act of 1998	*The Secretary shall undertake a program of inventory and monitoring of National Park System resources to establishbaseline information and to provide information on the long-term trends in the condition of National Park System resources. The monitoring program shall be developed in cooperation with other Federal monitoring and information collection efforts to ensure a cost-effective approach*"
National Park Service Organic Act, 1916	The mission of the National Park Service is "*...to promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental purposes of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations*"
NEPA 1969	*Requires certain knowledge of resource conditions to direct and evaluate effects of management actions.*
Forest & Rangeland Renewable Resources Planning Acts of 1974 and 1976	*Express Congressional insistence on inventory and monitoring of natural resources on all public lands in the U.S.*
Executive Order 13186 to Protect Migratory Birds 2001	Federal agencies shall…*"promote research and information exchange related to the conservation of migratory bird resources, including coordinated inventorying and monitoring and the collection and assessment of information on environmental contaminants and other physical or biological stressors having potential relevance to migratory bird conservation."*
Other Acts	Fish and Wildlife Coordination Acts, 1958 and 1980; Migratory Bird Treaty Act, 1974; Clean Water Act; Executive Order 11900 (Protection of Wetlands); and the Clean Air Act.

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 posses at least a minimal compliment 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 complimentary 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 re-construction 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 3 to 5 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 tracked and monitoring.

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

Appendix E: Organization and Personnel of the Central Alaska Network

<u>Board of Directors:</u>

Dave Mills (Chair), *Superintendent, Yukon-Charley Rivers National Preserve*
Paul Anderson, *Superintendent, Denali National Park and Preserve*
Gary Candellaria, *Superintendent, Wrangell-St. Elias National Park and Preserve*

<u>Technical Committee:</u>

Maggie MacCluskie (Chair), *Coordinator, Central Alaska Network*

Wrangell-St. Elias National Park and Preserve:

- Devi Sharp, *Chief of Resources*
- Eric Veach, *Fisheries Biologist*
- Mason Reid, *Wildlife Biologist*

Denali National Park and Preserve:

- Philip Hooge, *Assistant Superintendent*
- Guy Adema, *Physical Scientist*
- Carl Roland, *Botanist*

Yukon-Charley Rivers National Preserve

- Tom Liebscher, *Chief of Resources*
- John Burch, *Wildlife Biologist*
- Nikki Guldager, *Wildlife Biologist*

Sara Wesser, *Alaska Region Inventory and Monitoring Coordinator*

Robert Winfree, *Alaska Region Science Advisor*

Nancy Deschu, *Alaska Region Hydrologist*

Karen Oakley, *Biologist, Biological Resources Division, US Geological Survey*

Appendix F: 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. 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 seventeen 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 twenty-five 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 kilometers (128 miles) 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 in located in interior and southcentral Alaska (Fig. 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 meters (100 feet) 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 feet), and forests give way to shrublands consisting of moist tundra plants such as dwarf birch, willows, and sedges. Above 1,036 m (3,400 feet), 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 a 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 occurring 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 feet) to 6,666 m (20,230 feet) 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 feet) 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 kilometers (35-45 miles) long. The largest glacier on the north side is the 55 kilometer (34 mile) 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 10 species of fish, 1 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 6 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 three 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

WrangellSt. Elias encompasses 5.3 million hectares (13.2 million acres) in southcentral Alaska (Fig. 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 kilometer (60 mile) 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 pro-glacial 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 that strongly affects 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 kilometers (44 miles) long. Several of North America’s highest peaks are within the park including Mt. St. Elias [5,489 m (18,008 feet)] and Wrangell Mountain [4,269 m (14,005 feet)], 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 faults zones generate 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 miles), 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 has significantly advanced our understanding of the flora of Wrangell-St. Elias, however. 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 degrees. 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, 4 species of amphibians, 239 species of birds, and approximately 38 species of terrestrial mammals and 9 species of marine mammals that occur in Wrangell-St. Elias. The park is also home to unknown number of invertebrate species.

