National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Denali National Park and Preserve

Natural Resource Condition Assessment

Natural Resource Report NPS/NRSS/WRD/NRR—2011/424

ON THE COVER. Toklat River and the Alaska Range
Photograph by: Barry Drazkowski, SMUMN GSS, August 2009

Denali National Park and Preserve

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Acronyms and Abbreviations

AK DEC – Alaska Department of Environmental Conservation

ADF&G – Alaska Department of Fish and Game

ANILCA – Alaska National Interest Lands Conservation Act

CAKN – Central Alaska Network

DENA – Denali National Park and Preserve

EPA – Environmental Protection Agency

EPMT – Exotic Plant Management Team

ESRI – Environmental Systems Research Institute

GIS – Geographic Information Systems

GMU – Game Management Unit

I&M – Inventory and Monitoring

NPS – National Park Service

NRCA – Natural Resource Condition Assessment

NRCS – Natural Resources Conservation Service

PDO – Pacific Decadal Oscillation

PRISM – Parameter-elevation Regressions on Independent Slopes Model

RAWS – Remote Automated Weather Stations

RSS – Resource Stewardship Strategy

SOC – Semi-volatile Organic Compund

SMUMN GSS – Saint Mary's University of Minnesota Geospatial Services

SRC – Subsistense Resources Commission

USFS – United States Forest Service

USFWS – United States Fish and Wildlife Service

USGS – United States Geological Survey

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Executive Summary

Denali National Park and Preserve was originally authorized as Mount McKinley Park in 1917. Its primary purposes were to serve as a game refuge and provide public recreational opportunities. With the passage of the Alaska National Interest Lands Conservation Act (ANILCA) in 1980, the park was expanded and two national preserve areas were added. Sport and subsistence hunting is permitted in these preserves, with subsistence harvest also occurring in the park additions. The original extent of Mount McKinley Park is now designated as wilderness.

Denali National Park and Preserve covers nearly 2.5 million hectares (six million acres) in central Alaska straddling the mountains of the Alaska Range. It supports a wide variety of species that coexist in a natural setting largely undisturbed by humans. Glaciers, braided streams, and permafrost are common physical features while fire plays an important successional role within the ecosystem. In recent years the park and preserve has received around 400,000 visitors annually, most arriving in the summer when weather conditions are favorable (NPS 2010).

One important purpose of the expanded park and preserve, as defined by ANILCA, is to provide subsistence opportunities for local rural residents who have a personal, family, or community history of using park and preserve resources (DENA 2004). Subsistence activities must be balanced with NPS management policies which "strive to maintain the natural abundance, behavior, diversity, and ecological integrity of native animals as part of their ecosystem, while recognizing that subsistence use by local rural residents have been, and are now, a natural part of the ecosystem serving as a primary consumer in the food chain" (DENA 2004). The most common forms of subsistence harvest in Denali include hunting, fishing, trapping, firewood harvest, and cabin log harvest. Further discussion of subsistence within the park and preserve can be found in chapter two of this assessment.

Due in part to its long history and appeal to researchers, there is a wealth of information available for many of Denali's resources, although much of it is anecdotal. Several wildlife species, such as wolves, caribou, and golden eagles, have been consistently monitored for 20 to 30 years, resulting in some of the most extensive wildlife datasets in the National Park system. Research within Denali's naturally regulated ecosystem has also proved valuable in developing scientific models of predator/prey systems.

In 2003, the National Park Service (NPS) Water Resources Division received funding through the Natural Resource Challenge program to systematically assess watershed resource conditions in NPS units, establishing the Watershed Condition Assessment Program. This program, now titled the Natural Resource Condition Assessment (NRCA) Program, aims to provide documentation about the current conditions of important park resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. Findings from the NRCA, including the report and accompanying map products, will help Denali managers to:

- develop near-term management priorities.
- engage in watershed or landscape scale partnership and education efforts.

- conduct park planning.
- report program performance (e.g., Department of Interior's Strategic Plan "land health" goals, Government Performance and Results Act).

Specific project expectations and outcomes for the Denali NRCA are listed in chapter three.

For the purpose of this condition assessment, key park resources were identified by NPS staff and are represented as indicators in the project framework (Table 13). While this list of indicators is not all inclusive, it includes natural resources and processes that are currently of the greatest concern to park management in Denali. The final project framework contains 18 indicators. This framework outlines the resources (indicators), measures, stressors, and the reference condition when available.

This study involved reviewing existing literature and data for each of the indicators in the framework, and, where appropriate, analyzing the data in order to provide summaries or to create new spatial or statistical representations. After gathering data regarding current condition of indicator measures, a qualitative statement was developed comparing the current conditions to a reference condition when possible. The discussions in chapter four represent a comprehensive summary of available existing information regarding the current condition of these resources. They represent not only the most current published literature, but also unpublished park information and, most importantly, the perspectives of park experts.

Due to its size, ecological diversity, and the remoteness of a large portion of the park and preserve, assessing the condition of Denali at a park-wide scale is problematic. However, the data that are available suggest that Denali National Park and Preserve is generally in good or moderate condition with stable trends (Table 1). There is still relatively little human impact in most areas of the park and preserve and it continues to function as a naturally regulated ecosystem. The majority of biological components are in good condition with a stable trend. Only wolves and lake ecosystem function are in moderate condition, with wolves also showing a declining trend. Physical resources are generally in moderate condition with individual indicators trending in a variety of directions.The overall condition of one physical resource (permafrost) is unknown, with two additional resources (soundscape and ecosystem contaminants) having an unknown trend. Glacial features are of the highest concern with a clearly declining trend, likely attributable to climate warming.

Table 1. Summary of condition and trend for selected natural resource indicators within Denali National Park and Preserve. Green circles indicate that a resource is in good condition or of low concern while yellow circles indicate moderate condition and gray circles represent unknown condition. Arrows signify trend; an upward arrow indicates an improving trend, a horizontal arrow a stable trend, and a downward arrow a declining trend. Triple gray arrows signify unknown trend.

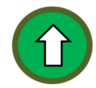
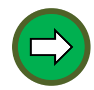
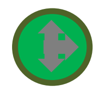
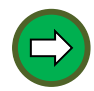
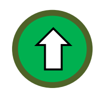
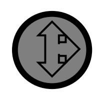
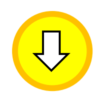
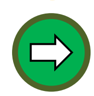
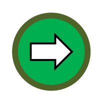
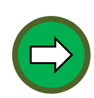
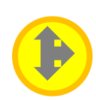
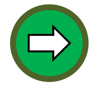
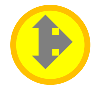
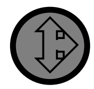
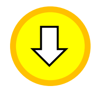
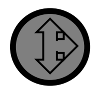
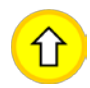
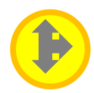
Component	Indicator	Condition
Extent and Pattern		
Landscape Pattern/Structure		
	Landcover/Soils/Expected Vegetation	
Biological Components		
Species		
	Denali Caribou Herd	
	Dall's Sheep	
	Moose	
	Trumpeter Swans	
	Breeding Birds	
	Wolves	
	Grizzly Bears	
	Golden Eagles	
Communities		
	Native Plant Community	
Ecological Processes		
	Fire	
Aquatic Habitat		
	Lake Ecosystem Function	

Table 1. Summary of condition and trend for selected natural resource indicators within Denali National Park and Preserve. Green circles indicate that a resource is in good condition or of low concern while yellow circles indicate moderate condition and gray circles represent unknown condition. Arrows signify trend; an upward arrow indicates an improving trend, a horizontal arrow a stable trend, and a downward arrow a declining trend. Triple gray arrows signify unknown trend. (continued)

Component	Indicator	Condition
Chemical and Physical Characteristics		
Chemical Parameters		
	Air Quality	
	Ecosystem Contaminants	
	Water Quality	
Physical Parameters		
	Glacial Features	
	Permafrost	
	Paleontological Resources	
	Soundscape	

Several threats or stressors have been identified that apply to multiple resources within the park and preserve. These include airborne contaminants, scenic overflights, and climate change. Denali is projected to become warmer and drier over the next century, potentially impacting nearly every resource within the park and preserve. Temperatures are projected to increase at an average rate of about 1°F per decade, resulting in a transition from average annual temperatures below freezing (~24°F) across the park and preserve, to temperatures near or above the freezing point (~32°F) (SNAP et al. 2009). These changes will affect not only permafrost and glaciers, but also vegetation, lakes and streams, chemical cycling, wildfire regime, insect and disease outbreaks, as well as wildlife distribution and habitat use (DENA 2007, Redmond and Simeral 2006).

While a wide variety of research has been conducted in Denali, many data gaps remain. Several of these are currently being addressed with new monitoring protocols for glacial features and permafrost, as well as significant studies in lake ecosystems, paleontology, and soundscape. Remaining data needs are further addressed in chapters four and five of this assessment.

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Chapter 1 NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks". For these condition analyses they also report on trends (as possible), critical data gaps, and general level of confidence for study findings. The resources and indicators emphasized in the project work depend on a park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators for that park, and availability of data and expertise to assess current conditions for the things identified on a list of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement, not replace, traditional issue and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- are multi-disciplinary in scope[1]
- employ hierarchical indicator frameworks[2]
- identify or develop logical reference conditions/values to compare current condition data against[3,4]
- emphasize spatial evaluation of conditions and GIS (map) products[5]
- summarize key findings by park areas[6]
- follow national NRCA guidelines and standards for study design and reporting products.

NRCAs Strive to Provide…

Credible condition reporting for a subset of important park natural resources and indicators

Useful condition summaries by broader resource categories or topics, and by park areas

[1] However, the breadth of natural resources and number/type of indicators evaluated will vary by park

[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition reporting by broader topics and park areas

[3] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions

[4] Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers")

[5] As possible and appropriate, NRCAs describe condition gradients or differences across the park for important natural resources and study indicators through a set of GIS coverages and map products

[6] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on a area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested

Although current condition reporting relative to logical forms of reference conditions and values is the primary objective, NRCAs also report on trends for any study indicators where the underlying data and methods support it. Resource condition influences are also addressed. This can include past activities or conditions that provide a helpful context for understanding current park resource conditions. It also includes present-day condition influences (threats and stressors) that are best interpreted at park, watershed, or landscape scales, though NRCAs do not judge or report on condition status per se for land areas and natural resources beyond the park's boundaries. Intensive cause and effect analyses of threats and stressors or development of detailed treatment options is outside the project scope.

Credibility for study findings derives from the data, methods, and reference values used in the project work—are they appropriate for the stated purpose and adequately documented? For each study indicator where current condition or trend is reported it is important to identify critical data gaps and describe level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject matter experts at critical points during the project timeline is also important: 1) to assist selection of study indicators; 2) to recommend study data sets, methods, and reference conditions and values to use; and 3) to help provide a multi-disciplinary review of draft study findings and products.

NRCAs provide a useful complement to more rigorous NPS science support programs such as the NPS Inventory and Monitoring Program. For example, NRCAs can provide current condition estimates and help establish reference conditions or baseline values for some of a park's "vital signs" monitoring indicators. They can also bring in relevant non-NPS data to help evaluate current conditions for those same vital signs. In some cases, NPS inventory data sets are also incorporated into NRCA analyses and reporting products.

In-depth analysis of climate change effects on park natural resources is outside the project scope.

However, existing condition analyses and data sets developed by a NRCA will be useful for subsequent park-level climate change studies and planning efforts.

Important NRCA Success Factors …

Obtaining good input from park and other NPS subjective matter experts at critical points in the project timeline

Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ➩ indicators ➩ broader resource topics and park areas)

Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings

NRCAs do not establish management targets for study indicators. Decisions about management targets must be made through sanctioned park planning and management processes. NRCAs do provide science-based information that will help park managers with an ongoing, longer term effort to describe and quantify their park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[7] and help parks report to government accountability measures[8].

Due to their modest funding, relatively quick timeframe for completion and reliance on existing data and information, NRCAs are not intended to be exhaustive. Study methods typically involve an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in our present data and knowledge bases across these varied study components.

NRCAs can yield new insights about current park resource conditions but in many cases their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Over the next several years, the NPS plans to fund a NRCA project for each of the ~270 parks served by the NPS Inventory and Monitoring Program. Additional NRCA Program information is posted at: http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm.

NRCA Reporting Products…

Provide a credible snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:

Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations
(near-term operational planning and management)

Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values
(longer-term strategic planning)

Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public
("resource condition status" reporting)

[7] NRCAs are an especially useful lead-in to working on a park Resource Stewardship Strategy(RSS) but study scope can be tailored to also work well as a post-RSS project

[8] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget

Chapter 2 Introduction and Resource Setting

2.1 Introduction

2.1.1 Enabling Legislation

Photo 1. This arch was erected over the park road in 1926 by the Alaska Railroad just beyond the McKinley depot. The actual park boundary was several miles to the west (NPS photo, in Norris 2006).

Denali National Park and Preserve has expanded and evolved from the historic establishment of Mount McKinley Park in the early 1900s to the present combination of wilderness area, national park, and national preserves. Mount McKinley National Park was originally authorized by the U.S. Congress in 1917 as a game refuge to "set apart as a public park for the benefit and enjoyment of the people ... for recreation purposes by the public and for the preservation of animals, birds, and fish and for the preservation of the natural curiosities and scenic beauties thereof ..." (39 Stat. 938). Mount McKinley National Park was enlarged and renamed Denali National Park and Preserve in 1980 as part of the Alaska National Interest Lands Conservation Act (ANILCA, 16 USC §§ 3101-3233, Pub. L. 96-487). Section 101 of ANILCA describes the purpose of enlarged national parks and preserves in Alaska, including Denali, as being to:

- Preserve lands and waters for the benefit, use, education, and inspiration of present and future generations.
- Preserve unrivaled scenic and geological values associated with natural landscapes.
- Maintain sound populations of, and habitat for, wildlife species.
- Preserve extensive, unaltered ecosystems in their natural state.
- Protect resources related to subsistence needs.
- Protect historic and archeological sites.
- Preserve wilderness resource values and related recreational opportunities such as hiking, canoeing, fishing, and sport hunting.
- Maintain opportunities for scientific research in undisturbed ecosystems.

- Provide the opportunity for rural residents engaged in a subsistence way of life to continue to do so.

Additional purposes specific to Denali National Park and Preserve are outlined in Section 202 of ANILCA. These purposes are:

- To protect and interpret the entire mountain massif and the additional scenic mountain peaks and formations.

- To protect habitat for, and populations of fish and wildlife, including, but not limited to, brown/grizzly bears, moose, caribou, Dall's sheep, wolves, swans and other waterfowl.

- To provide continued opportunities, including reasonable access, for mountain climbing, mountaineering, and other wilderness recreational activities.

The Denali Wilderness was established under Section 701 of ANILCA. The Wilderness Act directs this land, approximately 768,900 hectares (1.9 million acres) in size and including 99 percent of the former Mt. McKinley National Park, to be

> "administered for the use and enjoyment of the American people in such manner as will leave them unimpaired for future use and enjoyment as wilderness, and so as to provide for the protection of these areas, the preservation of their wilderness character, and for the gathering and dissemination of information regarding their use and enjoyment as wilderness."

Section 1313 of ANILCA addresses the purpose of national preserves created by the act:

> "A National Preserve in Alaska shall be administered and managed as a unit of the National Park System in the same manner as a national park except as otherwise provided in this Act and except that the taking of fish and wildlife for sport purposes and subsistence uses, and trapping shall be allowed in a national preserve under applicable State and Federal law and regulation."

The authorizing language described above will be one of the primary directives for setting natural resource reference conditions and defining specific areas of natural resource management interest for this Natural Resource Condition Assessment.

2.1.2 Geographic Setting

Denali National Park and Preserve covers nearly 2.5 million hectares (six million acres) in central Alaska. The Denali Visitor Center, located on the northeast edge of the park and preserve boundary is accessible by the George Parks Highway and The Alaska Railroad from Anchorage to the south and Fairbanks to the north. Several landing strips in and around Denali provide additional access points. The majority of the park and preserve is accessible only by foot, dogsled, snowmobile, or aircraft. The main park road is the only means for vehicular access and its use is limited by weather and park regulations for much of the year (MacCluskie and Oakley 2005).

The sheer size of Denali National Park and Preserve and its relatively long history are two of its greatest assets. The original Mount McKinley National Park portion of Denali has been protected since 1917 and encompasses 809,370 hectares. This area, along with the additional 1.6 million hectares added by ANILCA, supports a diverse number of species that coexist in a natural setting largely undisturbed by humans. This situation creates a prime opportunity for the research of subarctic ecosystems. For these reasons, the United Nations Man and the Biosphere Program designated Denali National Park and Preserve as an International Biosphere Reserve in 1976.

The southern portion of the park and preserve is dominated by the Alaska Range and Mount McKinley, reaching its peak at 6,194 meters (20,321 feet) above sea level. Mount McKinley towers over the lowlands to the north by 5,486 meters (17,998 feet), a vertical relief greater than that of Mount Everest measured from base to summit. On a clear day, Mount McKinley can be seen from Anchorage, more than 209 km (130 miles) away, because of central Alaska’s exceptional air quality.

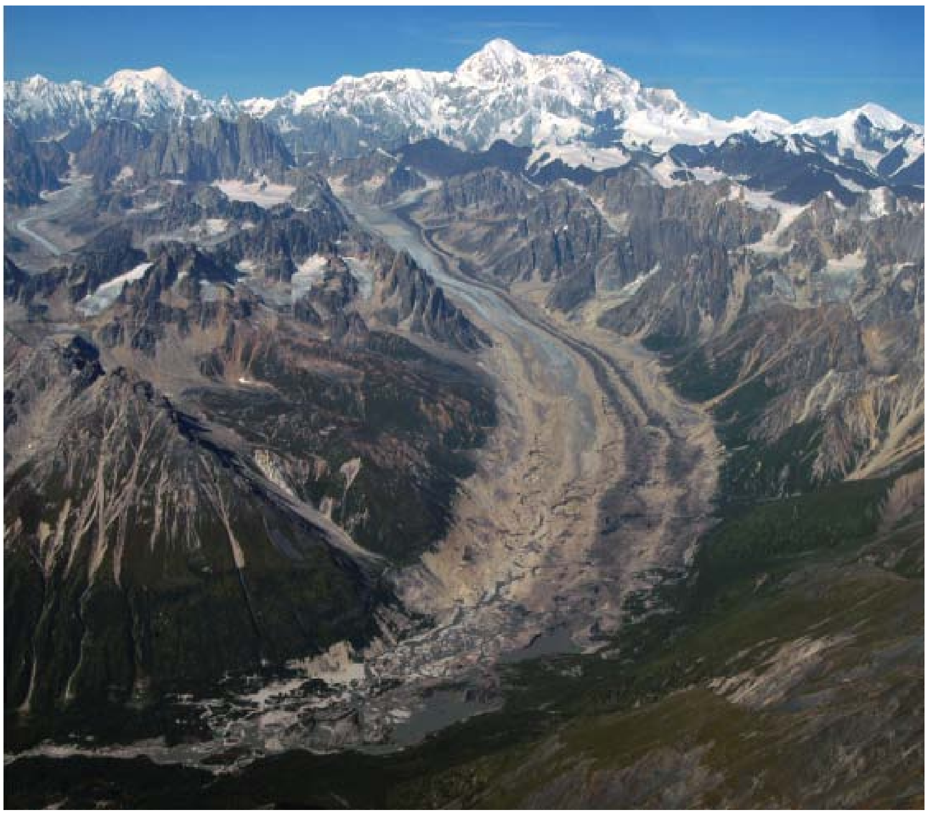

Photo 2. A view of Mount McKinley and the terminus of Buckskin Glacier (photo courtesy of R. Karpilo, Jr., in Thornberry-Ehrlich 2010).

In the northern park and preserve, large, braided glacial streams are a prominent feature and permafrost is common. Wildfires and floods are natural and important components of the disturbance regime in this area. The mineral rich Kantishna Hills, extending north from the Alaska Range, contain many streams where placer mining occured intermittently throughout the twentieth century.

The landscape of Denali has been shaped by the repeated advance and retreat of glacial ice over two million years during the Pleistocene Epoch (Roland 2004). At its greatest extent, ice covered at least half of the current park and preserve area (Figure 1). Only areas of Denali well north of the Alaska Range were free of ice and served as a refugium for plants and wildlife. This ice-free area, known as Beringia, was connected to Asia but cut off from North America by the Cordilleran ice sheets (Roland 2004). Glaciers, including some of the largest in North America, still cover approximately 17% of the total park and preserve area today (Adema 2007).

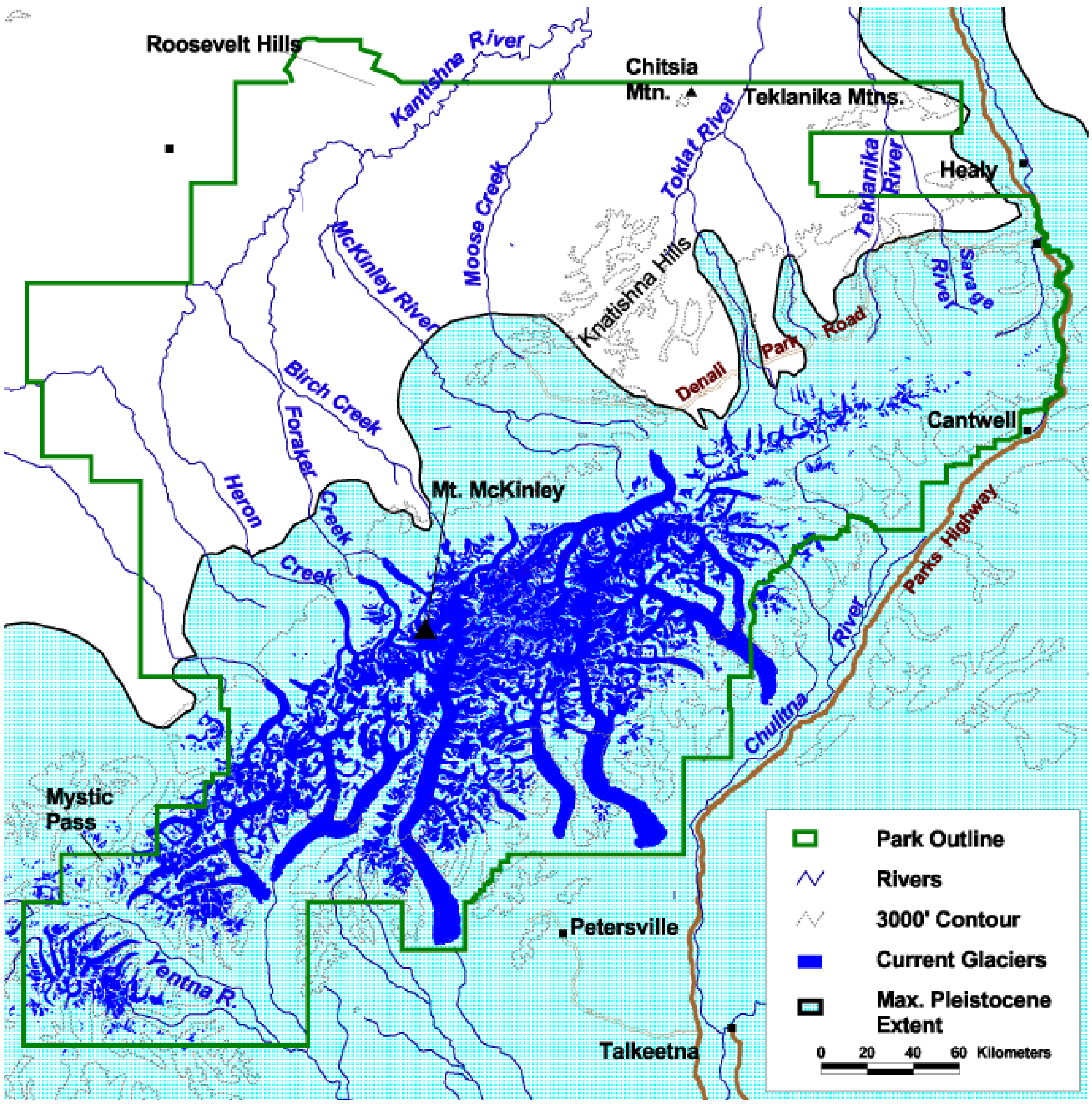

Figure 1. Maximum extent of the Cordilleran Ice Sheet in Denali during the last peak glacial advance. Areas in the north not covered by ice were part of the refugium of Beringia (Roland 2004).

Climate

Two major climate regimes exist within Denali National Park and Preserve: a transitional maritime climate to the south of the Alaska Range and a continental interior climate to the north (Figure 2; DENA 2007a). On the northern side, where park headquarters and most other facilities are located, temperatures are typical of a continental climate with very warm summers and cold winters (Sousanes 2006). There is also less precipitation here than in the south because of the location on the leeward side of a major mountain range. The maritime climate on the south side of the Alaska Range is influenced by the prevailing weather patterns of the Gulf of Alaska, with milder air temperatures, less seasonal variation, and more precipitation.

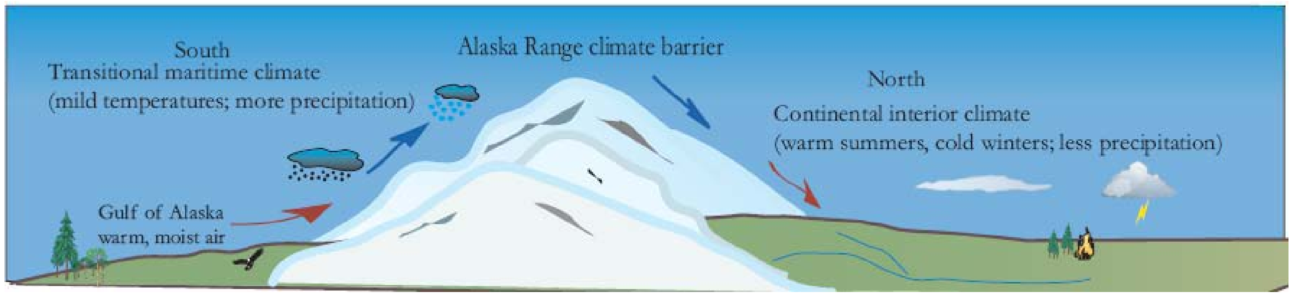

Figure 2. Conceptual image of the two distinct climate regimes north and south of the Alaska Range (DENA 2007a).