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

Alaska's system of National Parks and Preserves contains approximately 40% of the state-wide 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's sea lions occur in both Icy and Disenchantment Bays. Dall's porpoise and harbor porpoise, and 5 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 G: 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 kilometers (125 miles) 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 loggingrelated 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 ice bergs. 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 kilometers (100 miles) 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 to18 aircraft per day during routine training, and 164 to 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 feet) 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 H: 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 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 (ultraviolet B radiation), Natural Resources Conservation Agency (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 just to the east of the preserve in Eagle, and at Ben Creek. 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 7 sites: Healy, Ruth Glacier, Talkeetna, Telida, Lake

Minchumina, McKinley River and Wonder Lake. In and near Wrangell-St. Elias, RAWS are located at 10 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 6 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 feet) to 1346 m (4,400 feet). 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 the 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 capabilities 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 track 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 (NAPD)
- Interagency Monitoring of Protected Visual Environments (IMPROV)
- National Park Service Gaseous Pollutant Monitoring Network (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 ultraviolet-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 8-9 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 Resource Conservation Agency (NRCA). NRCA 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 10 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 more effectively cover variable terrain 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, 6 aerial markers were established at a diversity of sites that represent various elevations, slopes, aspects and terrain. Markers are read from the air with via Cessna 185 planes within 2 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 5 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. Benchmark glacier monitoring is more intensive than index glacier monitoring, and eleven long-term measurement stakes are surveyed and assessed for mass balance trends in 2002. In addition, 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 on the Yukon (by Eagle), Nation and Kandik rivers, which are maintained by the USGS. 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, however few of them (6 of 17) have been located within the boundaries. 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 3-6 years in length and range from the early 1900's to the late 1970's.

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. The devices 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 Prtarmigan 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 3 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 1970's, 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 3 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. 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 in1991. Each station is sampled 6 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 & 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 TM 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 4 randomly chosen transects that are ³ 2 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 tree density and 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. More intensive monitoring will continue to take place in the Rock Creek watershed, which was the original focus area of the monitoringprogram. Across elevation gradients of forest, treeline and tundra, white spruce reproduction and seed germination are measured, and permanent vegetation plots are measured every eight years. In the future it is anticipated that for a small subset of the landscape-level permanent plots process-related variables such as growth and reproduction of tree species and vegetation phenology will be examined.

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. Population size, annual breeding effort and locations of brood rearing and staging areas data 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 1980’s. 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 5 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 8 and 20 routes are conducted annually. Routes are walked and at approximately every 200m, observers listen for all bird calls for an 8-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 4 study sites within areas of spruce bark beetle infestation. These sites could be revisited in future years to track 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 is 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 peer-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. The peer reviewers also suggested that 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 state-wide scale. Results from these analyses will provide Denali and the network with guidance on if and how to continue 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 track 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 ft 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 so as 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 in entered into a database that includes track species, location, days since snowfall and various habitat parameters. Surveys will be repeated every 3 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 3 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 3 species.

Moose

Beginning in 1994, aerial moose surveys have been conducted within the northern portion of the Yukon-Charley. This portion comprises 51 percent 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 1950's.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 1970's 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 1980's.

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 1960's. 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 3 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 I: 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 3 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 for the park by Mark Clark of the US 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 6 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 CAN)

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, 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. As such, 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 white fish 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 ptarmigans. Glaciers and icefields have receded, leaving b**road 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 J: 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 staffs 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	X		⬣
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		⬣
Permafrost	X		
Snow Characteristics	X	X	⬣
Ice in/out dates	X	X	
Glacial Ablation	X		⬣
Weather	X	X	
Fire	X	X	
Fuels		X	
Ice & Mud coring	X		
Streambed morphology		X	⬣
Vegetation Changes	X	X	
Lake size	X		
Sound	X		
Aviation	X	X	
Generators	X		
Snowmachines	X		
Wildlife			
Swans	X		
Bald Eagles	X		
Golden Eagles	X		⬣
Frogs on McCarthy Road	X		
Squirrels	X		
Salmon carcass counts	X		
Fish habitat		X	
Small mammals	X	X	⬣

Potential Vital Sign	WRST	YUCH	DENA
Aquatic insects	X	X	⬢
Marine Mammals	X		
Fish abundance		X	
Bear/human impacts	X		
Ungulate status & trends	X		⬢
Predator/prey relationships	X	X	
Population demography in relation to habitat use		X	
Fauna population genetics		X	
Passerine bird populations			⬢
Vegetation			
Structure and Composition			⬢
White Spruce Growth/Reproduction			⬢
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	

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