Consistent long-term climate records are available for the two climate regimes that characterize Denali National Park and Preserve. Daily weather observations, including minimum and maximum temperatures and precipitation amounts have been recorded at park headquarters on the north side of the Alaska Range since 1925 (Table 2). The mean annual temperature at park headquarters is -2.7°C. Temperature extremes at this location range from -47.8°C to 32.8°C. Mean maximum temperatures are -11.7°C for January and 18.6°C for July. The mean minimum temperatures for the same months are -16.6°C and 6.5°C, respectively. Total precipitation is relatively low at 37.8 cm, with annual snowfall totals averaging about 202 cm. The sub-zero temperatures in winter coupled with relatively low snowfall amounts contribute to the presence of widespread permafrost. In the northwest corner of the park and preserve, within the Minchumina basin, the temperatures are warmer and there is less precipitation, which drives the wildland fire disturbance regime that influences this area.

Table 2. McKinley Park monthly climate summary, period of record: 1/1/1926-12/31/2010 (adapted from Sousanes 2008).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Temperature (°C)													
Max	-11.7	-8.6	-4.1	3.6	11.7	17.6	18.6	15.8	10.3	0.7	-7.9	-11.2	3.0
Min	-21.3	-19.6	-17.2	-8.9	-0.9	4.6	6.5	4.4	-0.4	-9.2	-17.2	-20.6	-8.3
Average Precipitation (cm)													
Total	1.8	1.5	1.0	1.0	2.0	5.6	7.6	6.9	4.1	2.5	2.0	2.0	37.8
Snow Fall	29.5	24.9	19.8	15.2	6.6	0.5	0.0	0.0	8.4	32.0	31.8	6.4	201.9
Snow Depth	41.7	48.8	52.1	44.2	6.9	0.0	0.0	0.0	2.5	8.9	19.8	31.2	21.1

The transitional maritime climate on the south side of the Alaska Range is characterized as a blend of the mild, moist maritime influences of the coastal zone of the Gulf of Alaska and the cold, dry continental influences of Interior Alaska. The mean annual temperature in Talkeetna, a town southeast of the park boundary, is 1.1°C, over 3 degrees warmer than park headquarters and above the freezing level (Table 3). The mean annual precipitation is 70.1 cm, or nearly double that of park headquarters. Snowfall totals along the southern flank of the Alaska Range are high, and snowcover is often present through much of the spring. The mean minimum January air temperature is -16.6 °C and the mean maximum July temperature is 19.9°C. Permafrost is generally absent from the south side and the landscape is characteristic of the warmer, wetter climate.

Table 3. Talkeetna monthly climate summary, period of record: 9/1/1949-9/30/2010 (adapted from Sousanes 2008).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Temperature (°C)													
Max	-6.8	-3.3	0.9	7.1	13.9	18.7	19.9	18.2	13.1	4.4	-3.2	-6.4	6.3
Min	-16.6	-14.6	-12.2	-4.7	1.5	7.4	9.8	8.0	2.9	-4.4	-12.3	-15.8	-4.3
Average Precipitation (cm)													
Total	3.6	3.8	3.3	3.6	3.8	5.6	8.6	11.9	10.7	7.1	4.3	4.3	70.1
Snow Fall	47.2	50.8	43.4	23.4	2.3	0	0	0	3.0	29.5	48.8	57.9	306.3
Snow Depth	68.6	76.2	78.7	45.7	5.1	0	0	0	0	5.1	20.3	43.2	27.9

The varied topography within a mountain range produces microclimatic differences over very short distances, making detailed descriptions of climate in mountain terrain more difficult than simply assessing climate regions. One constant is that the climate in all subarctic areas is affected by the extreme solar radiation conditions of high latitudes. Denali National Park and Preserve is located between 62° and 64° north latitude and experiences strong seasonal fluctuations in incoming solar radiation with nearly 21 hours of daylight on the summer solstice and only about 4 hours of daylight on the winter solstice (Hooge et al. 2006).

Climate normals, defined as the arithmetic mean computed over three consecutive decades (NCDC 2008), are also available for several weather stations near Denali. Temperature and precipitation normals are available for five stations, with one additional station having only a precipitation normal. The most recent climate normal period available is 1971 to 2000. Monthly temperature and precipitation normals for stations near Denali are shown in Figure 3, Figure 4, Figure 5, and Figure 6. Figure 7 shows average snow depth for eleven locations in and near the park and preserve. Plate 1 displays the locations of the weather stations included in these figures.

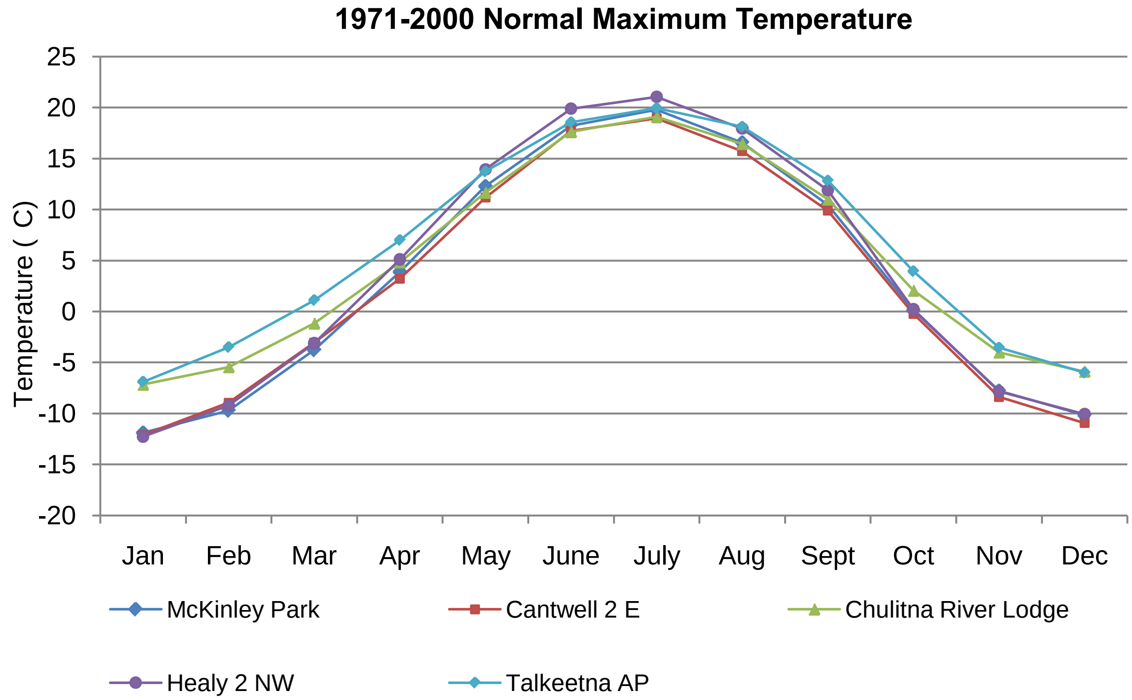

Figure 3. Maximum monthly temperature normals (degrees Celsius), calculated for weather stations near DENA (Keen 2008).

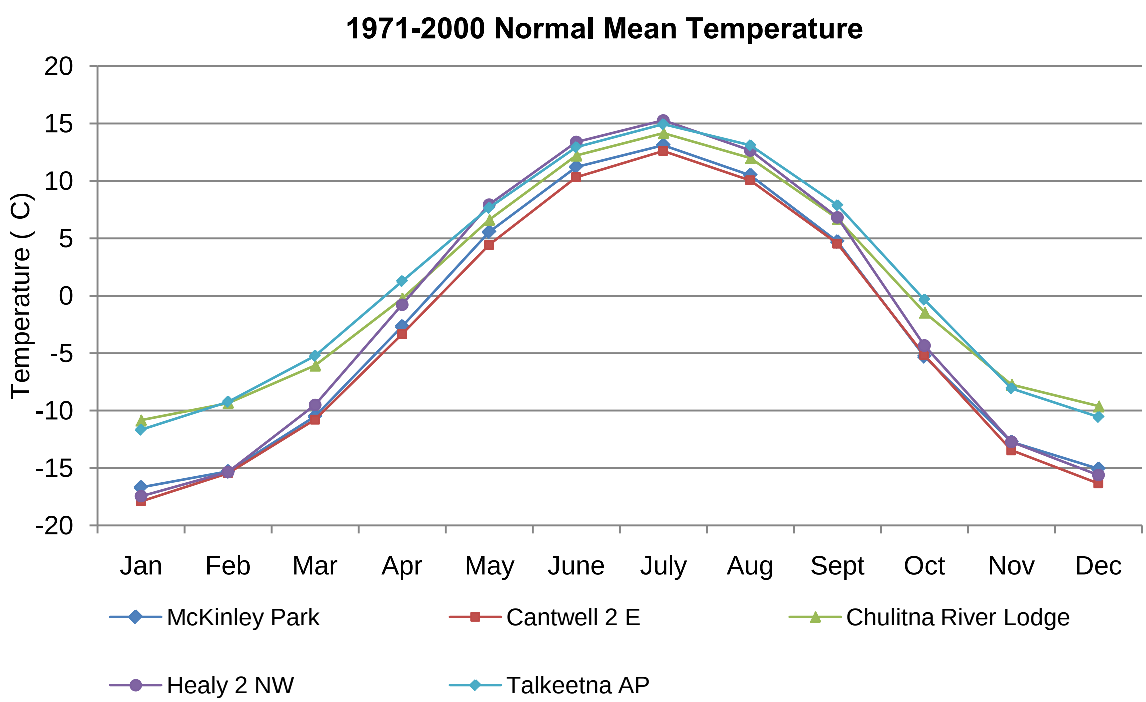

Figure 4. Mean monthly temperature normals (degrees Celsius), calculated for weather stations near DENA (Keen 2008).

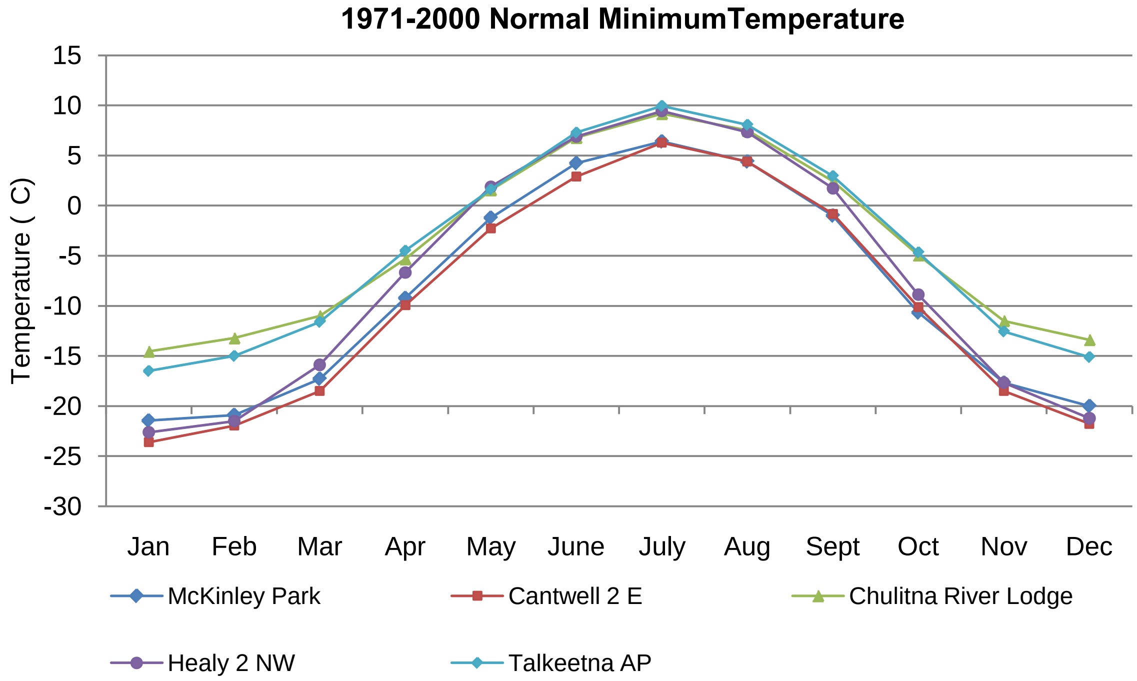

Figure 5. Minimum monthly temperature normals (degrees Celsius), calculated for weather stations near DENA (Keen 2008).

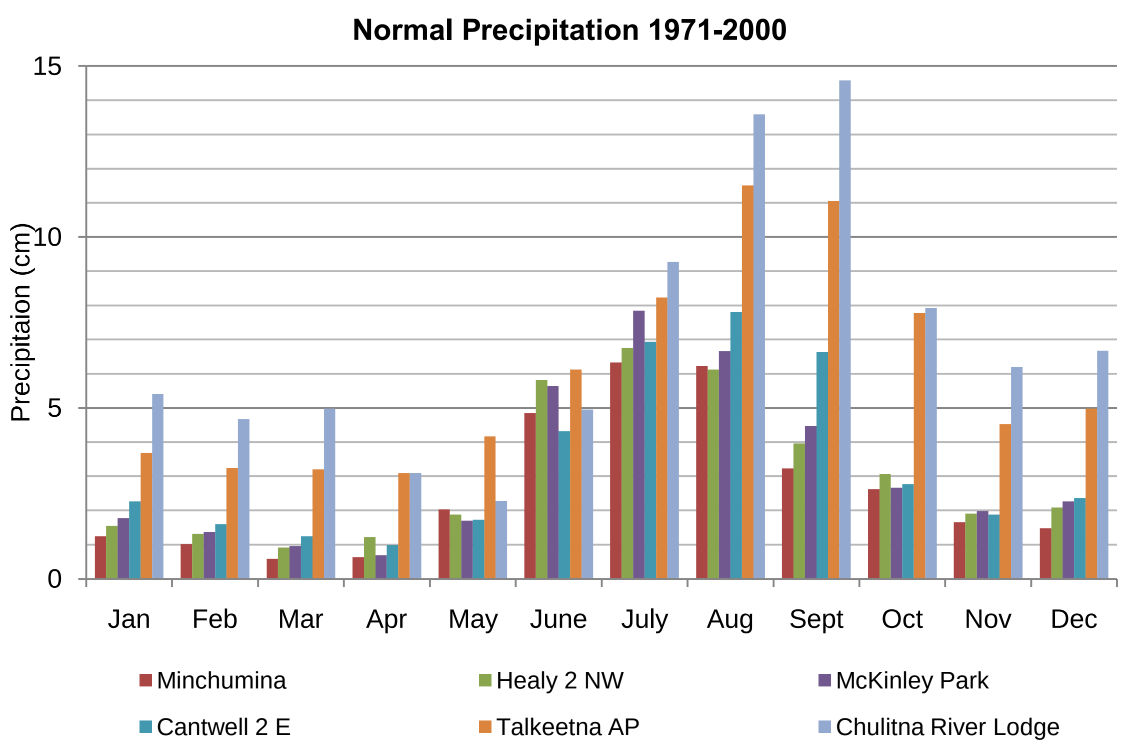

Figure 6. Monthly precipitation normals (centimeters), calculated for weather stations near DENA (Keen 2008).

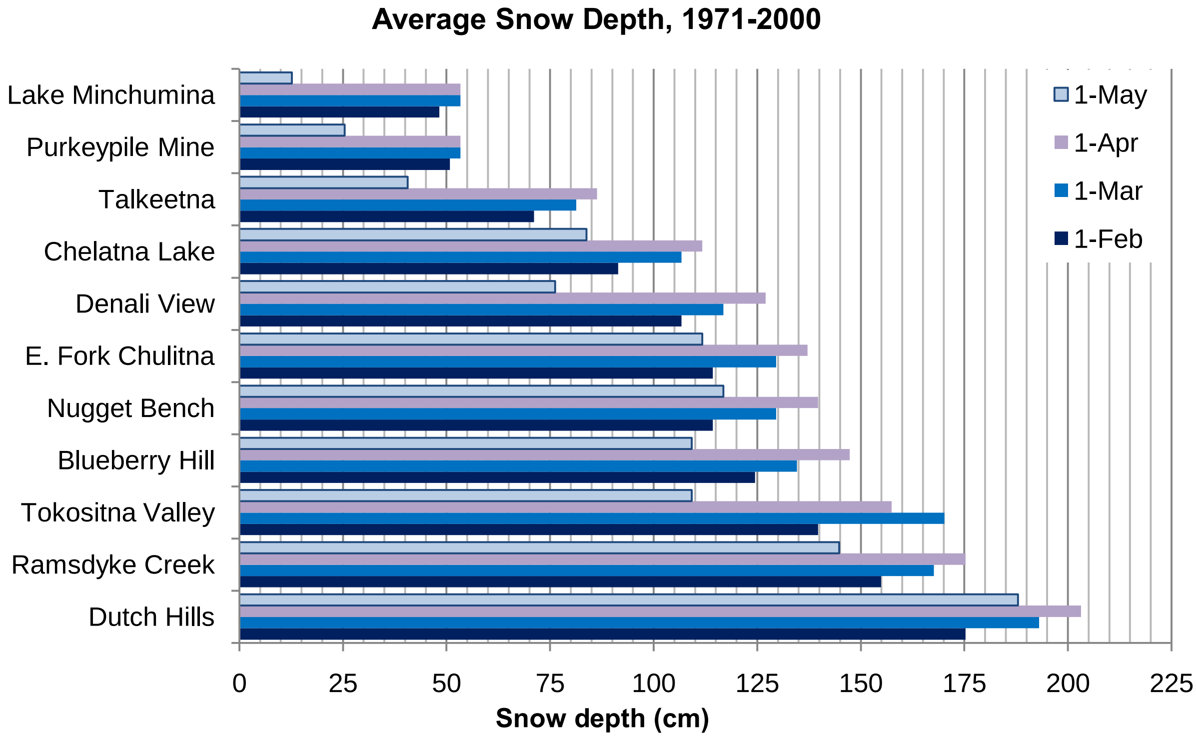

Figure 7. Average snow depth (centimeters) for snow courses in and near Denali, 1971-2000. (Keen 2008).

A long-term park-wide climate monitoring program was initiated as part of the Central Alaska Network's Inventory and Monitoring Program. The objective of this program is to monitor and record weather conditions at representative locations in order to identify long and short-term climate trends, provide reliable climate data to other researchers, and to participate in larger scale climate monitoring and modeling efforts. The locations of these recently added stations are depicted on Plate 1 as RAWS stations.

Even with these new sites, however, there are very few climate/weather stations in the remote parts of the national park units in Alaska, including Denali. In order to understand climate patterns and variation in data sparse regions of the Alaska national parks, the Alaska Region Inventory and Monitoring Program collaborated with Oregon State University's PRISM Climate Group to generate spatially gridded average monthly and annual precipitation and temperature data set for the 1971 – 2000 normal period. The PRISM (Parameter-elevation Regressions on Independent Slopes Model) climate mapping system integrates existing climate station data with scientific understanding of general climate processes and local climate features to generate statewide models. The PRISM models for annual mean temperature and precipitation are depicted in Plate 2, Plate 3, and Plate 4.

Climate in Alaska is constantly fluctuating on multiple temporal scales (Redmond and Simeral 2006). These fluctuations present challenges in determining climate trends. Keen (2008) calculated annual temperature trends for various time periods for the Central Alaska Network, and the results varied depending on the range of years included in the calculation (Table 4).

Table 4. Trends of CAKN regional annual temperatures for various intervals. Adapted from Keen (2008).

Years	Number of Years	Degrees C / century	R	P=0.01
1900 to 2004	105	0.37	0.23	0.25
1926 to 2004	79	0.24	0.11	0.28
1946 to 2004	59	1.40	0.48	0.33
1926 to 1975	50	- 1.77	0.50	0.35
1977 to 2004	28	0.78	0.16	0.46

One climate fluctuation of particular importance in Alaska is the Pacific Decadal Oscillation (PDO) (Keen 2008). Mantua et al. (1997) formally identified this pattern of climate variability in a study relating climate oscillation to salmon production. The PDO, which is related to sea surface temperatures in the northern Pacific Ocean, affects atmospheric circulation patterns and alternates between positive and negative phases (Wendler and Shulski 2009). A positive phase is associated with a relatively strong low pressure center over the Aleutian Islands, which moves warmer air into the state, particularly during the winter (Wendler and Shulski 2009). Some of the variation in Alaska's climate over time can be explained by major shifts in the PDO which occurred in 1925 (negative to positive), 1947 (positive to negative), and 1977 (negative to positive) (Mantua et al. 1997). Hartmann and Wendler (2005) found that much of the warming that occurred in Alaska during the last half of the twentieth century was influenced by the PDO shift in 1976-77. The PDO index, which is based on monthly anomalies in sea surface temperature of the North Pacific, is depicted along with mean annual temperatures for McKinley Park and Talkeetna in Figure 8. Climate change in central Alaska will be further discussed in section 2.2.3 of this report.

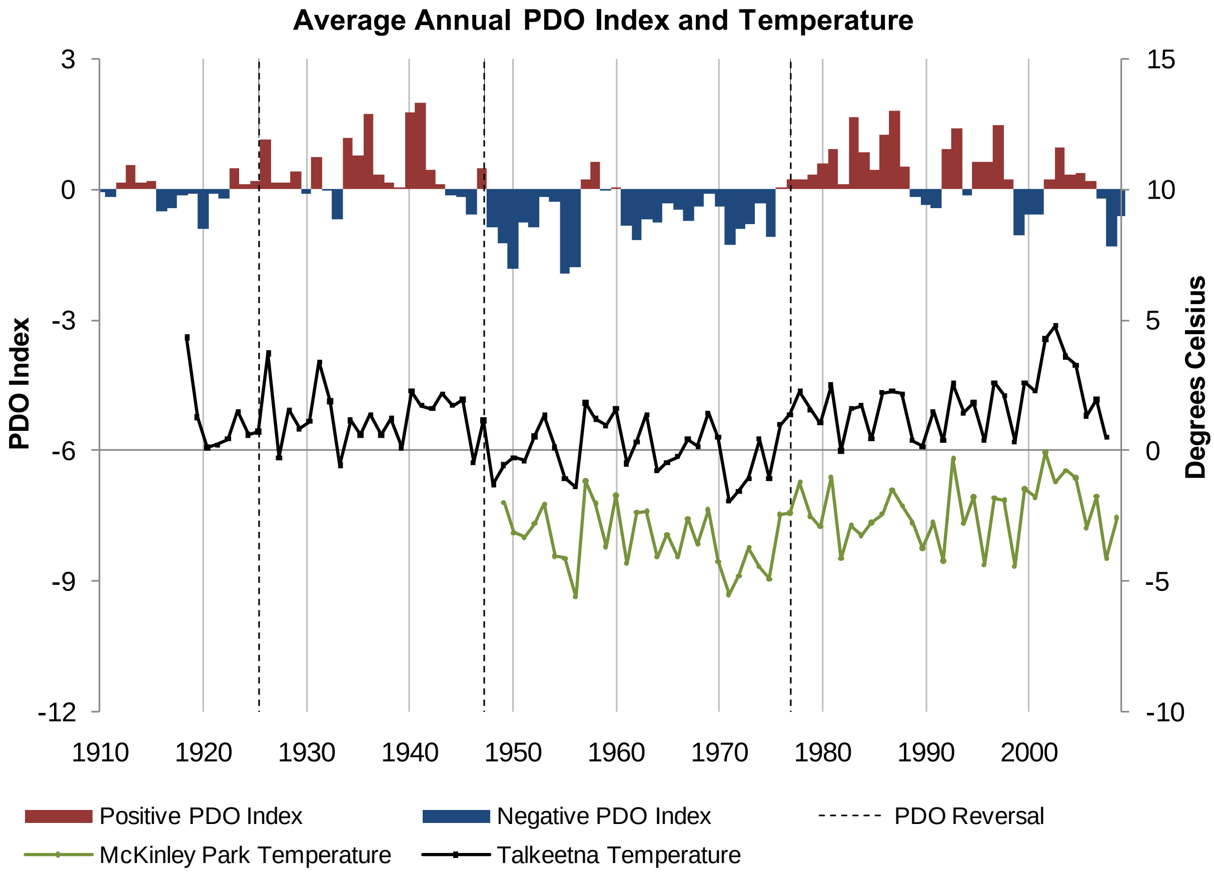

Figure 8. Annual average PDO index and annual mean temperature for McKinley Park and Talkeetna, (Mantua 2010, Alaska Climate Research Center 2010, Western Regional Climate Center 2010). Vertical dashed lines represent reversals in PDO polarity in 1925, 1947, and 1977.

2.1.3 Visitation Statistics

Since record-keeping began in 1922, Denali National Park and Preserve has received over 14.5 million visitors (NPS 2010a). Visitation peaked between 1986 and 1995 when an average of just over 500,000 people entered Denali each year. Over the past decade numbers have averaged around 400,000 visitors per year. Approximately 80% of visitors come to the park between June and August, with visitation generally peaking in July (NPS 2010a). In 2009 there were nearly 90,000 overnight visitors, slightly fewer than in previous years. Approximately 2/3 of these overnight visitors utilized tent and RV campgrounds while the remainder camped in the backcountry (NPS 2010a).

Photo 3. Bus rides provide an excellent opportunity to view Denali’s wildlife along the park road (left) while scenic air tours (right) are a popular way to experience the Alaska Range and its glaciers (NPS photos, in DENA 2010a).

During the last decade, an average of 285,000 visitors utilized Denali’s bus transportation each year to access or tour the park and preserve. Approximately 17,000 visitors enter the park via local air-tour operators yearly, including 3,000 arrivals by air taxi and 14,000 scenic air tours (actual landings, not overflights alone). The number of scenic air tour visitors has increased by nearly 50% since the early 2000s (Ackerman 2010). An estimated 230,000 visitors arrive at Denali in private vehicles, with approximately 2,000 touring the park and preserve (beyond Savage River) in their own vehicles (DENA, Ackerman, pers. comm. 2011). On average around 150,000 visitors arrive each year on the Alaska Railroad, which stops at the entrance of the park and preserve near the Denali Visitor Center (Ackerman 2010). An estimated 2,200 visitors come to the park and preserve each year specifically for mountaineering, with the majority climbing on Mt. McKinley (DENA, Ackerman, pers. comm. 2011).

2.2 Natural Resources

2.2.1 Ecological Units and Watersheds

Denali National Park and Preserve contains five ecological sections based on physiography: the South Central Mountains and Cook Inlet Lowlands south of the Alaska Range, and the Alaska Mountains, Yukon-Kuskokwim Bottomlands, and Kuskokwim Mountains north of the range (Plate 5; Clark and Duffy 2006). The South Central Mountains section contains the southern half of the Alaska Range while the Alaska Mountains Section contains the northern half of the range, including Mount McKinley. Both sections consist of steep, rugged mountain ridges separated by broad valleys. About two-thirds of these sections have no soil and large areas also have no vegetation. Temperatures are often below freezing year-round and avalanches are frequent in the winter. Alpine and dwarf scrub vegetation are found at mid-elevations while spruce woodlands are common at lower elevations with riparian spruce-hardwood forests occasionally in valley bottoms. Fires are common in the forested areas of the Alaska Mountains section but are rare in the South Central Mountains, which, on average, receive the most precipitation of any section in the park and preserve (Clark and Duffy 2006).

Photo 4. Views of the South Central Mountains (left) and Yukon-Kuskokwim Bottomlands (right) sections of Denali National Park and Preserve (Clark and Duffy 2006).

The Kuskokwim Mountains section in northwestern Denali contains broad, gentle slopes with rounded or flat summits and deep narrow valleys. Open black spruce forests are abundant and white spruce-paper birch woodlands are common. Alpine vegetation and shrubs blanket the ridges and hillsides. Wildfires are common here as well as in the surrounding Yukon-Kuskokwim Bottomlands section. The Yukon-Kuskowim Bottomlands consist of large flat areas along the larger rivers in Denali. Some low rolling hills are present with broad valleys and basins. Meandering streams, side sloughs, and oxbow lakes are all abundant. Vegetation in the bottomlands ranges from spruce-poplar forests to willow and alder thickets and wet sedge meadows (Clark and Duffy 2006).

The Cook Inlet Lowlands in the south consist of rolling lands shaped primarily by glacial events. Major landforms include glacial plains and hills, outwash plains, and flood plains. Lowland black spruce forests are abundant along with spruce-poplar forests adjacent to large rivers, as well as alder and willow scrub thickets (Clark and Duffy 2006). These five ecological sections can be further divided into the twenty-two subsections listed in Table 5. These subsections are described in detail in Clark and Duffy (2006).

Table 5. The twenty-two subsections of Denali by ecological section (Clark and Duffy 2006).

South Central Mountains
Nonvegetated Alpine Mountains
Alpine Mountains
Boreal and Subalpine Mountains
Cook Inlet Lowlands
Glaciated Lowlands
Lowland Floodplains & Terraces & Fans
Alaska Mountains
Nonvegetated Alpine Mountains
Glaciated Uplands
Glaciated Lowlands
Alpine Outer Range and Kantishna Hills
Boreal Outer Range and Kantishna Hills
Alpine Mountains
Boreal Mountains
Teklanika Alpine Mountains and Plateaus
Teklanika Boreal Mountains & Plateaus
Toklat Basin Lowlands
Alpine Flood Plains & Terraces & Fans
Lowland Floodplains & Terraces & Fans
Yukon-Kuskokwim Bottomlands
Eolian Lowlands
Lowland Floodplains and Terraces
Minchumina Basin Lowlands
Kuskokwim Mountains
Boreal Low Mountains
Alpine Low Mountains

The high peaks of the Alaska Range divide watersheds in Denali. Many rivers south of the mountains, including the Tokositna, Kahiltna, and Yentna, begin at the bases of glaciers. The Tokositna River drains the Tokositna and Ruth Glaciers on the southern edge of Denali before entering the Chulitna River. The Chulitna collects many of the smaller streams on the eastern edge of the park and flows through Denali State Park before entering the Susitna River at Talkeetna. Further west, the Kahiltna River begins near the base of Kahiltna Glacier. It flows into the Yentna River, which begins as two forks in the southern preserve. Its east fork rises at the base of the Yentna Glacier while the west fork flows south of Mount Dall. The Yentna River flows into the Susitna River, which ultimately drains into the Cook Inlet.

North of the Alaska Range there are numerous small streams and rivers. Most flow north to the Tanana River, although a few on the western edge of Denali are part of the Kuskokwim River drainage. Prominent rivers in the eastern part of the park include the Teklanika and its tributary, the Savage River, an area frequented by visitors. The Teklanika flows into the Nenana River, which forms part of the park and preserve's eastern boundary. The Toklat River rises as several glacier-fed forks in the northern Alaska Range, and a non-glacier-fed fork from the Kantishna Hills. It drains much of the northeastern part of Denali and flows into the Kantishna River north of the park and preserve boundary. The Kantishna River, through its Bearpaw and McKinley River tributaries, drains the majority of the northwestern park and preserve. Many of its

McKinley tributaries are glacier fed while the Bearpaw drainage rises in the unglaciated Kantishna Hills. The Kantishna River flows north into the Tanana River which then joins the Yukon River and empties into the Bering Sea.

2.2.2 Resource Descriptions

Due to its size and relatively undisturbed nature, Denali encompasses a wide range of environmental conditions, habitats, and wildlife. In mountainous areas with steep, rocky slopes and ice cover, soils are thin or nonexistent and support little vegetation. Denali's vegetation is typical of subarctic areas with short growing seasons and nutrient-poor soils. Boreal forests and wetlands are found at the lowest elevations, giving way to shrublands at approximately 800 m elevation and alpine tundra vegetation (sometimes just centimeters high) above 1,000 m (MacCluskie and Oakley 2005).

Denali is known to support 753 vascular plant species, 37 mammals, 167 birds, 10 fish, and one amphibian species. Large mammals include moose (*Alces alces*), caribou (*Rangifer tarandus*), wolves (*Canis lupus*), grizzly bears (*Ursus arctos*), black bears (*Ursus americanus*), and Dall's sheep (*Ovis dalli*). The park and preserve also supports a large number of smaller animals, including snowshoe hare (*Lepus americanus*), beaver (*Castor canadensis*), Arctic ground squirrel (*Spermophilus parryii*), and other furbearers and rodents. These species are important both for subsistence users and as prey sources for large carnivores. Eighty percent of Denali's bird species are migratory, including the golden eagle (*Aquila chrysaetos*), trumpeter swan (*Cygnus buccinator*), and numerous passerines (order Passeriformes).

Photo 5. Beaver (left) and Arctic ground squirrel (right) are just two of the small mammal species found at Denali National Park and Preserve (NPS photos, in DENA 2010a).

Chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), and chum salmon (*O. keta*) have all been found within the park and preserve's streams. Sockeye salmon (*O. nerka*) have also been reported by the ADF&G in streams south of the Alaska Range. Plate 6 shows the distribution of salmon within the park and preserve as reported by the ADF&G (2010a). The species present in each watershed are shown in Table 6. However, the ecology of salmon within the park and preserve is largely understudied.

Table 6. Salmon distribution by species and life stage within the streams of Denali National Park and Preserve (ADF&G 2010a). P = present, S = spawning, R = rearing.

Watershed	Chinook	Chum	Coho	Sockeye
North of the Alaska Range				
Fish River			P	
Foraker River				
above Lake Minchumina		P	P,S	
below Lake Minchumina	P	P	P	
Birch Creek	P	P,S	P,S	
McKinley River	P	P,S	P	
Kantishna River and tributaries below McKinley confluence	P,S	P	P	
Bearpaw River	P,S,R	P,S,R	P (below Moose Cr.)	
Moose Creek	P,S,R	P,S	P,S	
Toklat River		P,S	P,S	
South of the Alaska Range				
Granite Creek (Kahiltna drainage)				P
Tokositna River	P,R	P	P,S,R	P,S

Geology affects many components within the park landscape including hydrology and soils, which in turn influence vegetation and wildlife. While the core of the Alaska Range is composed of igneous granitic rock, the majority of the park north of the range is underlain by sedimentary bedrock. Denali contains three rock provinces that run in east-west bands through the park and preserve: the Yukon-Tanana Terrane, the Pingston/McKinley Terranes, and the Kahiltna Terrane (Clark and Duffy 2006). These provinces are separated by the Denali fault system, a series of major crustal fractures that arc from Canada to Bristol Bay and into the Bering Sea (Plate 7).

The Yukon-Tanana Terrane is the oldest and furthest north of the three provinces (Thornberry-Ehrlich 2010). It covers nearly half the park and preserve and contains the most highly altered marine and volcanic rocks with smaller overlays or veneers of Quaternary and Tertiary sediments. The Pingston/McKinley Terranes are found along the crest of the Alaska Range and contain slightly younger, less altered marine sediments occasionally pierced or covered by much younger granitic and volcanic rocks. The Kahiltna Terrane contains the youngest rock and covers the southern third of the park and preserve. It includes Mt. McKinley and other mountains of igneous rock that have pierced through shallow marine sediments (Clark and Duffy 2006). These different terranes and the physical processes that act upon them result in a variety of different geologic sources or “parent material” for soils and surficial landforms in the park and preserve, as shown in Plate 8. A geological resources inventory has been completed for the park and preserve and is described in Thornberry-Ehrlich (2010). A summary of major geological events in Denali’s history is presented in Table 7.

The slopes of Denali have yielded many significant paleontological finds, particularly in recent years. Trace fossils from the Cretaceous Period, including dinosaur tracks, have been found at several locations within the park and preserve, in addition to marine and plant fossils from the Paleozoic and Mesozoic Eras (DENA 2008). The first theropod track, found in June of 2005, provided the first evidence of dinosaurs in interior Alaska.

Table 7. A summary of major geologic events in the history of Denali National Park and Preserve (Thornberry-Ehrlich 2010).

Eon	Era	Period		Epoch	Geologic Events
PHANEROZOIC	CENOZOIC	QUATERNARY		HOLOCENE	Cantwell ash fall with volcanism from southerly source (~3,700 ybp) and multiple glaciation events.
				PLEISTOCENE	Multiple glacial advances starting ~2 Ma to 8,000 ybp; intense glacial erosion of rapidly uplifting Alaska Range.
		TERTIARY	NEOGENE	PLIOCENE	Deposition of Nenana Gravel shed from uplifting Alaska Range; units include sandstone, conglomerates, claystone, and lignite. Uplift and exhumation of Mt. McKinley. Movement along Denali fault system likely resumes.
				MIOCENE	Deformation and thrust faulting cause a surge in uplift of the Alaska Range; beginning of Yakutat terrane accretion. Regional subsidence due to crustal thickening and continued sedimentation and coal deposits of the Tanana foreland.
			PALEOGENE	OLIGOCENE	Deposition in subsidence basins north and south of the Alaska Range; several phases of igneous intrusion and volcanism at 38 Ma.
				EOCENE	Cantwell volcanism and McKinley intrusive sequence from 41 to 57 Ma results in flows, breccias, and tuffs, as well as granodiorite intrusion with some sulfide mineralization; Prince William wedge accretes.
				PALEOCENE	Emergent Alaska Range continues to shed sediments into foreland pull-apart basin, leading to piles of sandstone, siltstone, shale, tuff layers, coal, and conglomerates of the Cantwell Formation; strike-slip movement along Denali fault. Continued intrusion of granites in the Alaska Range, including the McKinley and Ruth plutons.
	MESOZOIC	CRETACEOUS			Multiple phases of igneous intrusive activity (granites and granodiorites), volcanism, and orogenesis as the Chugach wedge accretes to the continent; continued flysch deposition in shallow basins; pervasive deformation and metamorphism at 115 to 106 Ma, 74 Ma, and 65 to 60 Ma; uplift of Alaska Range continues. Final closer of ocean between Talkeetna Superterrane, and previously accreted terranes to the north.
		JURASSIC			Orogenic activity increases as Talkeetna superterrane is accreting, pushing miniterranes within the intervening basin toward the continent; intense deformation and metamorphism; continued deposition of Mesozoic flysch in segmented, forearc, and backarc basins
		TRIASSIC			Final accretion of Yukon-Tanana terrane; abundant submarine basalt flows form Nikolai Greenstones; continued deposition of redbed sandstones, conglomerates, tuffs, argillites, and limestones; Pingston, McKinley, and Chulitna terranes are pushed toward the margin of North America.
	PALEOZOIC	PERMIAN			Deposition of alternating limestone and argillite beds of the Eagle Creek Formation, as well as massive marine limestone, mudstone, and greywacke.
		PENNSYLVANIAN			Widespread volcanism forms andesitic Tetelna Volcanics, later metamorphosed to greenschist; continued marine deposition of cherts, pillow basalts, shales, fossiliferous limestones, sandstones, and argillites.
		MISSISSIPPIAN			Moose Creek Member basaltic to intermediate volcanism, later metamorphosed to greenschists (Totatlanika Schist).
		DEVONIAN			Andesitic tuff from island arc volcanism, red and brown chert deposits, and shallow marine basin limestone.
		SILURIAN			Marine deposition and coral growth; intermittent volcanic activity. Continued deposition of turbidites, sandstones, argillites, dolomitic limestones, cherts, volcanic flows and ash falls, shales, and conglomerates; intermittent igneous activity, including mafic dike intrusions; multiple phases of deformation and metamorphism change sediments to quartzites, phyllites, slates, marbles, gneisses, meta-volcaniclastic schists, and greenstones.
		ORDOVICIAN			
		CAMBRIAN			
PRECAMBRIAN					Shallow marine basins covered large area south of ancient North American continent; resulted in deposition of quartz-rich sediments interlayered with volcanic flows and ash and limestone. Formations include Keavy Peak Formation and Birch Creek Schist.

2.2.3. Resource Issues Overview

The size and remoteness of Denali National Park and Preserve make it difficult to monitor and determine the park-wide condition of its resources. It is also challenging to track human use in remote backcountry areas such as the national preserves. In addition, park managers are concerned about the impacts of activities outside the park and preserve that are beyond their control. These include the long-range transport of airborne contaminants, scenic tour overflights, state wildlife management policies (particularly predator control activities), and dangers faced by migratory birds when they leave the park and preserve to overwinter.

<u>Subsistence</u>

Subsistence harvest is a vital activity for Alaskans living in and around Denali National Park and Preserve. In 1980, Congress recognized the importance of the subsistence lifestyle in Alaska by making it one of the purposes of ANILCA (DENA 2004):

> "Through Title VIII of ANILCA, Congress established a policy 1) that rural residents engaged in a subsistence way of life be provided the opportunity to do so, consistent with sound management principles and the conservation of healthy fish and wildlife populations; 2) that the utilization of public lands in Alaska is to cause the least adverse impact possible on rural residents who depend upon subsistence resources; 3) the non-wasteful subsistence uses of fish and wildlife be the priority consumptive use should it become necessary to restrict the taking; and 4) that in managing subsistence activities the federal land managing agencies shall cooperate with adjacent landowners and land managers, including Native corporations, state and federal agencies" (DENA 2004).

The intent of Congress was to limit subsistence harvest to local rural residents who have a personal, family, or community history of using park and preserve resources (DENA 2004). In allowing for subsistence harvest in Denali, Congress recognized that harvest activities must be balanced with National Park Service management policies which "strive to maintain the natural abundance, behavior, diversity, and ecological integrity of native animals as part of their ecosystem, while recognizing that subsistence use by local rural residents have been, and are now, a natural part of the ecosystem serving as a primary consumer in the food chain" (DENA 2004).

The Denali Subsistence Resources Commission (SRC) was established in 1984 as an advisory committee to provide recommendations to the Secretary of the Interior and the Governor of Alaska regarding subsistence harvest in the park and preserve (DENA 2004). It consists of nine members "representing different geographical, cultural, and user groups for the Denali area" (DENA 2004). Some of the major topics covered by the SRC include resident eligibility, park access, harvest monitoring, methods and means of taking, research needs, use of cabins and shelters, trap line management, and timber management (DENA 2004). The SRC and park staff developed a Subsistence Management Plan (SMP) to help clarify the management of subsistence activities on park and preserve land (DENA 2004).

In 1990, the federal government assumed full responsibility for subsistence harvest management on federal public lands in Alaska (DENA 2004). The Federal Subsistence Board (FSB) was established to oversee the Federal Subsistence Program and make decisions regarding rural/non-rural determinations, community eligibility, which species and populations to harvest, when seasons open and close, harvest limits, and harvest methods (DENA 2004).

Subsistence harvest is allowed on land added to Denali National Park by ANILCA in 1980 and in the Denali National Preserves. Sport hunting is only allowed on National Preserve lands, and there is no harvest of any kind within the Denali wilderness boundary (Plate 9). The most common forms of subsistence harvest in Denali include hunting, fishing, trapping, firewood harvest, and cabin log harvest. Data on subsistence harvest is reported voluntarily, limiting the comprehensiveness of databases and reports that can be derived using this information as a source (DENA 2004). Wildlife populations within Denali are generally considered to be regulated by nature, with subsistence harvest having a minimal influence (DENA 2004).

Subsistence harvest levels can vary considerably from year to year due to factors such as weather, animal migration patterns, natural fluctuations in wildlife population cycles, and from political and regulatory factors (DENA 2004). Harvest levels were probably much greater in the past in Denali than they are today (DENA 2004). Subsistence use levels also vary with socio-economic trends such as fur prices and the availability of seasonal jobs, which influence reliance on and ability to engage in hunting, gathering, fishing, and trapping (DENA 2004).

The communities of Cantwell, Lake Minchumina, Nikolai, and Telida are designated subsistence resident zone communities which are defined as having a significant concentration of people who have historically used Denali for subsistence harvest (DENA 2004). Information on these communities is found in Table 8 below. There are an additional 16 local families issued permits that do not live in one of these communities but have traditionally used Denali for subsistence activities (DENA 2004).

Table 8. Designated subsistence resident zone communities for Denali National Park and Preserve (DENA 2010b).

Village	2009 population	% Native Alaskan	Primary subsistence activities	Special notes
Cantwell	200	27%	Hunting	Must live within 3 miles of post office
Lake Minchumina	17	<5%	Trapping, hunting, fishing	Residents also garden and work part time
Nikolai	87	81%	Fishing	
Telida	3 (one family)	100%	Trapping	Some now live in Nikolai

In all, an estimated 320 local rural residents are eligible for federal subsistence harvest activities in Denali based on 1990 census information (DENA 2004). Census data showed a population increase in all but one of the resident zone communities between 1980 and 1990 (DENA 2004), with the population of Cantwell continuing to grow from 1990 to 2000 (ADF&G 2011). Thus, the number of eligible subsistence users continues to increase since citizens in these resident zone communities are automatically eligible for subsistence permits (DENA 2004). Despite the growing number of people eligible for subsistence use permits, the relative number of users involved in subsistence harvest within Denali is decreasing (DENA 2004).

Studies in the early to mid 1980s revealed that Denali's subsistence communities were dependent on moose, caribou, rock and willow ptarmigan, spruce grouse, hare, ducks, geese, salmon, and limited species of freshwater fish (DENA 2004). Seventy percent of the resources harvested were large mammals (DENA 2004). Black bear, brown bear, and Dall's sheep were the least commonly harvested large mammals. Fish accounted for 21% of the resources harvested by these communities (DENA 2004).

Firewood and cabin log harvest

The species most commonly used for firewood and structures are spruce and birch, although willow, alder, and cottonwood are also used to smoke fish and meat (DENA 2004). According to a 1999-2000 survey, 55.3% of Cantwell residents used wood in some subsistence capacity (DENA 2005). Firewood and cabin logs are harvested year round in the park and preserve, but most frequently in the winter when snow and ice make transportation more efficient (DENA 2004, 2005). Collection of dead and down wood for personal use is allowed within the park and preserve and does not require a permit (DENA 2004). Firewood harvest of live standing timber is allowed on federal lands but requires a permit from the park superintendent; these permits are only issued if there is not an adequate supply of dead or down timber for qualified subsistence users (DENA 2004).

Cabins in Denali support subsistence activities such as furbearer trapping (DENA 2004). The cutting of cabin logs in the park and preserve must meet several criteria: logs must clearly be taken for subsistence use, an application for harvest must be made to park staff including a building plan, the applicant must own the land they intend to build on with the exception of federal public land such as Denali, and the cutting cannot significantly alter stand composition and age classes of white spruce (DENA 2004). There are also strict regulations in place regarding new cabin construction and repairs to old cabins in Denali that likely decrease the amount of logs harvested. A permit from the park superintendent is required for new cabins, and all new cabins must be designated "shared use," allowing other local subsistence users to utilize them as necessary (DENA 2004).

In 2009, a timber inventory was conducted in the Windy Creek area of the southern park addition, just northwest of Cantwell. Park managers plan to use these inventory results to develop a forest management program for subsistence use of timber products in this area. The inventory identified 360 acres of operable standing timber and determined that an annual allowable cut (AAC) of 2.7-3.6 acres/year, depending on rotation age, could be sustained (Sanders Forestry Consulting 2009). Further information on survey methods and more detailed results can be found in Sanders Forestry Consulting 2009.

Fishing Harvest

Fishing usually occurs during the summer and fall months (DENA 2004). Freshwater fish species that are harvested include burbot (*Lota lota*), Dolly Varden trout (*Salvelinus malma*), Arctic grayling (*Thymallus arcticus*), lake trout (*Salvelinus namaycush*), northern pike (*Esox lucius*), rainbow trout (*Oncorhynchus mykiss*), and whitefish (*Coregonus* and *Prosopium* sp.) (DENA 2004). All waterways within National Park and Preserve boundaries are under federal management jurisdiction.

Only 19% of Cantwell residents reported fishing for freshwater fish within the park and preserve boundaries (Table 9; DENA 2005). While Lake Minchumina residents rely heavily on fish, most harvest occurs outside the Denali boundary in Lake Minchumina. Some residents occasionally travel up tributaries into the northern preserve to fish. Nikolai residents fish primarily in areas west of Denali and generally do not travel as far as the park and preserve boundaries (Holen et al. 2006).

Table 9. Freshwater fish harvest by the Cantwell community in 1999 (DENA 2005).

Species	Kilograms harvested
Burbot	29.6
Dolly Varden trout	41.6
Arctic grayling	419.4
Lake trout	121.7
Rainbow trout	33.0
Whitefish	35.3

Trapping harvest

Trapping and bartering of furbearing animals for subsistence has a long history within Denali. Trapping occurs during the mid to late winter months when fur quality is at its peak and there is adequate snow cover for travel (DENA 2004). It is a particularly important subsistence activity in the northern regions of the park and preserve where there is a network of trails, shelters, and cabins that are accessed by dog teams or snowmobiles (DENA 2004). Species trapped for their fur include marten, mink, red fox, wolf, lynx, weasel, wolverine, river otter, beaver, and muskrat (DENA 2004). Hare and porcupine are also trapped by Cantwell residents for food (DENA 2005). In a 2002 survey of Lake Minchumina residents, 37% (10 people) reported participating in trapping activities (Holen et al. 2006), only one of three interviewed families reported having a trap line in Denali. Selected trapping harvest numbers for the entire Lake Minchumina community are shown in Table 10.

Table 10. Small and medium-sized mammals harvested by the Lake Minchumina subsistence community in 2002 (Holen et al. 2006).

Species	Number harvested
Marten	327
Beaver	25
Lynx	23
Mink	22
Weasel	17
Porcupine	15
Fox	10
Snowshoe Hare	10

Allocation of trapping areas varies among the different cultures and regions of the park and preserve. Some areas such as the northern region of Denali have strong formal and informal agreements and social norms regarding land distribution for subsistence trapping, whereas these traditions are less defined in the eastern and southern regions (DENA 2004). The subsistence trapping effort in Denali is greatly influenced by the price of various types of fur in the marketplace. When fur prices are low, many residents reduce their trapping effort (DENA 2004, Holen et al. 2006).

Hunting harvest
Subsistence hunting generally occurs during the fall and winter in Denali (DENA 2004). Mammals that are harvested include moose, caribou, Dall's sheep, and brown and black bears (DENA 2005, Holen et al. 2006). Birds harvested include ptarmigan, grouse, and various species of geese and ducks. Figure 9 shows the subsistence harvest cycle of various resources by season for Cantwell residents (DENA 2005).

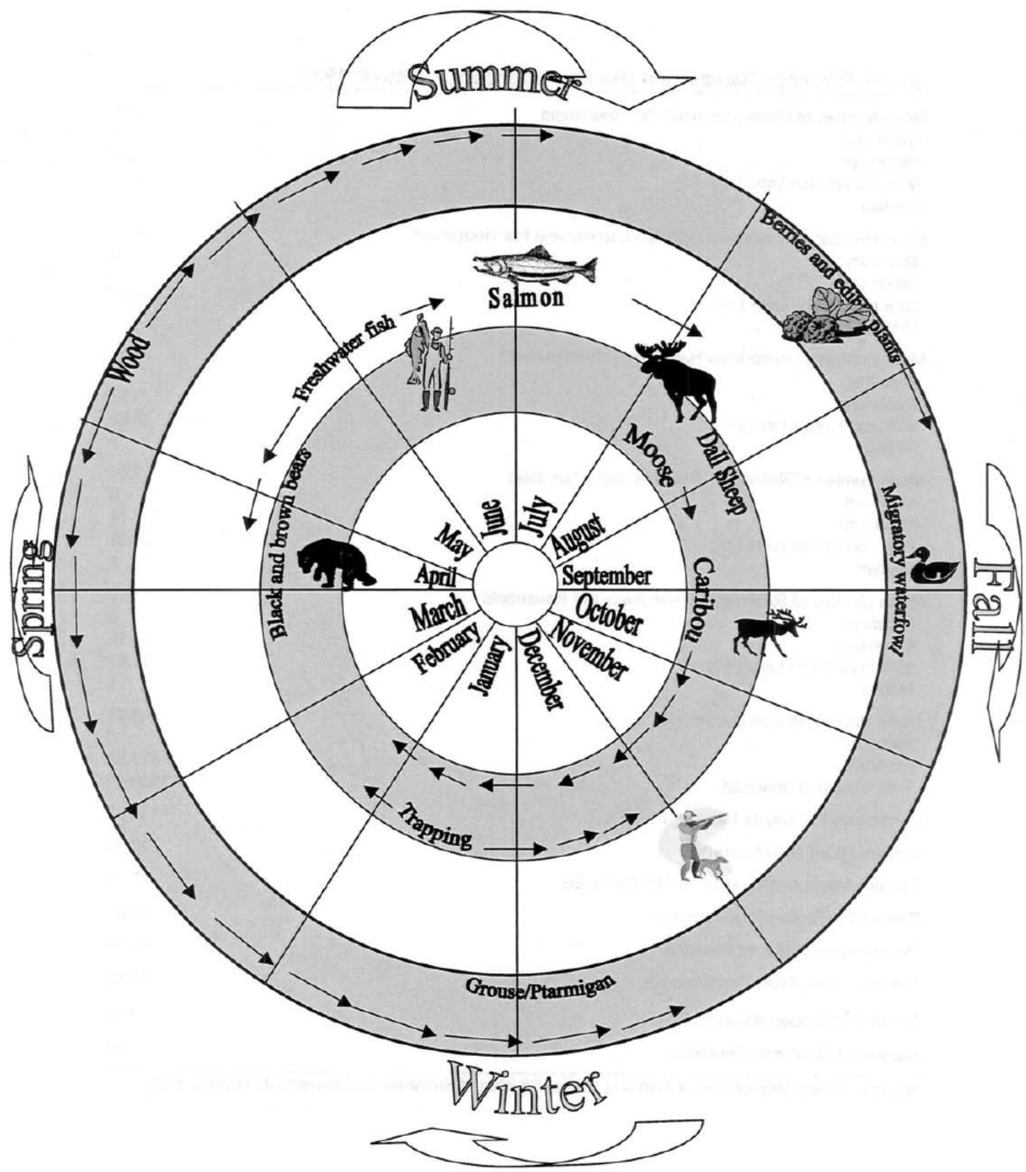

Figure 9. Seasonal resources harvested by Cantwell residents (from DENA 2005).

The Alaska Division of Subsistence conducted a study on fish and wildlife harvest levels for the community of Cantwell, Alaska (population 222 as of the 2000 census) between April 1999 and

March 2000 (DENA 2005). It is important to note that this study looks at the overall level of harvest for the community, including harvests in and outside Denali. Moose was the largest component of harvested resources (44.8%), followed by caribou, sockeye salmon, berries, king salmon, and hare (DENA 2005). The total harvest of wild resources for the study year was 12,519 kg for the entire community, or 133 kg per household and per capita harvest of 61 kg (DENA 2005). These numbers are similar to those reported in a 1983 survey which found 147 kg of wild resources per family, or 50 kg per capita, suggesting that subsistence harvest levels have changed little over the last 25 years (DENA 2005).

Over 60% of Cantwell residents surveyed in the study reported hunting moose within Denali National Park and Preserve, 50% reported hunting caribou, and 25% hunted bear within park and preserve boundaries (DENA 2005). The majority of this activity occurred near the community in GMU 13E which covers a portion of the park and preserve (Plate 9; DENA 2005). Other GMUs were utilized to a lesser degree for subsistence hunting, of which GMU 20C was the only other unit located in Denali (DENA 2005). Table 11 shows hunting harvest information for the Cantwell community during 1999-2000 while Plate 10 shows areas utilized by Cantwell subsistence hunters. Subsistence areas for other types of harvest and other communities are included in Appendix A.

Table 11. Selected wildlife harvest by Cantwell residents during 1999-2000 (Adapted from ADF&G community subsistence information system (CSIS) data).

Resource	Percent of households using resource	Percent of households harvesting	Reported harvest (animals)	Reported kg harvested	Average kg harvested per household	Per capita kg harvested
Moose	84.2	26.3	19.5	4416.6	59.7	27.5
Caribou	55.3	22.4	22.4	1320.6	17.8	18.1
Black Bear	11.8	5.3	3.9	102.5	1.4	0.6
Brown Bear	9.2	3.9	2.9	265.0	3.6	1.7

A 2005 report examined the use of off-road vehicles (ORVs) by Cantwell area residents for subsistence hunting activities in Denali. ORVs were not considered part of traditional subsistence use by the Park Service in their 1986 General Management Plan (GMP), but some Cantwell residents had been using ORVs prior to the passage of ANILCA in 1980 and requested a change to the policy in 1993 for park lands near the community after park staff began to enforce the ORV ban (DENA 2004). Residents traditionally utilized a variety of ORVs to move large mammals when hunting, and presented evidence of historical use of these vehicles. The Denali SRC agreed that Cantwell residents should be allowed reasonable access to park lands using ORVs at the same level as 1980 when the policy changes went into effect (DENA 2005).

The NPS was concerned about vegetative damage and soil loss caused by ORVs, as well as the effect on the park soundscape, visitor experience, and potential archaeological site damage (DENA 2005). NPS agreed to study the ORV issue for the Cantwell area in light of the evidence presented. The NPS revised their position to allow ORV use for subsistence harvest in areas where these vehicles had been traditionally employed, and that such determinations should be made on a community or area basis (DENA 2004). After interviewing Cantwell residents and examining the evidence they provided, NPS decided that ORV usage was a traditional means of access for subsistence harvest in this particular community (DENA 2005). At the present time, only certain stable or improved ORV trails may be used for subsistence harvest, in order to prevent further damage to wetlands, vegetation, and soils. Plate 11 shows a map of ORV trails open to the Cantwell subsistence community.

A study of subsistence harvest in the Lake Minchumina, Nikolai, and Telida communities was conducted in 2001-2002 (Holen et al. 2006). In the Lake Minchumina community, moose make up the second largest portion of subsistence harvest behind fish. Traditional moose hunting areas include portions of the northern Denali National Preserve. Caribou are scarce in the area and none were harvested in 2001-2002. The study found that Denali is generally too far for Nikolai residents to travel to hunt and fish, although Telida residents sometimes enter the northern Preserve area to hunt moose (Holen et al. 2006).

Hunting by subsistence users versus sport hunters is generally separated geographically in Denali. Sport hunters primarily utilize the remote southern preserve where trophy size animals are more likely to be found (DENA 2004). Subsistence users are more focused on the northern areas of the park and preserve and the Cantwell area where ground access is more convenient due to rivers, roads, and trails (DENA 2004). If sport hunting were to intensify in the northern regions of Denali, competition with subsistence users would greatly increase (DENA 2004). Cantwell residents said that urban sport hunters are increasingly hunting near their community and hurting wildlife populations, forcing local residents to begin hunting more exclusively inside Denali (DENA 2005).

An increasing number of recreational users in developed and backcountry areas of Denali have raised the potential for conflicts between consumptive and non-consumptive users (DENA 2004). There is also political pressure from special interest groups to close or restrict subsistence harvest activities in Denali (DENA 2004). To protect the public, a restriction is currently in place on the discharge of firearms in the Kantishna area, a common access point for subsistence users in the northern park addition. From September 1-15, no firearms can be discharged within one mile of the Kantishna Road. This essentially results in the closure of a 10 km^2 area during the first half of the moose hunting season (DENA 2004).

<u>Climate Change</u>

Climate is widely recognized as one of the most fundamental drivers of ecosystem condition and ecological change, particularly in Alaska (CAKN 2010a, Sousanes 2006). As a primary driver influencing many other ecosystem components (vegetation, wildlife, disturbance regime, etc.), climate also has numerous management consequences and implications (Redmond and Simeral 2006, Sousanes 2006). Denali's subarctic ecosystems are extremely sensitive to natural climate variability and to long-term natural or anthropogenic climate change (DENA 2007b). Extreme weather and climate phenomena often threaten the very survival of many subarctic plant and animal species.

Unusually mild winters throughout much of Alaska in recent years and a substantial increase in temperatures during the 1990s are interpreted by many as a sign of large scale global warming (Redmond and Simeral 2006). Winter temperatures in interior Alaska have increased approximately 4°C (7°F) over the past few decades, and average arctic temperatures have reportedly increased at a rate that is nearly twice the average for the rest of the world over the last century (DENA 2007b). National Park Service weather records dating back to 1925 indicate that annual average temperatures and precipitation amounts at Denali have increased over time (DENA 2007b). The number of snow-free days has also increased and the growing season has lengthened (DENA 2007b). Evidence and projections in the central Alaska region point to potentially significant long-term climate change, affecting temperature and types of precipitation. Warmer temperatures in recent years have contributed to reduced snowfall in spring, earlier snowmelt, thawing of permafrost and permanent snowfields, and shorter seasons of river and lake ice (DENA 2007b). Changes in climate are expected to have a significant impact on vegetation, lakes and streams, chemical cycling, microbial biology, and wildlife distribution (Redmond and Simeral 2006, CAKN 2010a). The frequency of extreme weather events, insect and disease outbreaks, and wildfires may also be influenced by climate change (DENA 2008, SNAP et al. 2009).

There is a scientific consensus that human activities, particularly those that produce greenhouse gasses, have contributed to a general warming trend in global climate (IPCC 2007). Current warming has accelerated natural processes that release greenhouse gases into the atmosphere, such as permafrost thawing and ebullition (methane bubbling) from northern lakes, further contributing to global warming (Anisimov 2007, Walter et al. 2007). The decline of sea ice in the Arctic Ocean as a result of warming could also affect climate patterns in central Alaska (CAKN 2008).

Over the next century Denali is expected to become warmer and drier. Temperatures are projected to increase at an average rate of about 1°F per decade (SNAP et al. 2009). This will likely result in a transition from average annual temperatures below freezing (~24°F) across the park and preserve, to temperatures near or above the freezing point (~32°F) (SNAP et al. 2009). Winter temperatures will change most dramatically, possibly increasing by 10°F over the historical average by 2080. Precipitation is predicted to increase, yet increased evapotranspiration due to warmer temperatures and a longer growing season will likely lead to an overall drier climate (SNAP et al. 2009).

2.3 Resource Stewardship

2.3.1 Management Directives and Planning Guidance

In addition to NPS staff recommendations, two current programs guided the selection of key natural resources for this report: the Central Alaska Network Inventory and Monitoring (I&M) Program, and Denali's Resource Stewardship Strategy. During the development of each program and associated planning documents, important resources in the park and preserve were identified.

Central Alaska Inventory and Monitoring Program

In an effort to improve park management through expanded use of scientific knowledge, the I&M Program was established to collect, organize, and provide natural resource data as well as information derived from data through analysis, synthesis, and modeling (NPS 2009). The primary I&M Program goals are:

- Inventory the natural resources under National Park Service stewardship to determine their nature and status;

- Monitor park ecosystems to better understand their dynamic nature and condition and to provide reference points for comparisons with other altered environment;

- Establish natural resource inventory and monitoring as a standard practice throughout the National Park System that transcends traditional program, activity, and funding boundaries;

- Integrate natural resource inventory and monitoring information into National Park Service planning, management, and decision making;

- Share National Park Service accomplishments and information with other natural resource organizations and form partnerships for attaining common goals and objectives (NPS 2009).

To facilitate this effort, 270 parks with significant natural resources were organized into 32 regional networks. Denali is part of the Central Alaska Network (CAKN), which also includes Wrangell-St. Elias National Park and Yukon-Charley Rivers National Preserve. Through a rigorous multi-year, interdisciplinary scoping process, each network selected a number of important physical, chemical, and/or biological elements and processes for long-term monitoring. These ecosystem elements and processes are referred to as 'vital signs', and their respective monitoring programs are intended to provide high-quality, long-term information on the status and trends of those resources. The CAKN identified 35 vital signs: 15 related to animal life, 11 to the physical environment, 5 to plant life, and 4 to human use (Table 12). Fourteen of these vital signs had preexisting monitoring or research programs, allowing CAKN monitoring to begin in 2006. Several additional monitoring programs have been implemented since 2006 and others are in the final stages of protocol development.

Table 12. Vital signs of the Central Alaska Network Inventory & Monitoring Program (CAKN 2010b). Vital signs in bold are being monitored by CAKN in one or more parks as of May 2011.

Animals	Arctic Ground Squirrel	**Bald Eagles**
	Brown Bears	**Caribou**
	Freshwater Fish	**Golden Eagles**
	Macroinvertebrates	**Moose**
	Passerines	**Peregrine Falcon**
	Ptarmigan	**Sheep**
	Small Mammals	**Snowshoe Hare**
	Wolves	
Physical Environment	**Air Quality**	**Climate**
	Fire	**Glaciers**
	Land Cover	**Permafrost**
	Rivers & Streams	**Shallow Lakes**
	Snow Pack	**Soundscape**
	Tectonics & Volcanoes	
Plants	Exotic Species	Insect Damage
	Plant Phenology	**Vegetation Structure/ Composition**
	Subarctic Steppe	
Humans	Human Population	Human Presence
	Trails	Natural Resource Consumption

Resource Stewardship Strategy

Each national park is directed to develop a Resource Stewardship Strategy (RSS) as part of the park management planning process. Indicators of resource condition, both natural and cultural, are selected by the park. After each indicator is chosen, a target value is determined and the current condition is compared to the desired condition. Management plans are then developed for the next 15 to 20 years in order to achieve or maintain the desired condition for each indicator.

Denali's RSS (DENA 2009a) was approved by the Alaska Regional Office in late 2009, making it just the second unit in the National Park system to complete such a document (DENA 2009b). The RSS team identified 119 indicators, 46 of which the current condition is known. Target conditions were set for 80 indicators, with the remaining indicators requiring further research before targets and/or current condition can be identified (DENA 2009b). The full Denali RSS can be viewed on-line at www.nps.gov/dena/naturescience/rss.htm.

The RSS was referenced extensively to help define indicators, measures, reference conditions, and threats and stressors for this NRCA. This is unusual since, within the park management planning cycle, most National Park Service units will complete an NRCA before working on an RSS. Given the size of Denali and the complexity of ecological components that make up the park and preserve ecosystems, having an RSS in place to focus the efforts of the NRCA process was extremely helpful. The RSS also highlighted some key data gaps for specific ecological components that could be addressed as part of the NRCA process. These additional projects are described in chapter three.

2.3.2 Status of Supporting Science

Available data and reports varied significantly depending on the ecological component being studied. The sources used to assess condition or inform reference condition for each indicator are described in the individual indicator summaries in chapter four. Due in part to its long history and appeal to researchers, there is a wealth of information for many of Denali's resources, although much of it is anecdotal. However, several wildlife species, such as wolves, caribou, and golden eagles, have been consistently monitored for 20 to 30 years, resulting in some of the most extensive datasets in the National Park system.

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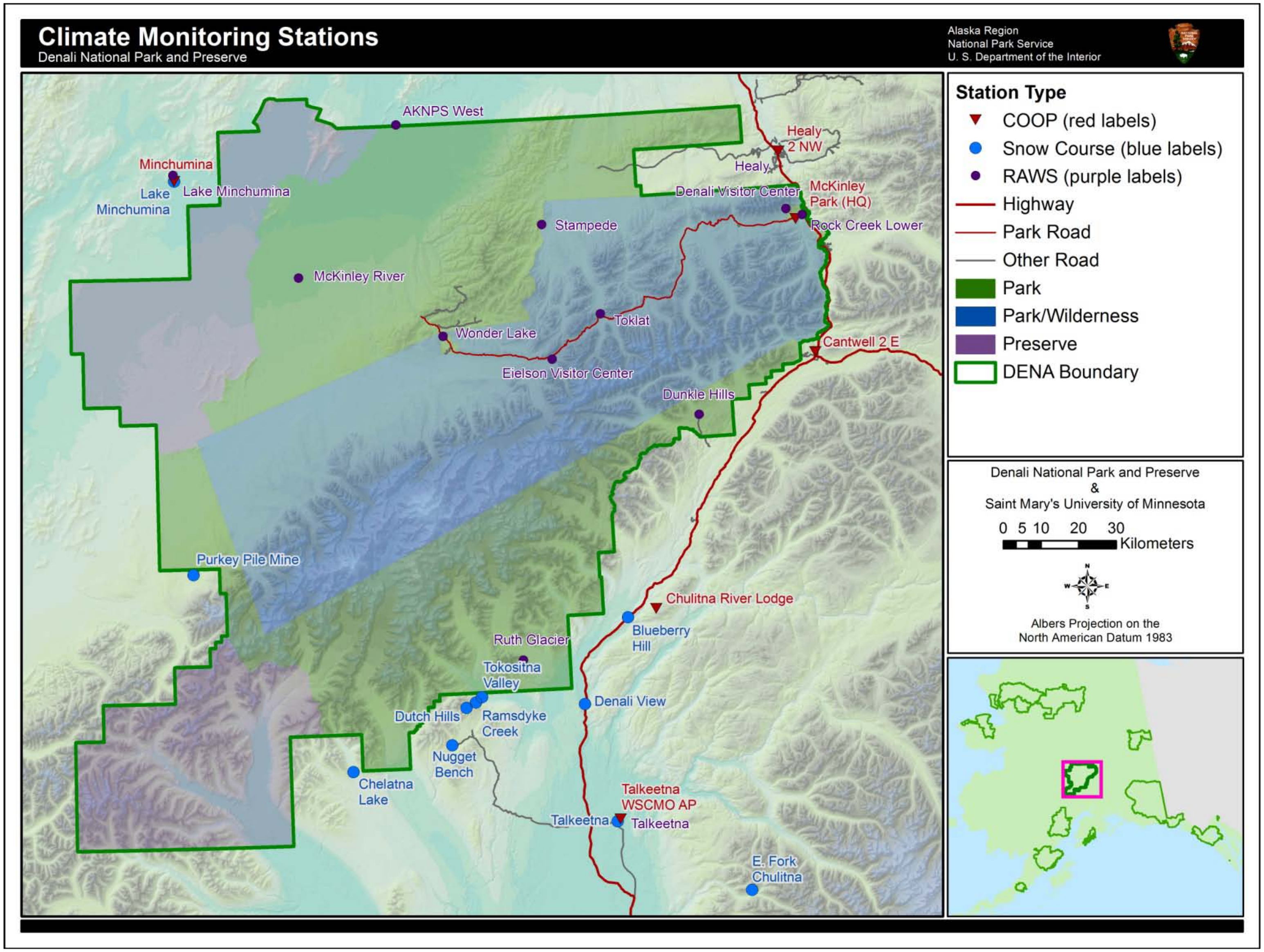


Plate 1. Climate monitoring locations in and near DENA (Keen 2008, NPS 2010b).

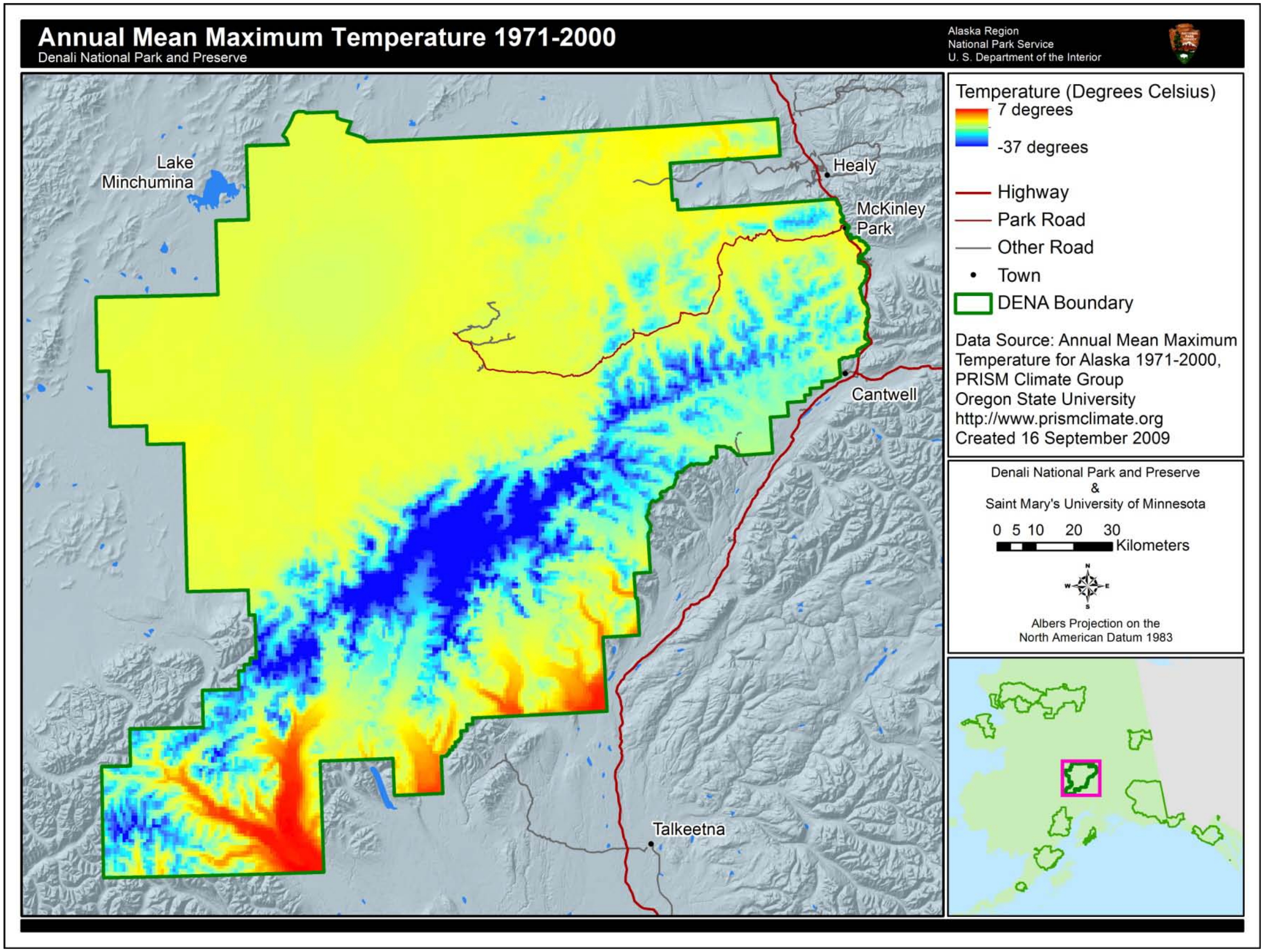


Plate 2. Annual mean maximum temperature, DENA, 1971-2000 (PRISM Climate Group 2009a, NPS 2010b).

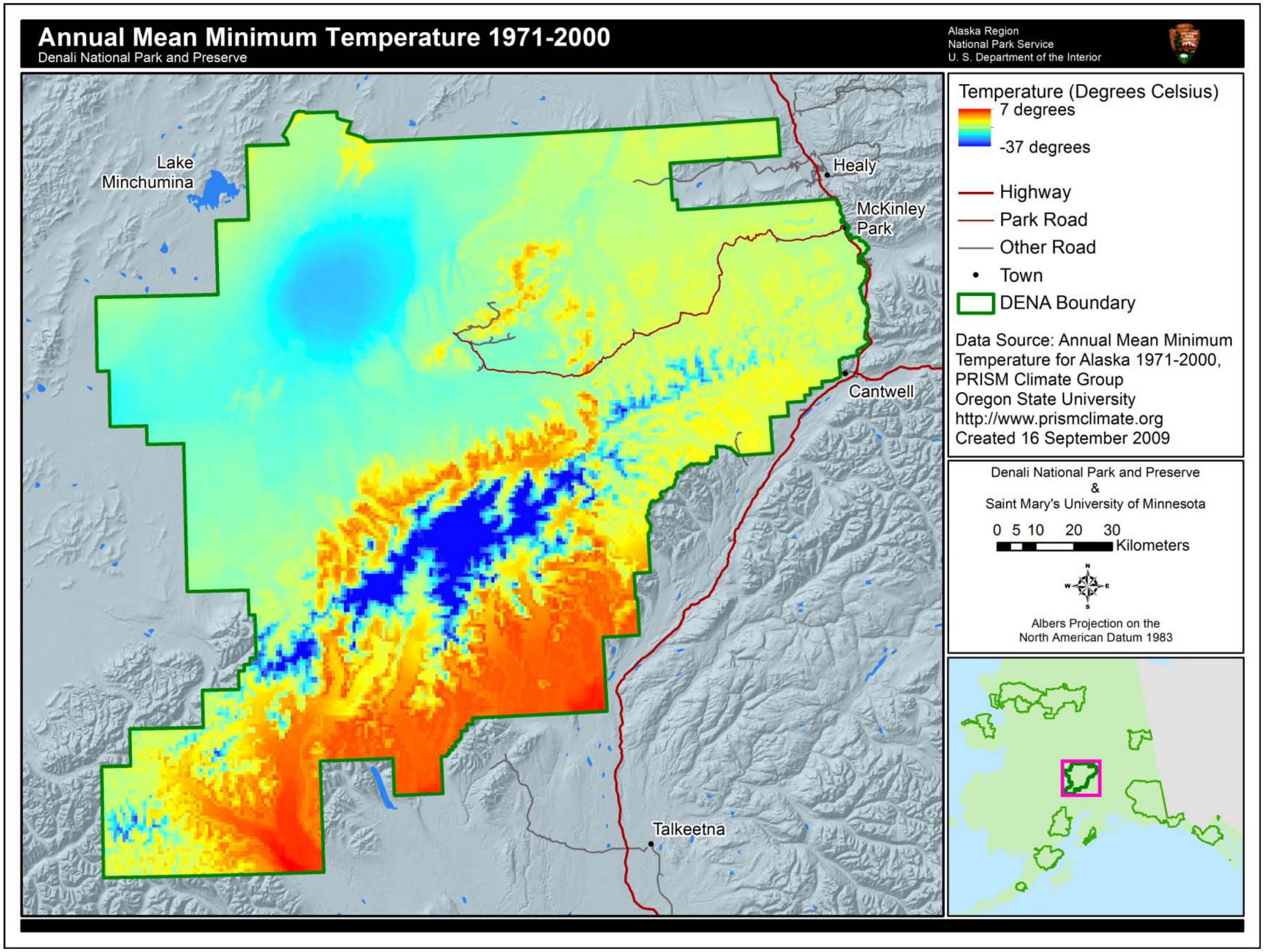


Plate 3. Annual mean minimum temperature, DENA, 1971-2000 (PRISM Climate Group 2009b, NPS 2010b).

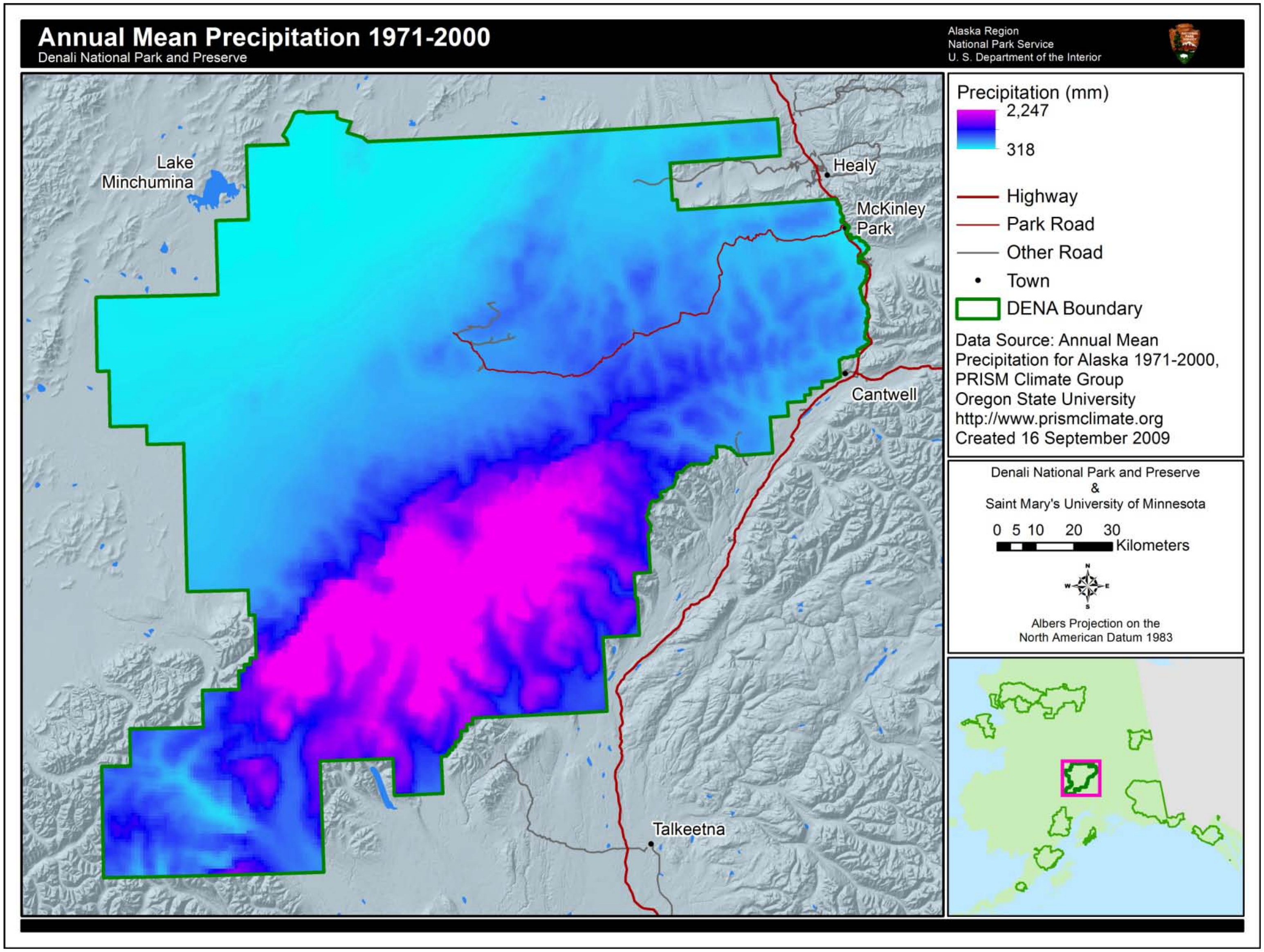


Plate 4. Annual mean precipitation, DENA, 1971-2000 (PRISM Climate Group 2009c, NPS 2010b).

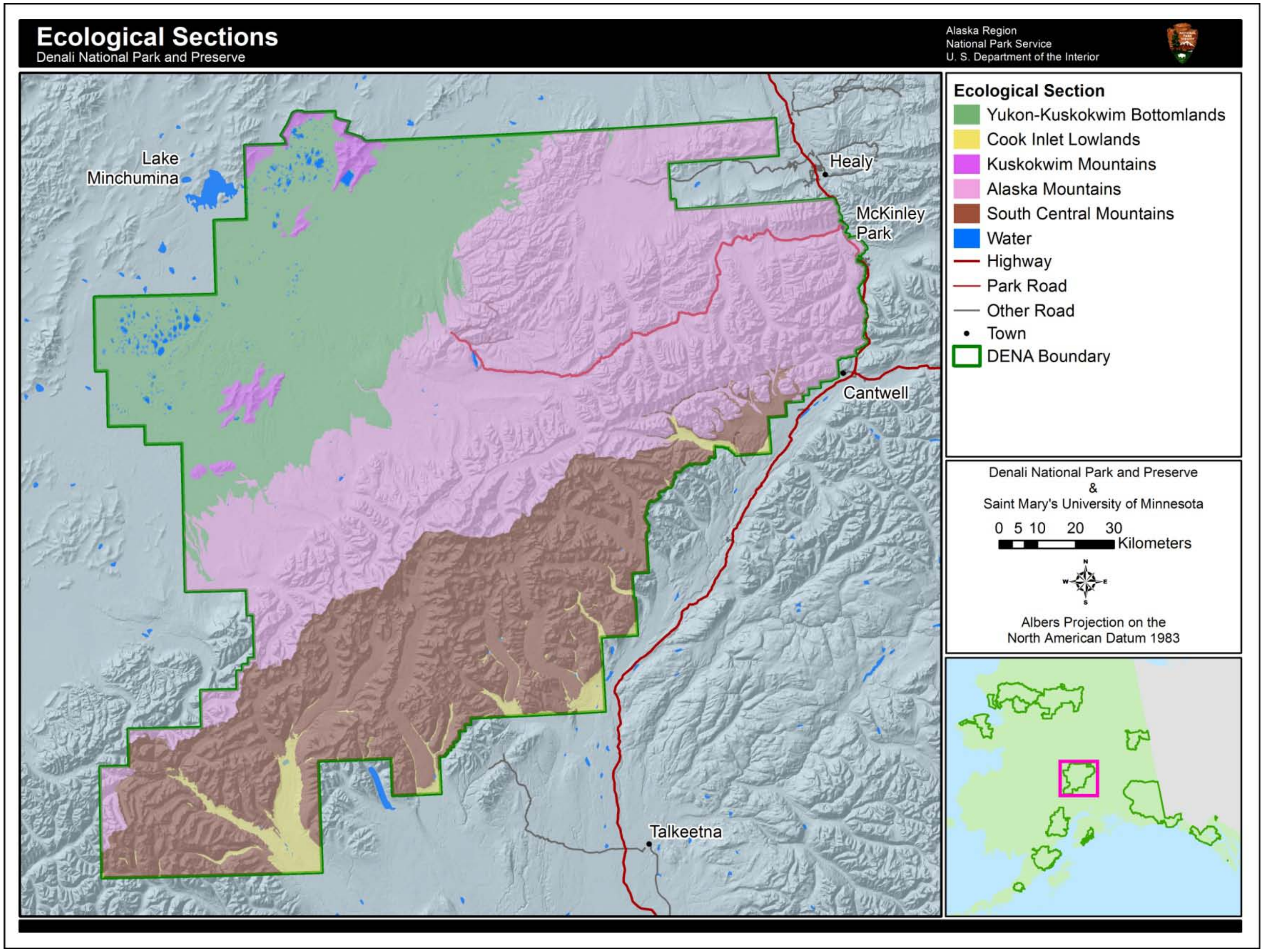


Plate 5. The five ecological sections within Denali National Park and Preserve (NPS 2010b).

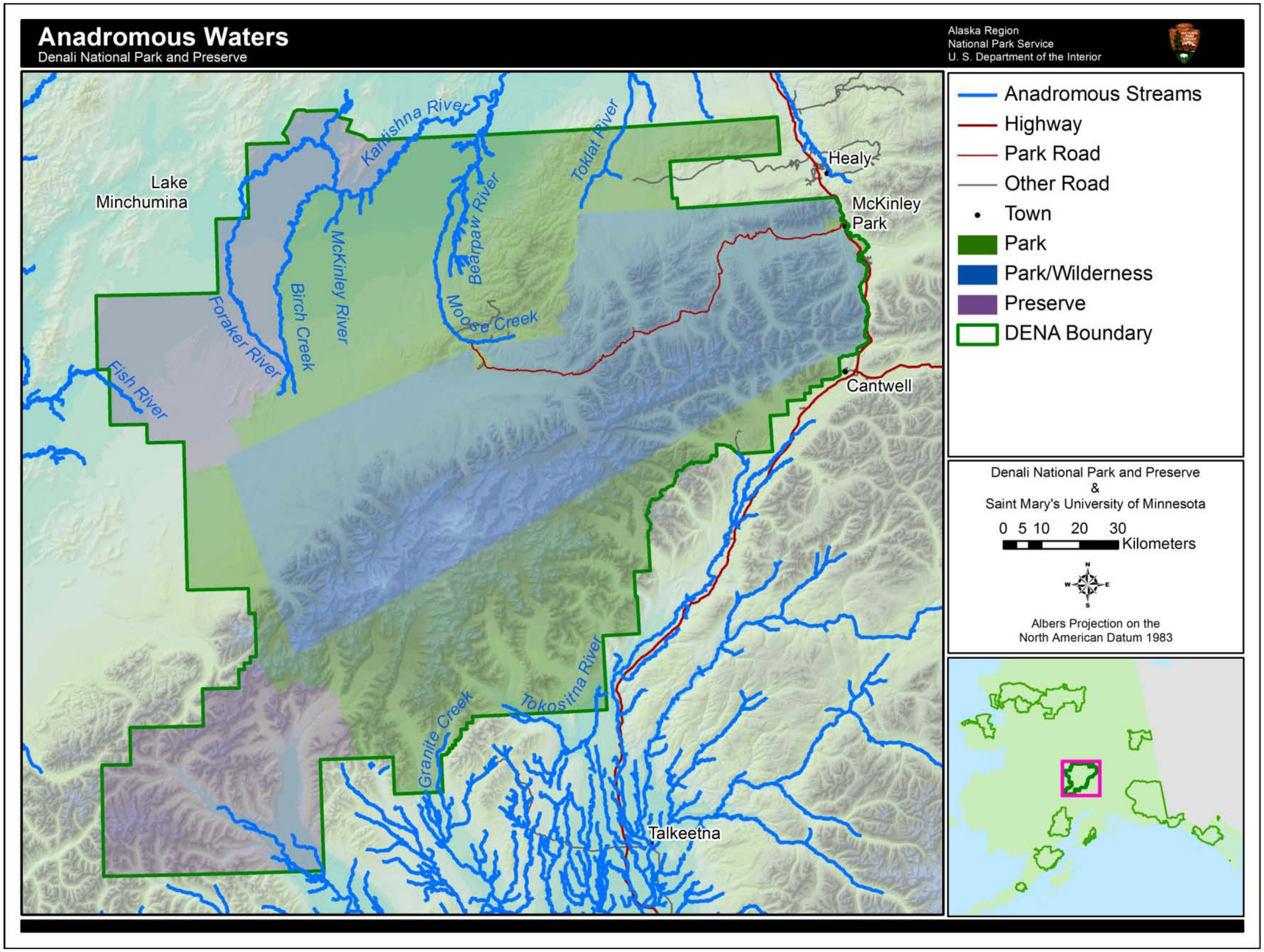


Plate 6. Streams within Denali where salmon have been observed by the ADF&G (2010a).

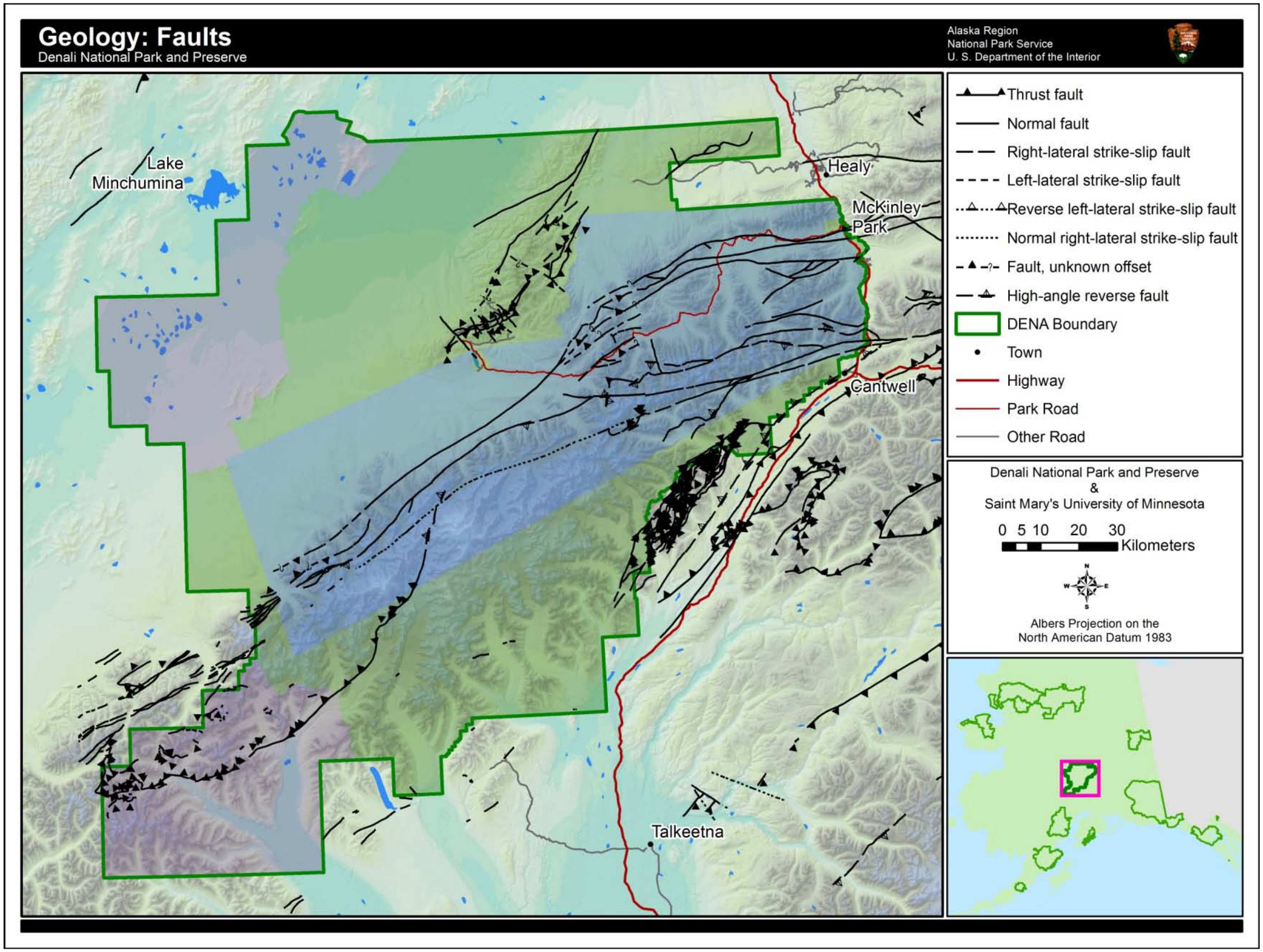


Plate 7. The Denali fault system runs generally northeast to southwest through Denali National Park and Preserve (NPS 2010b).

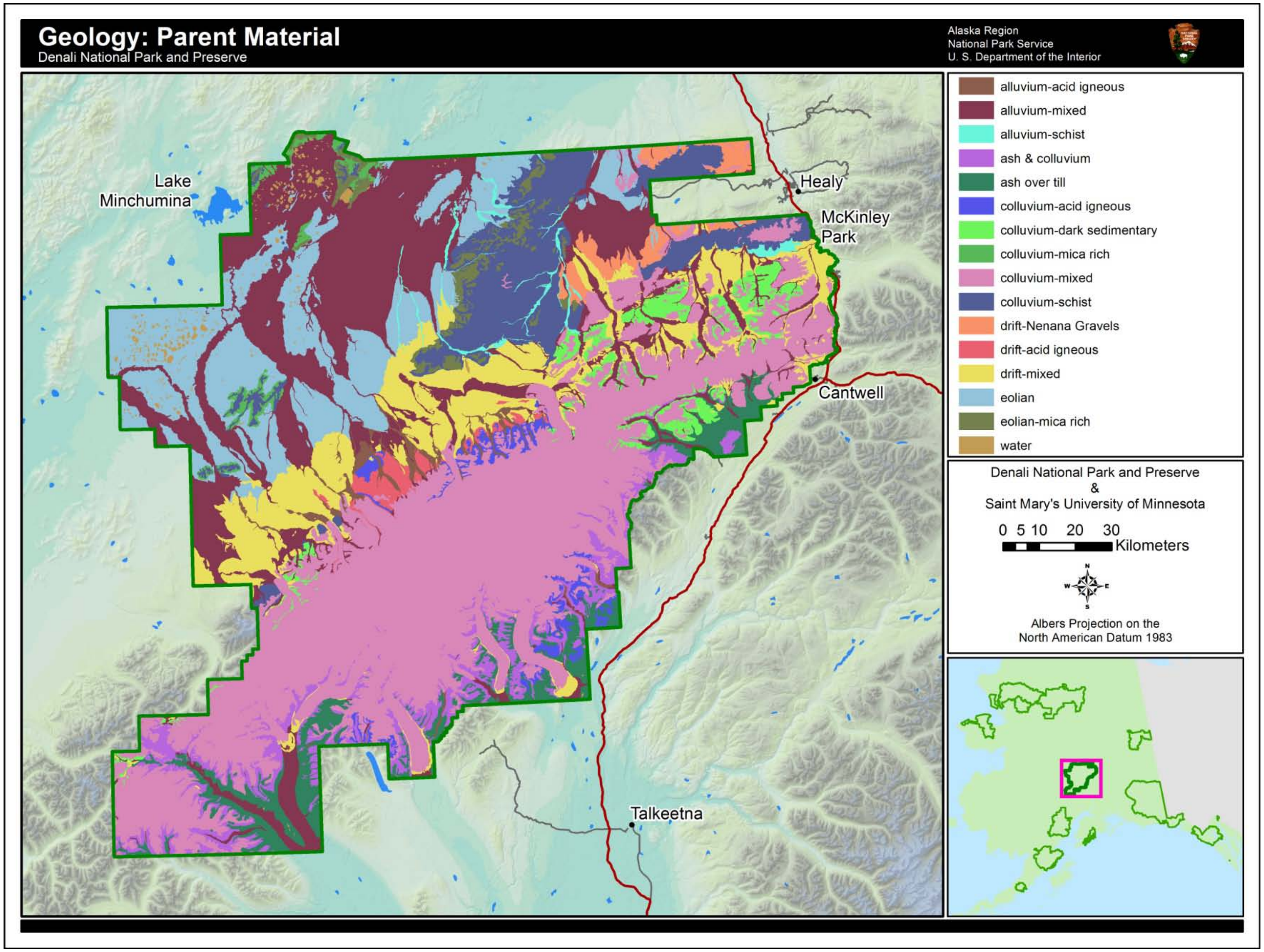


Plate 8. The parent material (geological source) for soils in Denali National Park and Preserve (NPS 2010b).

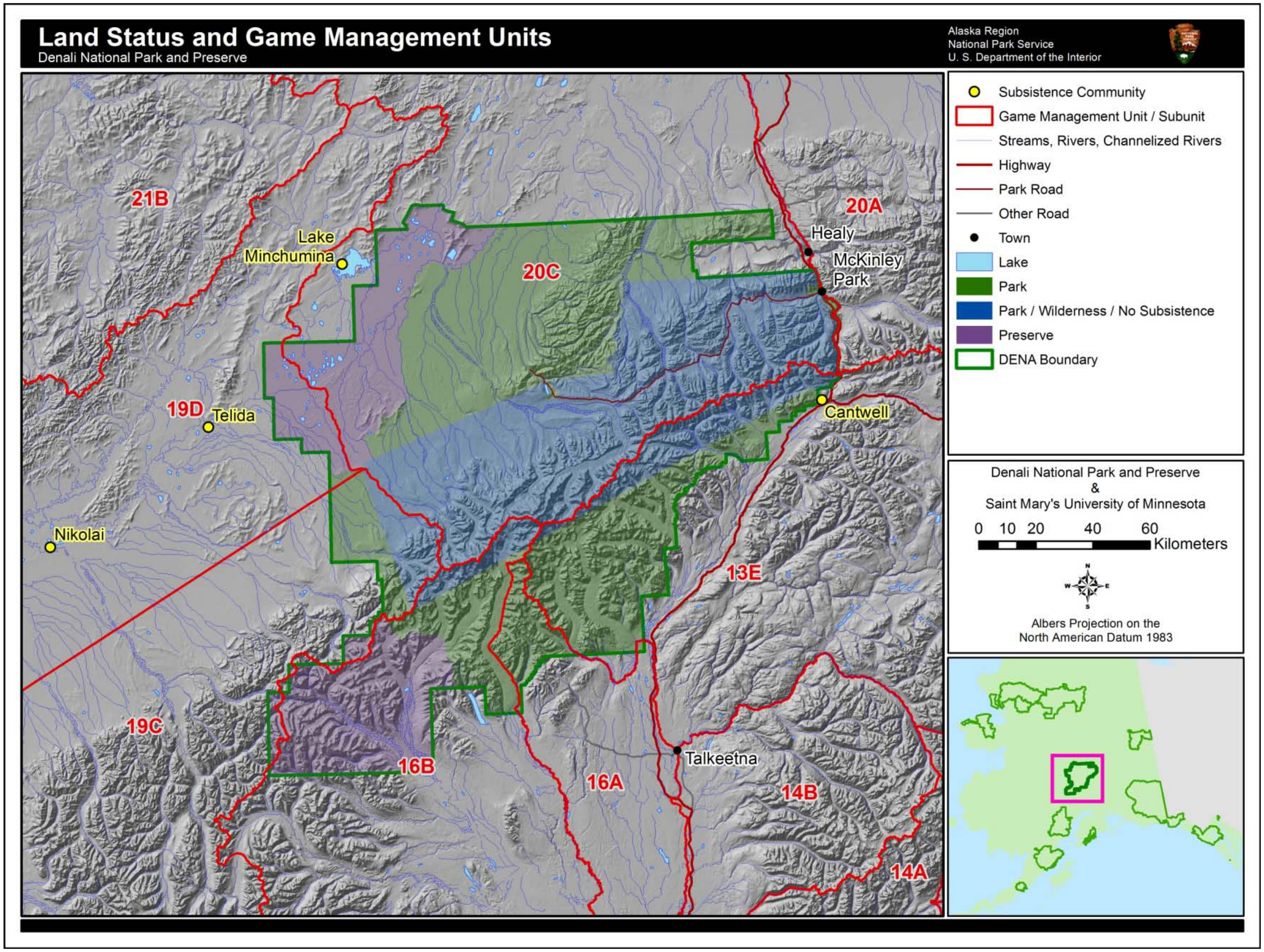


Plate 9. Land status and game management units within and around Denali National Park and Preserve (NPS 2010b).

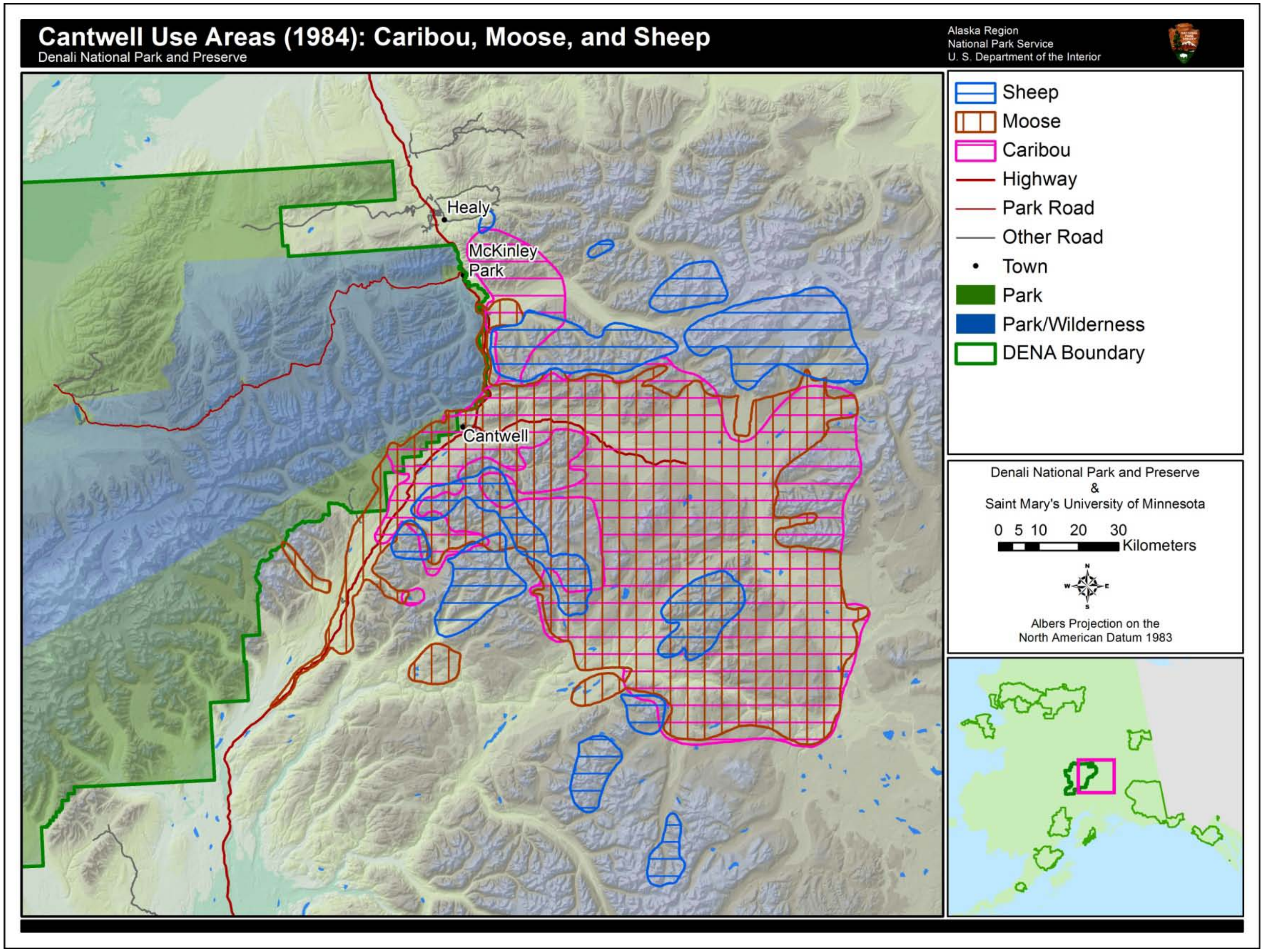


Plate 10. Cantwell subsistence harvest areas for caribou, moose, and sheep (NPS 2010b).

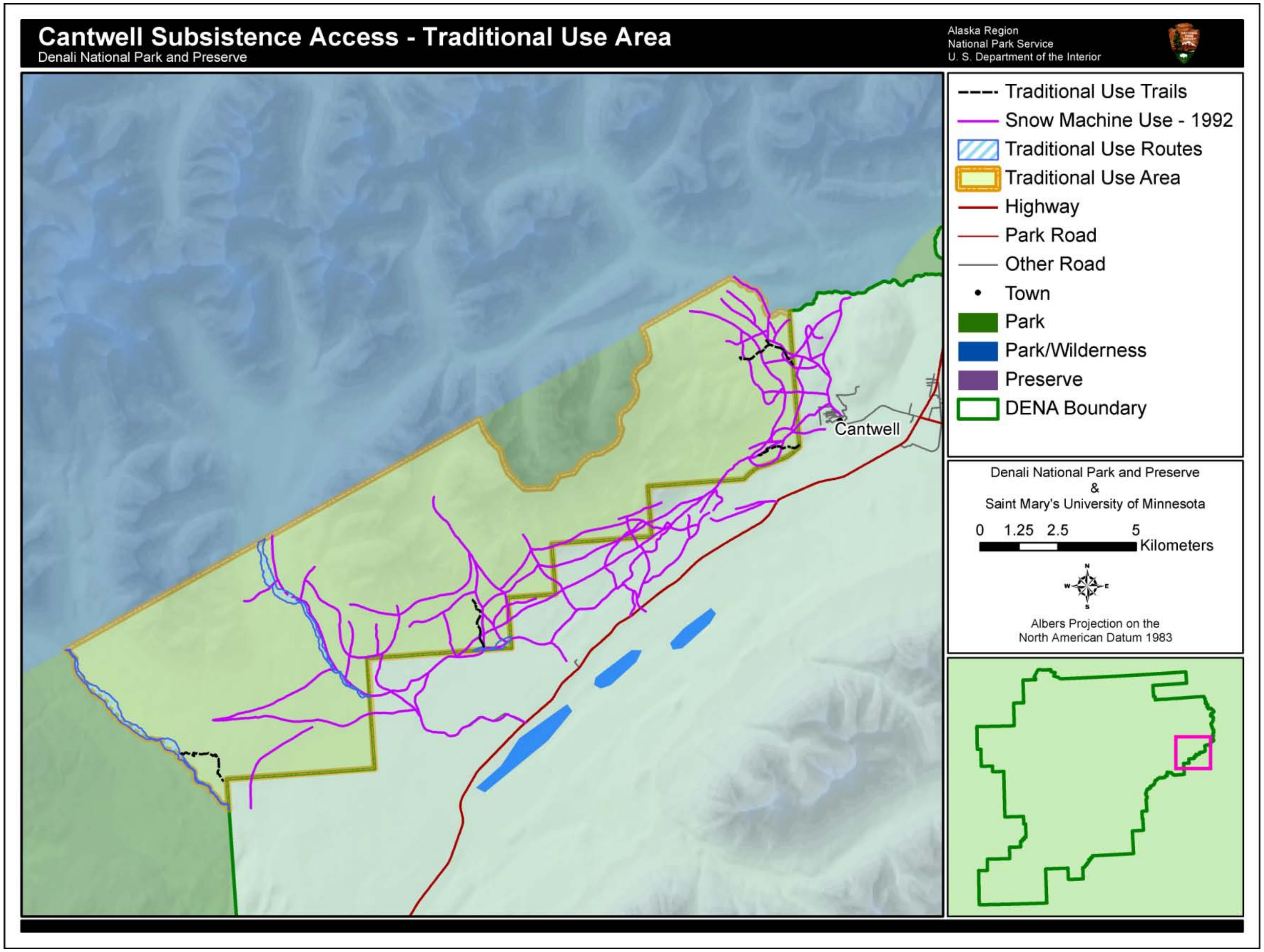


Plate 11. The Cantwell traditional use area (TUA) and access trails used for subsistence harvest (NPS 2010b).

Chapter 3 Study Scoping and Design

This NRCA is a collaborative project between the National Park Service (NPS) and Saint Mary's University of Minnesota Geospatial Services (SMUMN GSS). Stakeholders in this project include the Denali park resource management team and staff from the Alaska Regional Inventory and Monitoring Program including the Central Alaska Network (CAKN). Before embarking on the project, it was necessary to identify the specific roles of the National Park Service and SMUMN GSS. Preliminary scoping meetings were held, and a task agreement and a scope of work document were created cooperatively between the NPS and SMUMN GSS staff.

3.1 Preliminary scoping

Preliminary scoping discussions occurred on 27 and 28 August 2009, with official scoping meetings held from 26 through 30 October 2009. At these meetings, SMUMN GSS and NPS staff confirmed that the purpose of the Denali NRCA was to evaluate and report on current conditions, critical data and knowledge gaps, and selected existing and emerging resource condition issues of concern to Denali managers. Certain constraints were placed on this NRCA, including the following:

- Condition assessments are conducted using existing data and information.
- Identification of data needs and gaps is driven by the project framework categories.
- The analysis of natural resource conditions includes a strong geospatial component.
- Resource focus and priorities are primarily driven by Denali park resource management.

This condition assessment provides a "snapshot-in-time" evaluation of the condition of a select set of park natural resources that were identified and agreed upon by the project team. Project findings will aid Denali resource managers in the following objectives:

- Develop near-term management priorities (how to allocate limited staff and funding resources);
- Engage in watershed or landscape scale partnership and education efforts;
- Conduct park planning (e.g., Foundation Statement, Resource Stewardship Strategy); and
- Report program performance (e.g., Department of Interior Strategic Plan's "land health" goals, GPRA).

Specific project expectations and outcomes included the following:

- For key natural resource components, consolidate available park data, reports, and spatial information from appropriate sources, including Denali Resource Staff, the Park Permanent Data Set, NatureBib, NPSpecies, Inventory and Monitoring Vital Signs, and available/accessible third-party sources. The NRCA report will provide a component resource assessment and summary of pertinent data evaluated through this project.

- Define an appropriate description of reference condition for each of the key natural resource components and indicators to support statements of condition. These statements will describe the current state of a particular resource with respect to an agreed upon reference point.

- Resource assessment should clearly identify "management critical" data as articulated by NPS staff during project scoping. This will drive the data mining and gap definition process.

- Where applicable, develop GIS products that provide spatial representation of resource data, ecological processes, resource stressors, trends, or other valuable information that can be better interpreted visually.

- Conduct specific analysis on a limited range of datasets including: human influence on park natural resources; subsistence use; natural fire metrics and burn severity; wildlife habitat for specifically defined species; Kantishna Hills water quality; and soundscape impacts related to administrative aircraft overflights. Data collection and analysis for these indicators will be conducted in order to develop descriptive statistics about key natural resource components and will be carried forward to subsequent condition assessment projects.

- Discuss the issue of key natural resource indicators that are not contained within the park and preserve or controlled directly by park management activities (e.g. bear-human interactions, air quality). There are important stressors that impact key natural resource components in the park but are not under NPS jurisdiction.

- Describe the relationship between selected human uses and key natural resources at the reporting scales including but not necessarily limited to soundscape and subsistence activities.

- Utilize "gray literature" and reports from third party research to the extent practicable.

3.2 Study Design

3.2.1 Indicator Framework, Focal Study Resources and Indicators

The DENA Natural Resource Condition Assessment utilizes an assessment framework adapted from "*The State of the Nation's Ecosystems 2008: Measuring the Lands, Waters, and Living Resources of the United States",* by the H. John Heinz III Center for Science, Economics and the Environment. The use of this framework was endorsed by the National NRCA Program Manager as an appropriate vehicle for framing resource indicators, measures and resource condition. Each NRCA project represents a unique assessment of key natural resource components that are important to the specific park that is being assessed. As a result, the project framework is adapted by the NRCA project team to reflect the specifics of the individual project. The framework provides a systematic process for identifying important park resources on a continuum of spatial and ecological scales. These resources are assessed and described from the biotic or physical component to the landscape scale, and assessments may include management priorities and public perceptions.

Each natural resource is represented by an indicator(s) with explicit measures for that item. Measures are defined as those values or characterizations that evaluate and quantify the state of ecological health or integrity of an indicator. Stressors for each ecological attribute are identified as specifically as possible. A "stressor" is defined as any agent that imposes adverse changes to a component. These typically refer to anthropogenic factors that adversely affect natural ecosystems, but may also include natural processes or disturbances such as floods, fires, or predation (adapted from GLEI 2011). A "reference condition" is defined as a benchmark from which to compare current conditions as a way to understand any increase or decrease in condition that may have taken place over time. Reference conditions are defined based on discussions within the NRCA project team, agreement with park staff, and to best represent the intent of the park's authorizing language.

The information available for each of these attributes is evaluated to determine its usefulness in describing resource condition. The absence of information specific to each indicator's defined measures will constitute a critical data gap. Data gaps define information critical to achieve stated management priorities. They will also be used by management to focus future research or data collection efforts. The Denali RSS (DENA 2009) proved very beneficial in forming the framework for this NRCA. It helped park staff and SMUMN GSS to quickly focus in on key ecological components to be assessed, as well as identifying many measures, stressors, and data gaps.

Reference conditions in this project were identified cooperatively by SMUMN GSS and NPS stakeholders and drew extensively from the Denali RSS (DENA 2009). Generally, this condition represents a historical reference in which human activity and disturbance were not major drivers of population and ecological processes. Attempts were made to utilize existing research and documentation to identify reference conditions; however, several of the indicators lack a quantifiable reference condition according to literature and data reviewed for this project. When a specific reference condition for the park was unknown, an attempt was made to include state and federal standards and thresholds or data from other relevant locations in order to provide some context for interpreting results.

During the scoping process, Denali staff identified several additional projects to be incorporated into the NRCA process. Data for these resources/issues were available but not fully analyzed by park staff or other researchers, and had, therefore, been identified as "knowledge gaps" in the Denali RSS (DENA 2009). Topics prioritized for more in-depth analysis were:

- Subsistence activity maps (Appendix A): These maps are a presentation of known subsistence activity in and around the park. They include trapping, hunting, fishing, firewood harvest, and plant collection for subsistence communities near Denali.

- Fire analysis: This project had two primary goals: generation of basic fire statistics for the park and preserve, and analysis of burn severity datasets by assessing these data against the NRCS soils-vegetation unit database. Basic fire statistics include: total acres burned, starts per year, acres re-burned, range of natural variability for acres burned, number of natural fires and human starts, fire duration, and severity. Data were stratified into pre-1982 and post-1982 because of changes in suppression activity. Results are incorporated into chapter four, section 4.11 of this document.

- Kantishna Hills water quality (Appendix B): This project was designed to review six of the known historic reports and maps regarding water quality in Kantishna. The purpose of this review was to: spatially locate water sampling locations; attribute the spatial location data with details describing each study; review the data sampling protocol for each study; establish whether data from each study is consistent and can be analyzed or assessed with data from other studies; and, if possible, develop some conclusions about water quality conditions in the Kantishna area through data analysis.

- Impacts of administrative flights on soundscapes (Appendix C): GPS track logs from administrative overflights in 2008 were used to develop a map of major activity corridors and flight elevations. The representative tracks were modeled using NMSim (a software package by Wyle Labs that is used to model soundscape and includes different types of aircraft) to assess the area on the ground exceeding 25 decibels by each flight. The project goal was to provide information about the area of impact for the administrative flight corridors and the implications for natural resource condition.

- Habitat Analysis (Appendix D): The purpose of this project was to overlay basic current population distribution data for a selected list of wildlife species over NRCS soils data to explore trends. The project summarizes habitat usage by individual species and soil-vegetation units.

- Human Influence (Appendix E): The purpose of this project was to develop a map showing areas of cumulative human influence within the park and preserve. It includes data layers such as airstrips, buildings, campgrounds, cabins, ORV trails and snow machine routes, climbing routes, railroads, roads, social trails, traditional use trails and areas, utilities, trap lines and cabins, exotic plant infestations, and subsistence harvest. The map represents the core feature and then an area of influence buffer around the feature. Usage is examined from the standpoint of both frequency and intensity.

An initial project framework was accepted following NPS review in December 2009. During follow-up meetings between SMUMN GSS and NPS staff, some modifications to the organization of the framework were agreed upon to improve the report writing process. The final project framework contains 18 indicators (Table 13). This framework outlines the resources (indicators), measures, stressors, and the reference condition when available. It was approved by the Denali NRCA project team in January 2011.

Table 13. Final Denali NRCA framework.

Denali National Park and Preserve

Natural Resource Condition Assessment Framework

Indicators	Measure	Stressors	Reference Condition
Extent and Pattern			
Landscape Structure			
Landcover / Soils / Expected Vegetation	Existence and usefulness of data	Mining; Recreation/residential/ commercial development; ORV use; Non-native invasive plants; Climate change	To be determined
Biological Components			
Species			
Denali Caribou Herd	Population size and distribution	Possible loss of habitat due to climate and vegetation change; Potential for increased harvest in certain areas; Disturbance in wintering areas; Inhibition of normal migration patterns	Herd size and demography remains within range observed from 1987-2007
Dall's Sheep	Population size and distribution		Herd size and demography remains within range observed from 1987-2007
Moose	Population size and distribution		Herd size and demography remains within range observed from 1987-2007
Trumpeter Swans	Population size and distribution	Habitat change in the park; Loss of wintering habitat; Loss of lakes and ponds; Lead poisoning on wintering grounds	To be determined
Breeding Birds (Passerine Birds)	Diversity, distribution, frequency of occurrence		To be determined
Wolves	Population size and distribution	Wolf-human interaction; Predator control activities near the park; Excessive harvest; Lack of public sympathy	Population size and demography remains within the range observed 1987-2007
Grizzly Bears	Population size and distribution	Bear-human interaction; Predator control activities near the park; Excessive harvest; Lack of public sympathy	Distribution and demography remains within the range observed 1991-2007
Golden Eagles	Population size, distribution, and reproductive success of nesting populations in northeastern region of Denali	Repeated low-level over-flights during critical nesting period; Loss of wintering habitat and habitat used by non-breeding birds; Possibility of lead poisoning during migration and on wintering areas	Population size, distribution, and breeding success remain within the observed range of natural variability (1987-2007)

Table 13. Final Denali NRCA framework (continued).

Denali National Park and Preserve
Natural Resource Condition Assessment Framework

Indicators	Measure	Stressors	Reference Condition
Biological Components (continued)			
Communities			
Native Plant Community	Plant species composition as measured in vegetation monitoring program; Number of native plant species lost; Presence of exotic plant species; Species expected vs. found	Contamination; Climate change; Manipulated populations	Plant community composition - does not show human-caused changes; # native plant species lost - none; Exotic plant species - no introduction of exotic plant species; Plant community distribution - no significant anthropogenic change
Ecological Processes			
Fire	Number of acres burned per year; Number of natural fire starts per year; Total duration (days) of fire incidents annually from 1st start date to final declared out date; Fire season duration (days) and timing (dates); Percentage of burns by severity class annually	Climate change; Habitat fragmentation; Fire size/occurrence outside historic range of variability	# acres burned per year, # natural fire starts per year, and total duration - remain within range of natural variability (1952-current); Fire season duration and timing - remain within range of natural variability (1993-Current) - to be determined; % of burns by severity class annually - remain within range of natural variability (1983-Current) - to be determined
Aquatic Habitat			
Lake Ecosystem Function	Total acres of lake surface area of lakes over 1 acre; Number of lakes over 1 acre of surface; Selected standard measurements of limnological ecosystem function (i.e. primary productivity)	Exotic aquatics; Lakes drying	Lake surface area - total acres is within range of natural variation; # lakes - no change from range of natural variation; Measurements of limnological ecosystem function - to be determined

Table 13. Final Denali NRCA framework (continued).

Denali National Park and Preserve

Natural Resource Condition Assessment Framework

Indicators	Measure	Stressors	Reference Condition
Chemical and Physical Characteristics			
Chemical Parameters			
Air Quality	Concentration of ground-level ozone; Atmospheric deposition of sulfur in precipitation; Atmospheric deposition of nitrogen in precipitation; Visibility; Lichen community structure	Coal-fired and other types of power generators; Intercontinental contaminant transport; Increasing size and frequency of wildland fires in North America and Asia; Increasing global population and industrialization; Local development (shallow gas, etc.)	Air quality parameters - remain stable or improve, as measured for NPS Performance Management Data System (PMDS) Goal Ia3; Lichen community structure - to be determined
Ecosystem Contaminants	Presence of contaminants in air, snow, lake sediment, vegetation, and fish (from WACAP report)	Intercontinental transport of toxic airborne contaminants; Global fractionation; Increasing global development; Increasing global human population; Local development (shallow gas, etc.)	To be determined
Physical Parameters			
Glaciers	Total glacier-covered area; Extent and volume of selected glaciers	Climate change; Insolation	Change is driven by non-anthropogenic processes
Permafrost	Existence and usefulness of data	Climate change (especially temperature and snow cover); Wildfires	To be determined
Paleontological	Percentage of sites effectively protected by management plan; Percentage of documented paleontological sites that have a good evaluation; Paleontological inventory	NPS development and other management actions; Visitor impacts (access to and advertisement of site, fossil hunters); Erosion and other natural processes (acid rain, run-off, etc)	% Sites protected - 100%; % Sites of good quality - to be determined; Inventory - complete
Soundscape	Maximum % of motorized noise heard per hour; Maximum number of motorized noises per day that exceed natural ambient sound level; Maximum motorized sound level (dBA); Natural ambient sound level	Motorized noise from planes, snowmachines; Noise from cars, trains, and buses on borders of wilderness area and from park road	Varies by sub-zone (see Backcountry Management Plan (NPS 2006a))

3.2.2 Reporting Areas

NPS staff initially planned to use existing legislative and management boundaries as reporting areas for the Denali NRCA. These areas included front country, back country, park, preserve, south park area, north park area, and wilderness. However, NPS and SMUMN GSS staff realized that the majority of resources were present in multiple zones and often crossed reporting area boundaries. This caused significant overlap and complications in determining condition of ecological indicators. As a result, reporting areas were not used in this assessment.

3.2.3 General Approach and Methods

This study involved reviewing existing literature and data for each of the indicators in the framework, and, where appropriate, analyzing the data in order to provide summaries or to create new spatial representations. After gathering data regarding current condition of indicator measures, a qualitative statement was developed comparing the current conditions to the reference condition when possible.

Data Mining

Data mining began during the first scoping meeting. At that time, Denali staff provided SMUMN GSS with data and literature in multiple forms: NPS reports and monitoring plans, other reports from various state and federal agencies, published and unpublished research documents, nongovernmental organization reports, databases, and tabular data. Spatial data were provided in the form of the Alaska NPS Permanent Data Set and other data were provided directly from Denali NPS staff. Access was also granted to various NPS online data and literature sources, such as NatureBib and NPSpecies. Supplemental data were also acquired by SMUMN GSS through online literature searches and various state and federal government websites. Data and literature acquired throughout the data mining process were inventoried and analyzed for thoroughness, relevancy, and quality pertaining to the indicators identified in the project framework. The project team realized there may be information outside the reach of the investigative time frame and the reasonable scope of consideration for this project; however, all reasonably accessible and relevant data were used to conduct this assessment.

Data Analyses and Development

Data development and analysis was highly specific to each component in the framework and depended largely on the amount of information and data available on the topic plus recommendations from Denali staff. Specific approaches to data development and analysis can be found within each component assessment located in chapter four of this report.

Geographic information systems (GIS) technology was utilized to graphically depict the status and distribution of selected resources. GIS facilitates the spatial display of species extents, physical characteristics, priority resources, and other resource perspectives that are unavailable from more traditional sources. GIS products incorporated in this report will also be integrated into the park permanent dataset to facilitate future access.

Preparation and Review of Component Rough Draft Assessments (Phase I Documents)

Upon the completion of data mining and initial analysis, a “rough draft” (Phase I document) was developed for each specific indicator. These documents were sent to NPS staff for review to verify that all relevant literature and data were being utilized and for recommendations regarding the direction of data analysis and condition assessment.

Mid-project Review

Meetings were held in October 2010 so that SMUMN GSS staff could present interim findings to NPS staff, answer their questions, and gather their feedback. These meetings included discussion of Phase I documents so that NPS feedback could be incorporated into final drafts. Minor modifications were also made to the framework and project schedule, while additional projects were refined following the presentation and review of initial findings.

Development and Review of Final Component Assessments (Phase II Documents)

Final indicator assessments (Phase II documents) were developed by incorporation of comments provided by Denali staff during the review of Phase I documents and during mid-project meetings. Contact with staff was maintained throughout this process to address questions and comments pertaining to each indicator and to ensure accurate representation of staff knowledge. Once Phase II documents were completed, they were sent back to expert reviewers for a second thorough review and to provide an opportunity to add more insights. Any comments or feedback received during this second review were incorporated into the assessment document. As a result of this process, and based on the recommendations and insights provided by Denali resource staff and other experts, the final indicator assessments are considered to represent the most relevant and current data available and the sentiments of park resource staff and resource experts.

Indicator Assessment Format

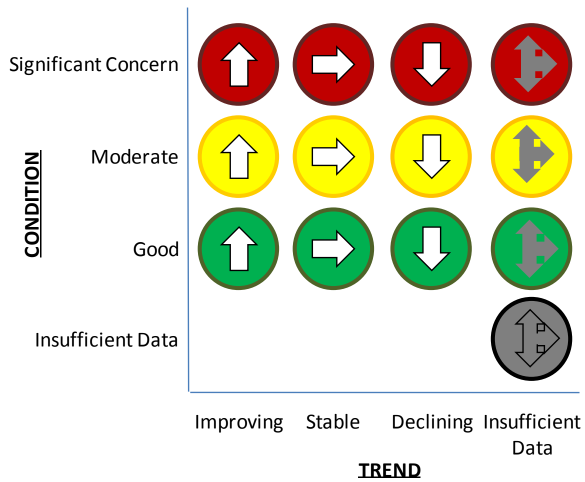
Indicator assessments are presented in a standard format and their structure, by major heading, is as follows:

Condition Graphic

The condition graphic provides a visual representation of the condition of the indicator within the park and preserve. This graphic, intended to give readers a quick representation of the authors' assessment of condition, does not replace the written statement of condition, which provides a more in-depth description of an indicator’s condition in Denali.

Figure 10 shows the designation graphics used to describe the condition of each indicator. Circle colors provide indication of condition or concern. Red circles signify that a resource’s condition is of significant concern to park management. Yellow circles signify that a resource’s condition is of moderate concern to park management, and green circles denote that an indicator is currently in good condition and of low concern. Gray circles signify that there is insufficient data to make a statement about concern or condition of the indicator.

Arrows inside of the circles signify the trend of the condition or concern of a particular indicator. Upward pointing arrows signify that the indicator is improving in recent history. Right pointing arrows signify that the indicator's condition is currently stable. Downward pointing arrows specify that the indicator's condition has worsened in recent history. Triple arrows specify that the trend of the indicator's condition is currently unknown. Figure 10 shows an example of the final condition graphic used in the indicator assessments.



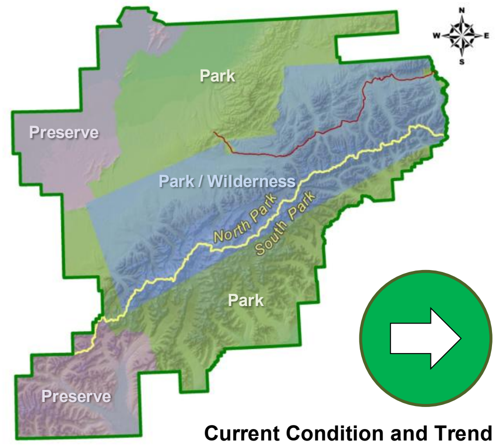


Figure 10. Symbols used for individual indicator assessments (left) with condition or concern designations along the vertical axis and trend designations along the horizontal. Example of the final condition graphic used in the indicator assessments (right).

Description

This section provides information regarding the relevance of the resource in Denali and, where applicable, informs the reader of the distribution of that resource in the park and preserve. This section explains characteristics of the indicator that help the reader understand subsequent sections of the document. Common topics covered in this section include management history, relationships to other indicators, and life history (for biota).

Measures

The measures used to define the condition of the indicator, as outlined in the framework, are listed in this section.

Reference Conditions/Values

This section explains the reference condition for each indicator, as defined in the framework. Additionally, explanations of available data and literature that speak to the reference condition are located in this section.

Data and Methods

This section describes the existing datasets used for evaluating the indicator. Methods used for processing or evaluating the data are also discussed where applicable. If adjustment or processing of data involved an extensive or highly technical process, these descriptions are included in an appendix for the reader or in a GIS metadata file for future users of the data.

Current Condition and Trend

The condition section of the indicator assessment provides a summary of the condition of the indicator and any trends based on available literature, data, and expert opinions of park staff. This section highlights the key information used in defining the overall condition for each indicator. It also provides a summary of the stressors to an indicator and outlines data needs, which if addressed, would be beneficial in determining the condition of a given indicator in future assessments.

Level of Confidence
At the request of NPS staff, a statement regarding confidence in each condition assessment is included.

Sources of Expertise
Key resources used in each indicator assessment are identified in this section.

Literature Cited

Denali National Park and Preserve. 2009. Resource stewardship strategy 2008-2027. Denali National Park and Preserve, Denali Park, Alaska.

Great Lakes Environmental Indicators Project (GLEI). 2011. Glossary, Stressor. Online (http://glei.nrri.umn.edu/default/glossary.htm). Accessed 7 March 2011.

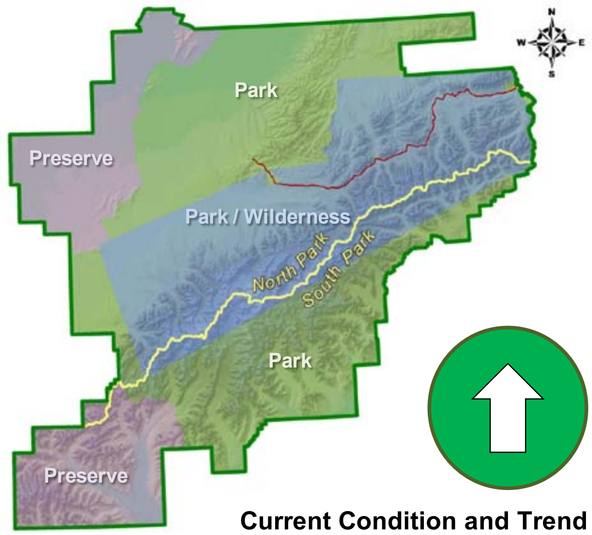
Chapter 4 Natural Resource Conditions

This chapter presents the background, analysis, and condition summaries for the 18 key resource indicators in the project framework and includes a brief discussion of water quality. The following sections discuss the key resources and their measures, stressors, and reference conditions. The summary for each indicator is arranged around the following sections:

1. Description
2. Measures
3. Reference Condition
4. Data and Methods
5. Current Condition and Trend (including threats and stressor factors, data needs/gaps, and overall condition)
6. Level of Confidence
7. Sources of Expertise
8. Literature Cited

The order of indicators follows the project framework (Table 13):

4.1 Landcover /Soils /Expected Vegetation*



Current Condition and Trend

* Landcover, soils, and expected vegetation are included in this NRCA in recognition of their ecological importance within Denali. At this time there is not enough data available for a full condition assessment of any of these components within the park and preserve. This assessment will focus instead on the existence and usefulness of related data.

Description

Soils and landcover vary greatly across Denali National Park and Preserve. The park and preserve straddles the mountains of the Alaska Range (Figure 11) which divides it into two major climatic zones on either side of the range (Clark and Duffy 2006). The northern side of the park and preserve has soils underlain by permafrost and modified by wildfires (Clark and Duffy 2006). In the southern portions of Denali, a more moderate climate influenced by the Gulf of Alaska makes permafrost much less widespread, which gives rise to a very different plant community than in the north.

Soils greatly influence many other landscape and ecosystem characteristics including vegetation patterns, hydrology, nutrient dynamics, habitat development, and landscape evolution (Martyn 2010). Soil structure, texture, and permeability can impact vegetational succession and nutrient cycling. Soils also influence the atmosphere by emitting or absorbing gasses such as carbon dioxide, methane, and water vapor (Martyn 2010). In Alaska, particularly in areas with permafrost, soils serve as an important carbon reservoir, sequestering this element from the atmosphere (Martyn 2010).

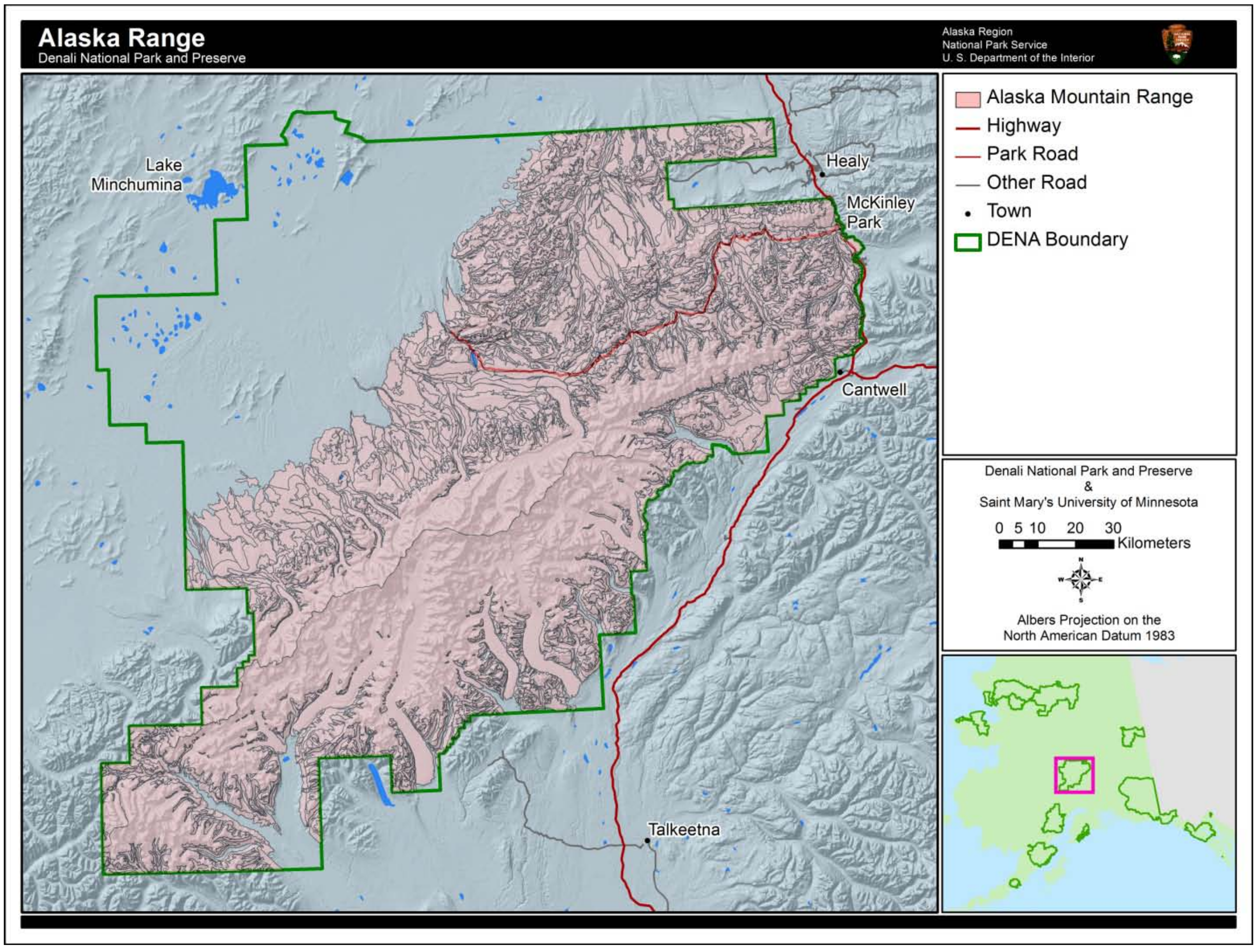


Figure 11. The Alaska Range within Denali National Park and Preserve (NPS 2010).

Measures

Existence and usefulness of data

Reference Conditions/Values

A soil survey and ecological site mapping were completed by the Natural Resources Conservation Service (NRCS) in 2004 to establish a baseline of knowledge regarding the soils and potential vegetative communities from which future changes can be detected (Clark and Duffy 2006). Aerial photographs from 1976 were used as a reference to compare landcover with repeat flyovers of the same areas in 2005 (Roland 2006).

Data and Methods

Landcover

The aerial photography study conducted by NPS staff looked at changes between 1976 and 2005, providing insight into the trends in landscape changes over the 30 year period. The three major vegetative changes noted in the paired aerial photography study were expansion of spruce into formerly treeless areas, invasion of open wetland areas by woody vegetation (Photo 6), and widespread colonization of formerly open floodplains and terraces by vegetation (Roland 2006). These changes are considered in many cases to be a directional shift, which means a change in the overall landscape mosaic as opposed to a simple successional shift in vegetation (Roland 2006). An ongoing vegetation monitoring program in Denali is collecting additional information on the plant communities in the park and preserve to detect these types of landscape level changes.

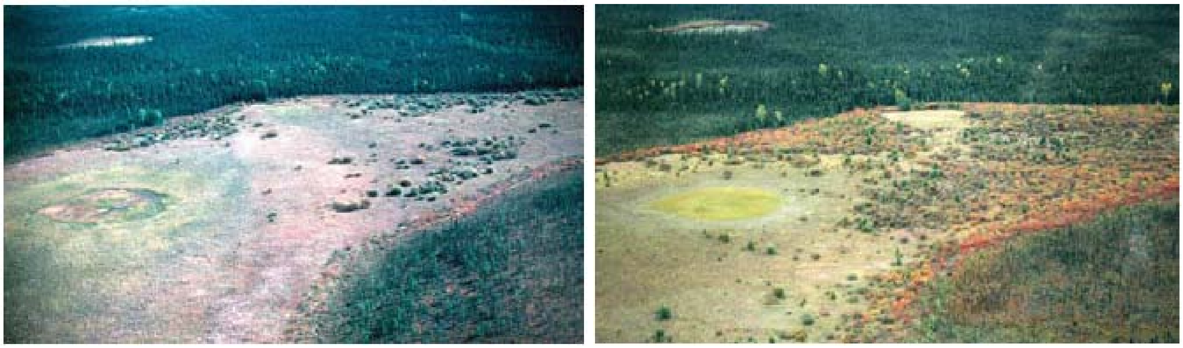


Photo 6. These aerial photos of a sedge meadow in the northern part of Denali National Park and Preserve from 1976 (left) and 2005 (right) show that the invasion of woody vegetation had begun in 1976 and was nearly complete by 2005 (from Roland 2006).

Soils/Expected Vegetation

The soil survey and ecological classification of Denali National Park and Preserve was conducted between 1997 and 2004 to describe and map the soils across the entire park and preserve (Clark and Duffy 2006). The survey involved digging soil pits and collecting additional data at 2,204 locations across the landscape over six field seasons from 1997 to 2002, with approximately 405,000 hectares surveyed each year (Clark and Duffy 2006). In addition to collecting data on soil types at the study sites, the survey recorded plant species at each location, photographed the landscape and plant communities, and gathered geomorphology data.

The National Ecological Unit Hierarchy (ECOMAP) method was used in this survey to classify the park and preserve into different regions. The ECOMAP hierarchy provides a system for classifying and mapping areas "based on associations of ecological factors at different geographic scales" (Clark and Duffy 2006). The hierarchy is divided into four scales, which are further broken down into eight units. The four scales and their associated units are: Ecoregion (Domain, Division, and Province), Subregion (Section and Subsection), Landscape (Landtype Association), and Land Unit (Landtype and Landtype phase) (ECOMAP 1993, Clark and Duffy 2006).

Before field work began, a draft ECOMAP Subsection map was developed specifically for Denali based on existing literature and data (Clark and Duffy 2006). Researchers used available data coupled with aerial photography of the park and preserve to draw polygons of similar landform, soils, and vegetation (DENA 2006). Study sites of representative areas were then selected from these polygons and examined in the field for soil and vegetation conditions. The main observations made during the survey included major soil types and associated landforms, site properties, and plant communities present (Clark and Duffy 2006). The extensive data gathered in the survey of Denali was used to create an updated ecological classification for the entire park and preserve.

The survey produced a complete soils map of Denali, datasets of soil properties and vegetation, and photographs that are spatially linked to the map, as well as the updated ecological classification of the park and preserve (DENA 2006). Multiple datasets were created which are housed in national and state soil databases, including the Soil Survey Geographic Database (SSURGO) which has GIS layers of soil map polygons and attributes, the NRCS National Soils Information System (NASIS) database, and the Alaska Soil Survey Field Database (SSFDD) which contains soil and vegetation data for all sample points in the survey with links to the SSURGO database (DENA 2006).

The databases created from the soil and ecological survey provide a baseline of knowledge for future monitoring of soils and the overall landscape of the park and preserve. Managers will be able to access this data for a wide range of ecological studies and spatial analysis (DENA 2006).

ECOMAP classification results

Ecoregional Scale – Domains, Divisions, and Provinces

Domains are the highest and most general level within the ECOMAP hierarchy. They are subcontinental divisions based on broad climatic similarity, such as lands with dry climates. Two domains are present in Denali: Polar and Humid Temperate (Figure 12). The line between these two Domains follows the crest of the Alaska Range with the Polar Domain to the north and the Humid Temperate Domain to the south (Clark and Duffy 2006).

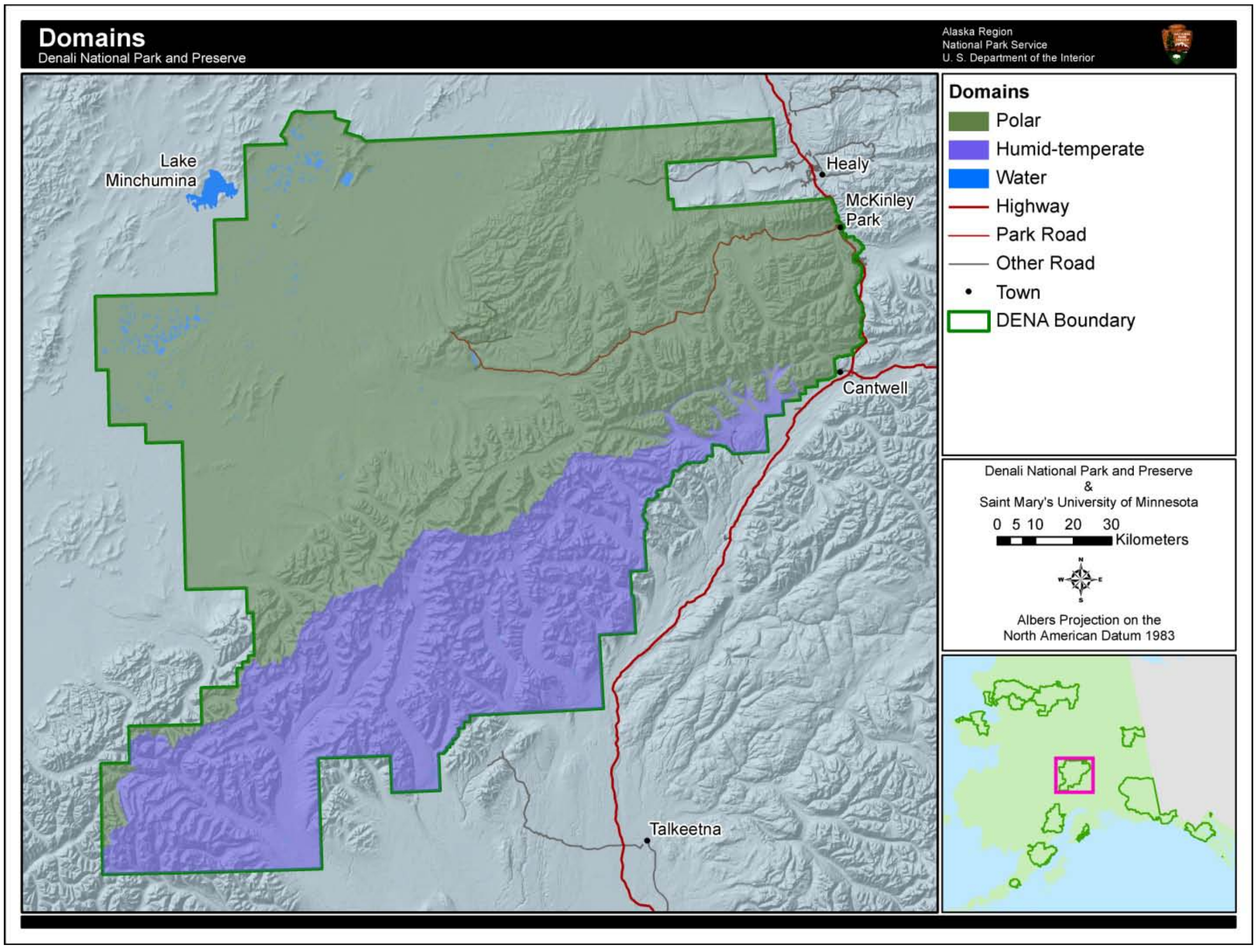


Figure 12. The two domains in Denali, which reflect the two climate divisions within the park and preserve (NPS 2010).

Domains are broken down further into Divisions, which are subdivided into Provinces. Divisions are determined by separating Domains into areas with similar vegetation (for example, forest or grassland). There are two divisions established for Denali, the Subarctic Division and Subarctic Regime Mountains (Clark and Duffy 2006). Provinces are subzones of Divisions that are defined by climate and weather patterns at the continental level, and are also described by common soil orders. Four Provinces are included in Denali: the Alaska Range Humid Tayga-Tundra-Meadow Province, Coastal Trough Humid-Tayga Province, Yukon Intermontane Plateaus-Tayga Province, and the Yukon Intermontane Plateaus-Tayga-Meadow Province *(*Clark and Duffy 2006).

Subregional Scale – Sections and Subsections
Sections are large areas of similar subregional climate, geomorphic process, stratigraphy, geologic origin, topography, and drainage networks. These areas are developed by comparing geologic maps to potential natural vegetation series groupings (Clark and Duffy 2006). There are five Sections within Denali: the Yukon-Kuskokwim Bottomlands, the Kuskokwim Mountains, the Cook Inlet Lowlands, the Alaska Mountains, and the South Central Mountains (Figure 13; Clark and Duffy 2006).

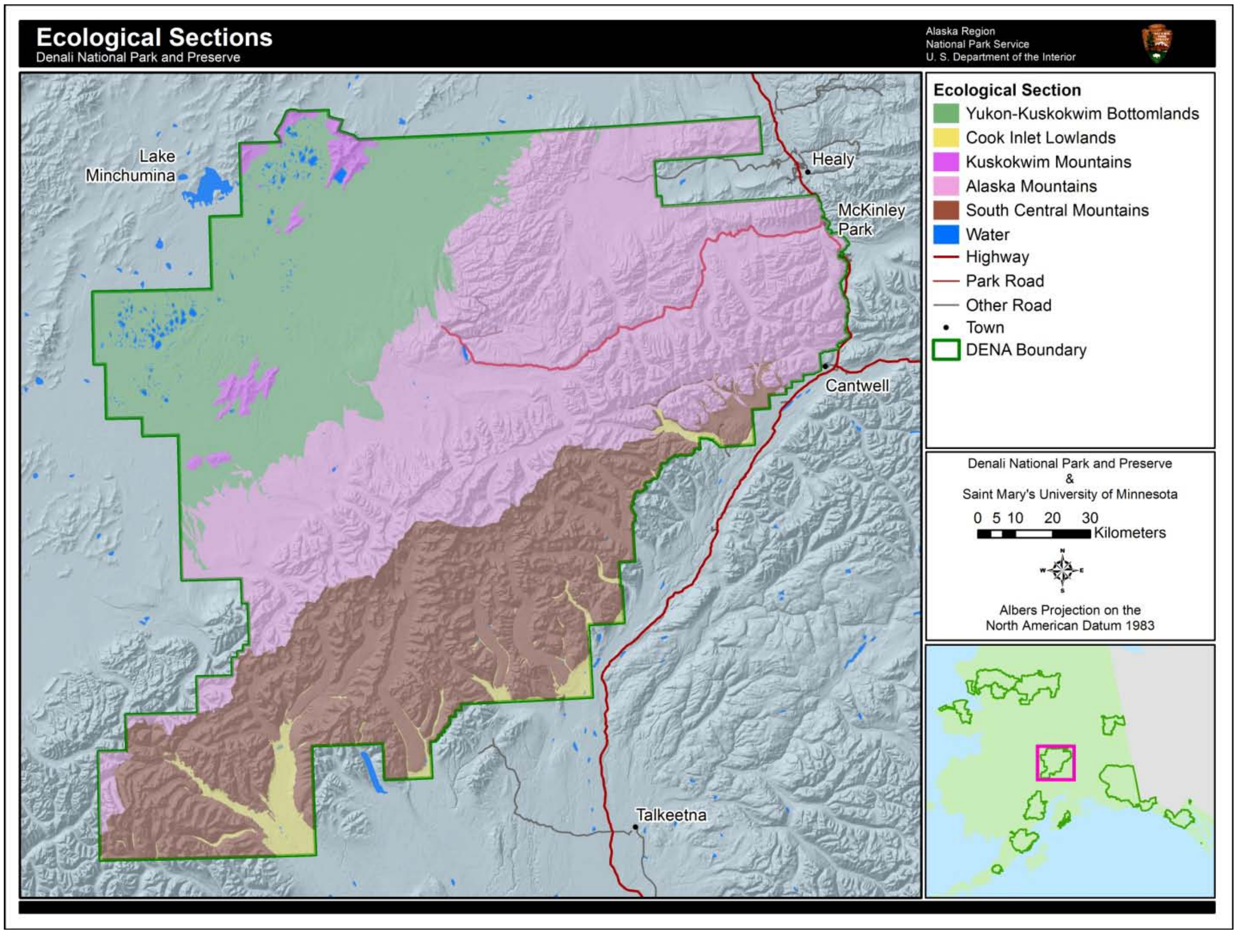


Figure 13. The five sections within Denali National Park and Preserve (NPS 2010).

The Alaska Mountains Section contains three main soil materials: gravelly colluvium (soil deposited by gravitational processes) in the mountains, drift in the valleys and lower mountain slopes, and loamy and gravelly alluvium (soil deposited by streams) on flood plains and terraces (Clark and Duffy 2006). Ground ice and permafrost are common in the Toklat Basin area of the section. The major soil orders found in this section include Inceptisols found on steep mountains, Spodosols on coarse alluvium and glacial deposits, Gelisols on gently sloping loamy drift and alluvial deposits, and Entisols on flood plains. However about two-thirds of this section has no soil and large areas have no vegetation (Clark and Duffy 2006).

The South Central Mountains Section is characterized by volcanic activity, with its steep slopes consisting of a mix of gravelly colluvium and volcanic ash (Clark and Duffy 2006). Volcanic ash originates from volcanoes in the Alaska Range and the Aleutian Range to the west. Major soil orders in this section include Andisols and Inceptisols on steep mountains, and Spodosols and Andisols on lower slopes (Clark and Duffy 2006). Two-thirds of this section also have no soil and therefore frequently no vegetation (Clark and Duffy 2006).

The Yukon-Kuskokwim Bottomlands Section, found in the northwestern region of Denali, is the second largest physiographic feature in the park (Clark and Duffy 2006). The section consists of lowland areas of plains, hills, relict sand dunes, bogs, fens, and ponds (Clark and Duffy 2006).

This area contains the largest contiguous area of soils affected by permafrost within Denali, and also includes the most wetlands of any section (Clark and Duffy 2006). The primary soil materials are loess and eolian sand found on the hills and plains, and stratified loamy textured alluvium and gravelly alluvium on the flood plains (Clark and Duffy 2006). The major soil orders in this section are Gelisols and Histosols in upland areas, with Entisols dominating the flood plains (Clark and Duffy 2006). Vegetation communities in this section include spruce-poplar forests, open black spruce forests, floodplain willow and alder thickets, and open sedge meadows (Clark and Duffy 2006). Wildfires and river floods are both common events.

The Kuskokwim Mountains Section is primarily a lowland area with a few isolated low mountains dispersed throughout (Clark and Duffy 2006). This section makes up only five percent of the park and preserve's total area. Open black spruce forests are common with alpine shrubs and sedges on hillsides and ridges (Clark and Duffy 2006). The major soil orders include Gelisols and Inceptisols (Clark and Duffy 2006). Wildfires are also common in this section.

The Cook Inlet Lowlands Section is another small region of the park and preserve, occupying less than five percent of Denali (Clark and Duffy 2006). The upland portions of the section include glacial plains and hills featuring mixed forest with scattered bogs and fens (Clark and Duffy 2006). In the lowlands black spruce forests are common along with mixed spruce-poplar forests and willow and alder thickets (Clark and Duffy 2006). Soil materials found in this section include volcanic ash and glacial drift in the uplands, and loamy and gravelly alluvium on the flood plains (Clark and Duffy 2006). Major soil orders in the section are Spodosols, Andisols, and Histosols in the uplands, and Entisols in the flood plains (Clark and Duffy 2006).

Subsections are smaller areas within Sections that have similar surficial geology, lithology, geomorphic process, soil groups, subregional climate, and potential natural communities (Clark and Duffy 2006). Boundaries for these units usually correspond to distinct changes in geomorphology (Clark and Duffy 2006). Subsections of the park and preserve were mapped at a scale of 1:250,000. There are a number of subsections within Denali, as depicted in Figure 14. A detailed description of each subsection is provided in Clark and Duffy (2006).

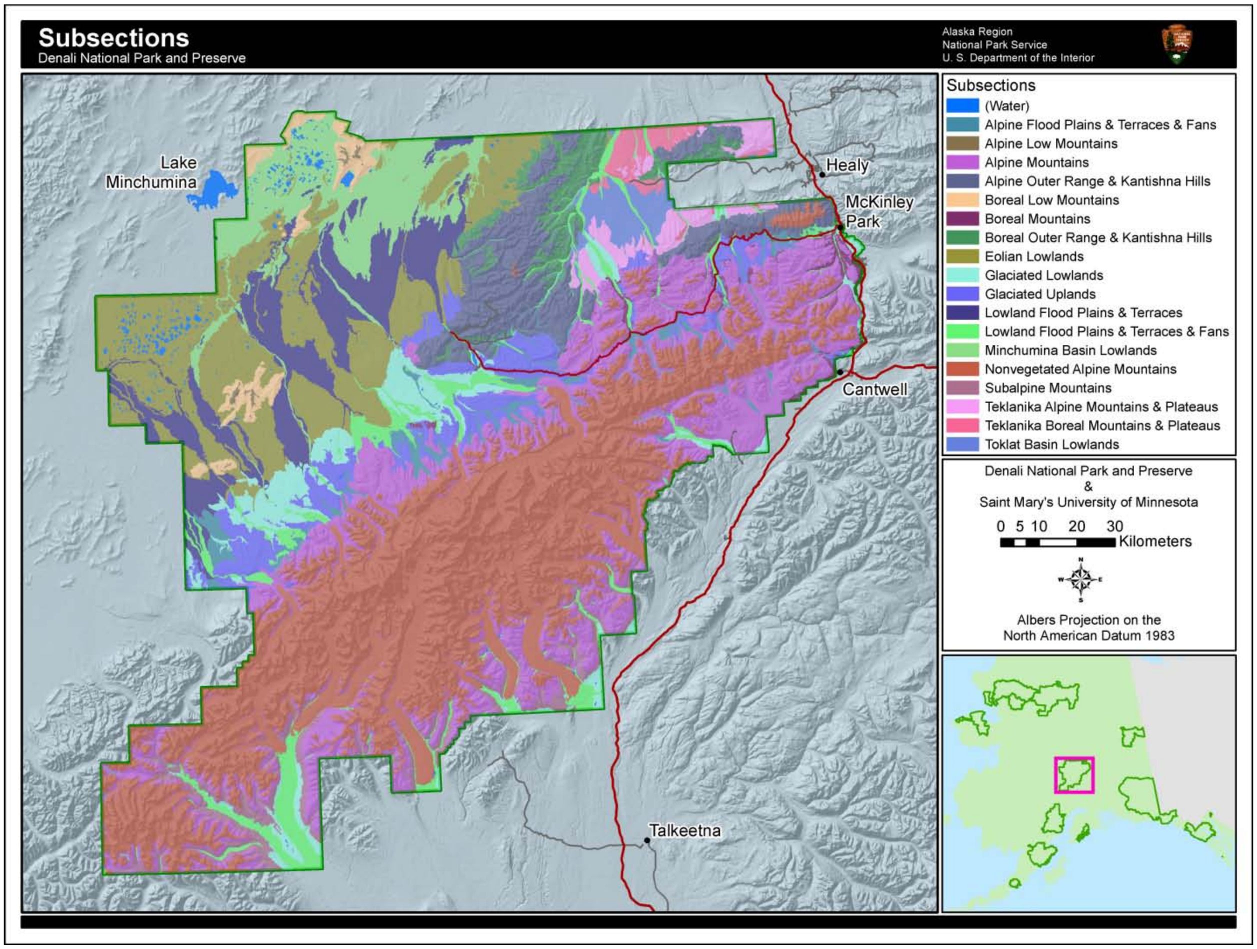


Figure 14. Subsections of Denali National Park and Preserve (NPS 2010).

Landscape Scale - Landtype Association

Ecological units at the landscape scale are classified by general topography, geomorphic process, surficial geology, soil family associations, potential natural communities, patterns, and local climate (Clark and Duffy 2006). These factors influence biotic distributions, hydrologic function, disturbance regimes, and land use. At this level of the hierarchy, local landform patterns become apparent and terrestrial features and processes may influence aquatic habitat characteristics (Clark and Duffy 2006).

Landtype Association is the single ecological unit at this scale within the hierarchy. These associations are based on similar geomorphic process, rock types, soil complexes, stream types, lakes, wetlands, or vegetation communities (Clark and Duffy 2006). Landtype associations are synonymous with detailed soil units, which are mapped at a scale of 1:63,360 (Figure 15; Clark and Duffy 2006). A brief description of each of the 152 Landtype Associations is available in Clark and Duffy (2006).

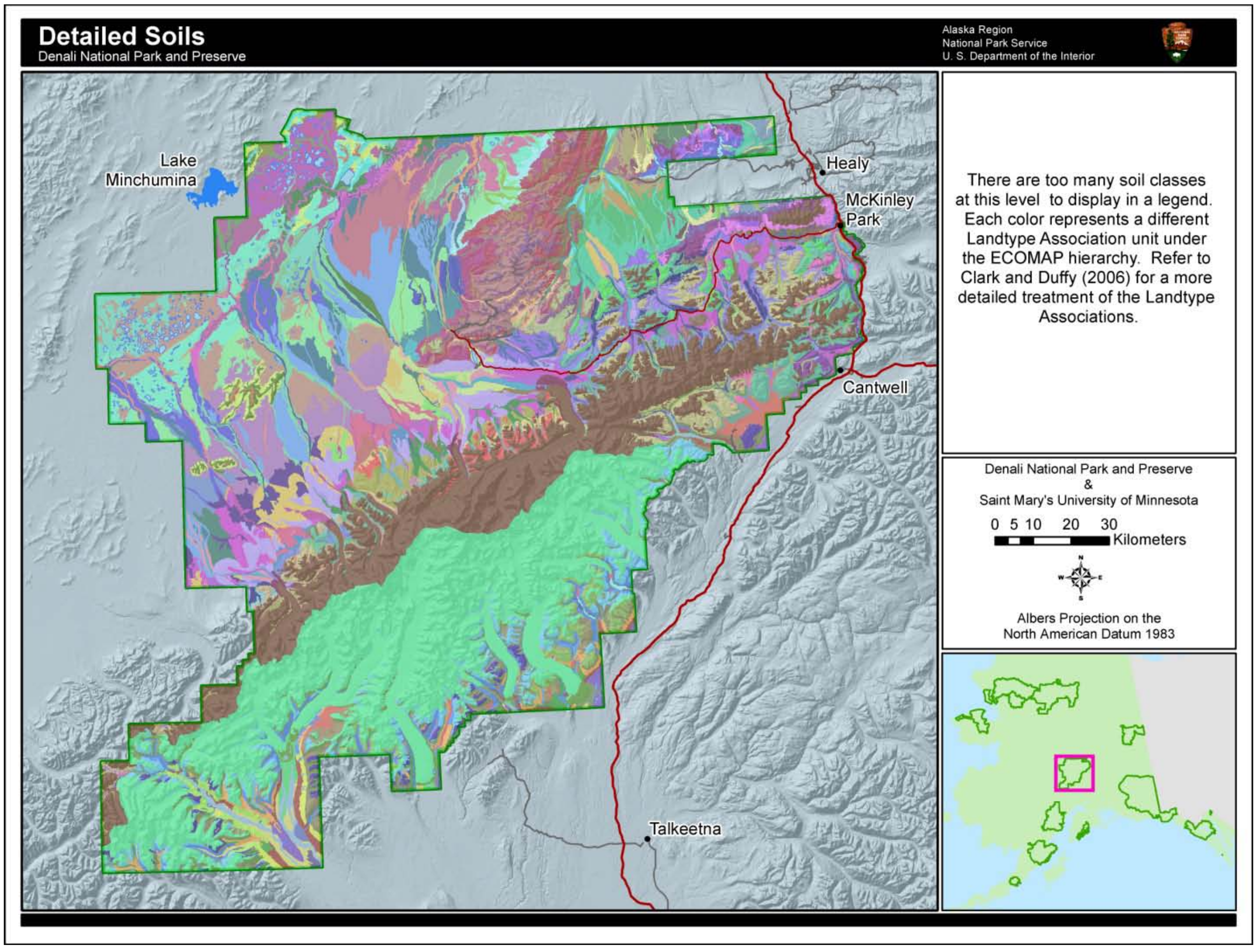


Figure 15. Detailed soils (Landtype Associations) map of Denali National Park and Preserve (NPS 2010).

Land Unit Scale – Landtypes and Landtype Phases

Clark and Duffy (2006) were able to classify the soils of Denali into the smallest units within the ECOMAP hierarchy – Landtypes and Landtype Phases. Landtypes are units within Landtype Associations or assemblages of Landtype Phases that have similar soils, landforms, rock types, geomorphic processes, and plant associations (Clark and Duffy 2006). There are 101 different Landtypes found within Denali, which are discussed in Clark and Duffy (2006). Landtype Phases are subdivisions within Landtypes that are defined by topography, hydrology, soil taxa, and plant associations. They are often established by the relationships between soil characteristics and potential natural plant communities (Clark and Duffy 2006). The two units at this scale were mapped in the field but are not represented in digital maps due to scale restrictions and the large number of polygons that exist at these levels.

Current Condition and Trend

<u>Existence and usefulness of data</u>

A wealth of information was collected over the six field seasons it took to complete the soil survey of Denali National Park and Preserve. The output of the study is a complete map of Denali's soils as well as its potential vegetative communities (Figure 16; Clark and Duffy 2006).

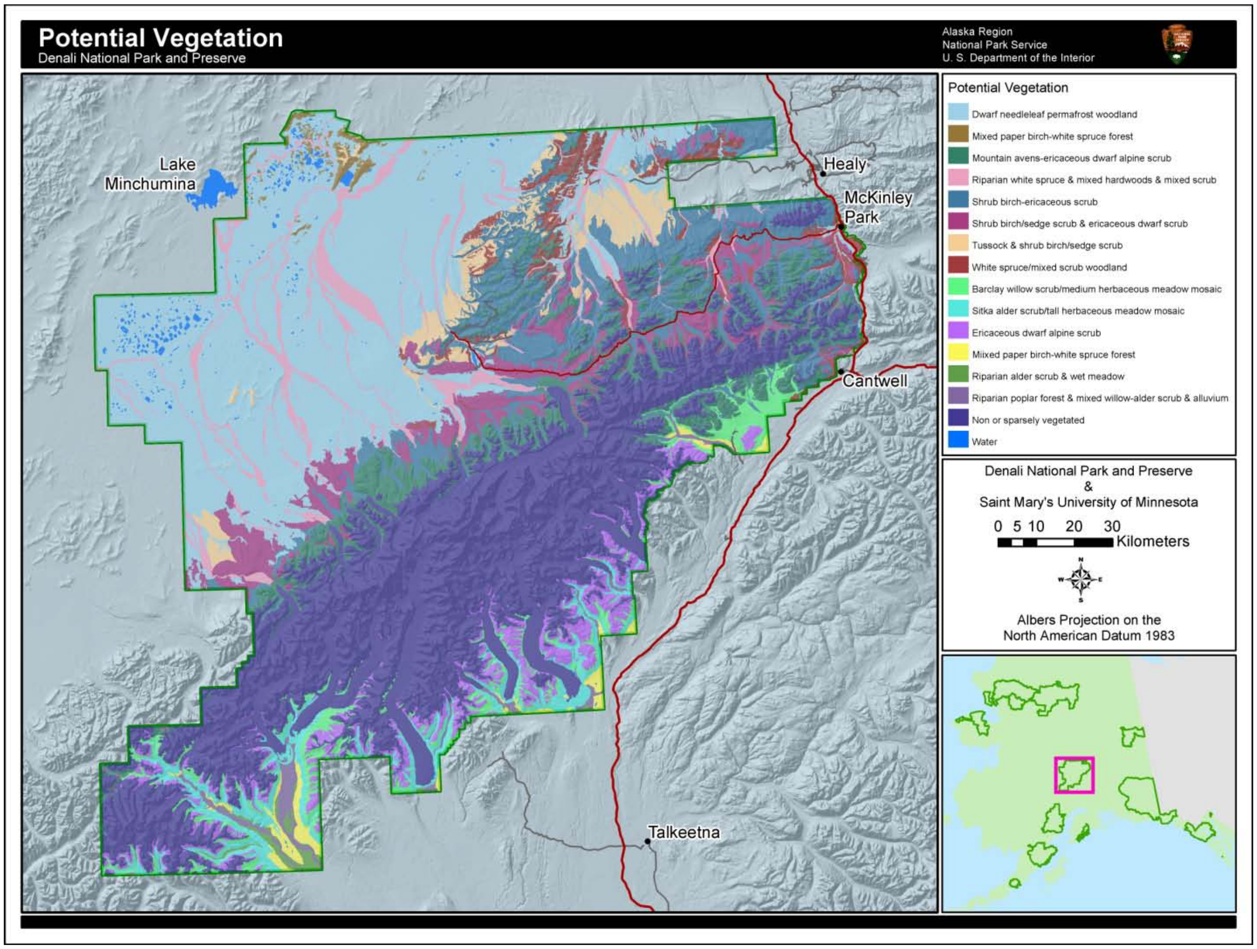


Figure 16. Potential vegetation based on the soil survey for Denali National Park and Preserve (NPS 2010).

SSURGO, NASIS, and SSFDD databases will be invaluable sources of information for park managers and researchers in Denali moving forward. The utility of these sources is increased by their connections to one another and spatial linkages to maps of the park and preserve. The soil survey represents one of the most complete datasets available for any ecological component in Denali National Park and Preserve (DENA 2006).

A list of plants occurring in different ecological units within the hierarchy was completed as a part of this survey. In total, 662 different plant species were documented at study sites with an additional 51 subspecies and three hybrids noted (Clark and Duffy 2006). Another 15 species were documented outside of the study site visits during the survey (Clark and Duffy 2006). Selkirk's violet *(Viola selkirkii)* is a rare plant that exists in a very limited range in the southern region of Denali which was linked to several plant communities during this survey, including Barclay willow/herbaceous meadow mosaic, Sitka alder/tall herbaceous meadow mosaic and riparian poplar and riparian alder type (see Figure 16; Clark 2007).

Threats and Stressor Factors

DENA (2009a) states that mining, recreational/residential/commercial development, off-road vehicle use, invasive plants, and climate change all threaten the condition of soils and landcover in Denali. Currently, invasive plants have only established themselves in disturbed areas of the park, such as along roadways and buildings, and are generally absent in the native plant communities (DENA 2009a).

Climate change may cause warming in the Denali region that could thaw permafrost and cause the soils to subside, which in turn would affect vegetative composition (Clark 2007). Warmer temperatures may also cause a shift in the treeline on Denali's slopes, allowing forests to advance upslope and replace tundra vegetation (DENA 2009b).

Data Needs/Gaps

Understanding changes in vegetation and landcover requires more rigorous and detailed information than was collected during the soil survey. To gather the necessary data, the CAKN Inventory and Monitoring Program began implementing an intensive, landscape-scale vegetation monitoring program in the park and preserve (Roland 2006). The monitoring program has been underway for several years and is beginning to yield baseline data for the plant communities in Denali. Once plot locations are visited for a second time, comparisons to the baseline condition will be possible to determine any changes in vegetation.

The goals of the vegetation monitoring program are to detect and quantify vegetation changes at multiple scales up to the landscape level like those captured by the repeat photography study, and to document the magnitude and ecological consequences of these changes using reproducible and statistically rigorous protocols (Roland 2006). Information collected from the vegetation monitoring program will build on the knowledge gained from the soil and ecological classification survey, and enhance the overall understanding of these two interrelated components.

Overall Condition

The datasets collected in the soil and ecological classification survey of Denali established a baseline condition of the park and preserve's soils and other ecological components. As a result of this survey, the state of knowledge regarding soils and expected vegetation within Denali is excellent. The existing knowledge of landcover is good and will improve as the vegetation monitoring program continues to collect data.

Level of Confidence

The NRCS soil survey produced large datasets and park-wide maps, providing a detailed snapshot of the condition of the park and preserve's soils and ecological landscape. This provides a solid baseline of knowledge for researchers studying any changes in the Denali landscape.

Sources of Expertise

This assessment relied greatly on the data compiled, analyzed, and discussed by Clark and Duffy (2006) and the Soil Survey and Ecological Classification resource brief from the National Park Service (DENA 2006).

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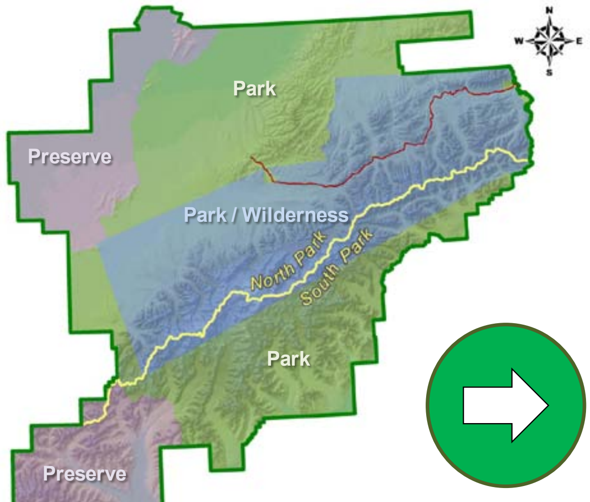
4.2 Denali Caribou (*Rangifer tarandus*) Herd



Current Condition and Trend

Description

Caribou are one of Interior Alaska's six keystone large mammal species (MacCluskie and Oakley 2005). The Denali Caribou Herd is one of 32 herds in Alaska. Each herd in Alaska uses separate calving grounds but may occupy the same areas during the winter season (ADF&G 2010). Caribou move regularly throughout the year based on forage availability and in order to avoid insects at lower elevations in the summer (ADF&G 2010). Composition surveys of the Denali Herd show that most bulls do not associate with females or use the same habitat during late winter (Adams and Roffler 2010).

Photo 7. Caribou in Denali National Park and Preserve (Photo by Kevin Stark, SMUMN GSS, 2010).

The range of the Denali Caribou Herd is almost exclusively within the boundaries of Denali National Park and Preserve. The herd inhabits portions of the park and preserve east of the Foraker River and north of the Alaska Range throughout most of the year. Some members of the Denali Herd will occasionally travel south of the Alaska Range toward the vicinity of Cantwell during the calving season (DENA 2010a). Biologists place great value on the research conducted on the Denali Herd because it is the only large barren-ground caribou herd in North America that is not under significant harvest pressure. The herd also shares its range with a natural complement of large predators and both predator and prey populations within Denali are naturally regulated (DENA 2010a). Caribou are a major prey species for wolves and calves are vulnerable to grizzly bear predation (MacCluskie and Oakley 2005, Adams et al. 1995).

Measures
Population size
Distribution

Reference Conditions/Values
DENA (2009) identifies herd size and demography values observed from 1987 to 2007 as the desired condition for the Denali herd. Annual population surveys of the Denali Caribou Herd have occurred since 1984, and this dataset provides the best available indication of the natural range of variability in the herd. This 25 year record is likely one of the longest consistent datasets for caribou in North America (Adams and Roffler 2009).

The Denali Caribou Herd reportedly exceeded 20,000 animals in the early 1940's (Murie 1944), declined to around 5,000 by 1968, and varied from 1,000 to 3,000 during the period 1970 to 1998 (Haber 1977, Adams et al. 1989). A map created by Boertje (1984) as part of a 1968 to 1970 study investigating caribou seasonal diets gives an example of their historic distribution (Plate 12).

In 1983, the population was increasing slightly, and 50% of calves produced were recruited into the herd (Adams and Roffler 2007). Due to several severe winters starting in 1988, the population hit a plateau of about 3,200 in 1989, and then declined by a third to 2,300 by 1992. This decline was associated with a drop in calf recruitment from 50% to only 5% (Adams and Roffler 2007). Since 1992, the population has been relatively stable (Adams and Roffler 2009).

Data and Methods
Intensive research has been conducted on the Denali Caribou Herd since 1984. Since 1986, the NPS and USGS have conducted an annual assessment of calf production, calf recruitment, adult female survival, and herd composition. This assessment is accomplished through capturing and radio-collaring individual animals. A sample of approximately 60 female caribou and 45 adult bulls is maintained (Adams and Roffler 2010). In 2009, an additional twelve 10-month-old female calves were radio-collared to monitor productivity and twelve 10-month-old male calves were radio-collared to study growth patterns, survival, and distribution of bulls (Adams and Roffler 2010).

Current Condition and Trend

<u>Population size</u>
Herd size was estimated at 2,070 in 2009 with little change over the previous 6 years (Figure 17). The current population size is within the range of values observed from 1987 to 2007. A summary of Denali Caribou Herd survey results is included as Table 14.

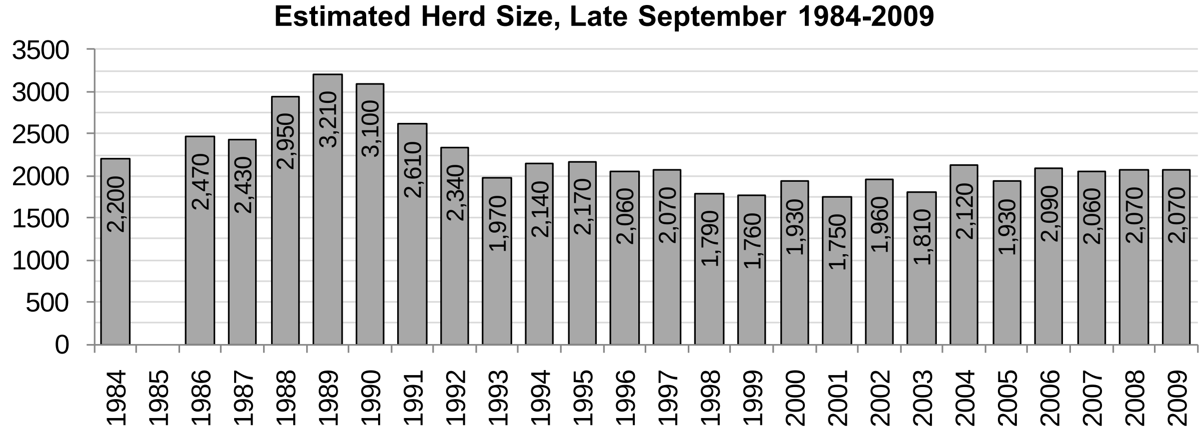


Figure 17. Population estimates for the Denali Caribou Herd, Denali National Park and Preserve, Alaska, late September, 1986-2009 (Adams and Roffler 2010).

Table 14. Results of helicopter composition surveys in late September and fall population estimates for the Denali Caribou Herd, Denali National Park and Preserve, Alaska, 1984-2009 (adapted from Adams and Roffler 2010).

	Fall Survey Results									Fall Herd	Estimated Fall Herd Composition		
				Ratios (:100 Cows)		Calf Sex Ratio	Bulls %[b]						
Year	Cows[a]	Calves	Bulls	Calves	Bulls	(m:100f)	S	M	L	Size	Cows	Calves	Bulls
1984	375	154	184	41	49					2200	1158	475	567
1985	654	183	368	28	56	72							
1986	547	210	305	38	56					2470	1272	488	709
1987	631	234	356	37	56	73	28	39	33	2430	1256	466	709
1988	678	221	451	33	67	70	27	34	39	2950	1482	483	986
1989	830	246	428	30	52	84	34	34	32	3210	1771	525	913
1990	777	130	387	17	50	59	39	28	33	3100	1861	311	927
1991	1067	72	409	6.7	38	112	32	39	29	2610	1799	121	690
1992	643	103	282	16	44	66	31	40	29	2340	1464	234	642
1993	849	54	336	6.4	40	74	26	46	28	1970	1350	86	534
1994	648	128	253	20	39	88	21	38	41	2140	1348	266	526
1995	685	131	204	19	30	75	29	29	42	2170	1457	279	434
1996	820	103	243	13	30	69	32	26	42	2060	1449	182	429
1997	777	124	228	16	29	110	38	28	34	2070	1425	227	418
1998	718	87	205	12	29	98	41	27	32	1790	1272	154	363
1999	667	92	261	14	39	51	30	34	36	1760	1151	159	450
2000	730	52	257	7.1	35	86	32	31	37	1930	1356	97	477
2001	778	90	248	12	32	64	22	38	40	1750	1220	141	389
2002	453	72	145	16	32	76	22	17	61	1960	1325	211	424
2003	743	58	264	7.8	36	71	23	23	54	1810	1263	99	449
2004	774	214	309	28	40	69	19	30	50	2120	1265	350	505
2005	848	163	279	19	33	52	32	27	41	1930	1269	244	417
2006	691	145	269	21	39	59	30	29	41	2090	1307	274	509

Table 14. Results of helicopter composition surveys in late September and fall population estimates for the Denali Caribou Herd, Denali National Park and Preserve, Alaska, 1984 - 2009 (adapted from Adams and Roffler 2010) (continued).

	Fall Survey Results									Fall Herd Size	Estimated Fall Herd Composition		
				Ratios (:100 Cows)		Calf Sex Ratio	Bulls %[b]						
Year	Cows[a]	Calves	Bulls	Calves	Bulls	(m:100f)	S	M	L		Cows	Calves	Bulls
2007	628	142	227	23	36	84	31	37	33	2060	1298	293	469
2008	677	152	222	22	33	85	32	30	38	2070	1333	299	437
2009	764	174	272	23	36	81	38	25	37	2070	1307	298	465

Based on a sample of 71 cows, the estimated natality rate in September 2009 was 73% for cows older than one year. This is slightly lower than the average natality rate of 77% observed from 1987 to 2008 (Figure 18). The observed calf:cow ratio in June 2009 was 35 calves:100 cows (Adams and Roffler 2010). Survival rate to late September was 29%, which is higher than the average of 23% since 1987 (Adams and Roffler 2010).

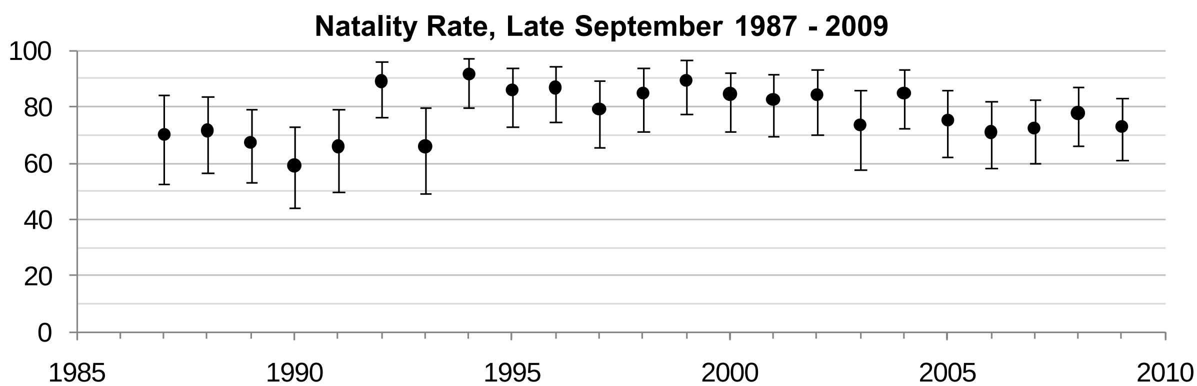


Figure 18. Estimated natality rates for the Denali Caribou Herd, Denali National Park and Preserve, Alaska during 1987-2009. Rates are based on observations of radio-collared females ≥ 1 year old, designed to approximate the age structure of the population, during the calving season (Adams and Roffler 2010).

Calf recruitment is an important indicator of population status (DENA 2008). From 2004 to 2008, the calf:cow ratio averaged 22.6:100 (Adams and Roffler 2009). Compared to numbers observed from 1998 to 2003, the average rate of calf production has doubled (DENA 2008). However, the ratios observed in recent years are not as high as ratios observed from 1984 to 1989 (Figure 19).

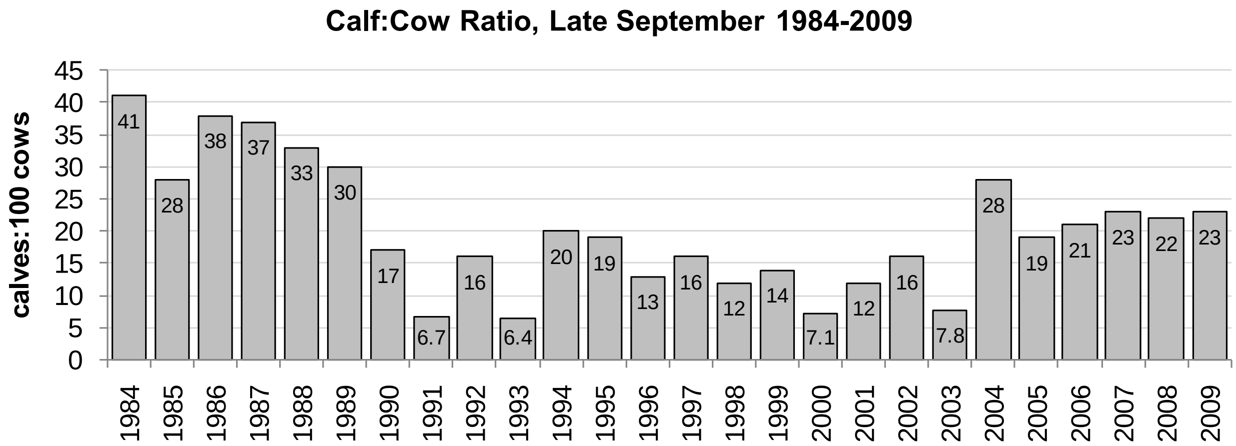


Figure 19. Calf:cow ratios for the Denali Caribou Herd, Denali National Park and Preserve, Alaska, late September, 1984-2009 (Adams and Roffler 2010).

The age structure of the female population shifted slightly in 2009 due to relatively high recruitment during 2008. Despite an increase in calf recruitment since 2004, low overwinter mortality rates and low recruitment prior to 2004 have led to a high proportion of older cows (≥13 years old) in the population (Adams and Roffler 2009). Since 2007, older cows have comprised approximately 20% of the female population, a number much higher than in the 1980s and 90s.

The total number of female caribou is stable, while bull populations appear to be increasing slightly (DENA 2008). The observed adult sex-ratio in 2009 was 36 bulls:100 cows, matching the average ratio from the previous five years (Adams and Roffler 2010). This ratio is higher than the mean 1995-1998 ratio of 29.5:100, but lower than the mean ratio of 56:100 seen from 1984-1989 (Table 14).

From September 2007 to September 2009, seventeen of the fifty-seven monitored bulls died, with the highest mortality occurring between August and October (Adams and Roffler 2010). The annual bull survival rate of 0.73 is significantly lower than the female rate of 0.92 (Adams and Roffler 2010). A study of wolf kills in Denali from 1986-1993 found that large bull caribou were primarily killed by wolves in August and September prior to the rut when they should be in peak physical condition. Wolf kills of bull caribou in Denali ended in December, although this could be simply because the bulls' regular movements took them beyond the range of the radio-collared wolf packs (Adams and Roffler 2010). To better understand these surprising findings, a new investigation of bull growth, survival, and seasonal distribution was added to the Denali caribou study in September of 2007.

<u>Distribution</u>
Cow locations obtained using the radio-collars from September 1986 to March 2008 are depicted on Plate 13. No published analysis of change in overall distribution of the Denali Caribou Herd over time has been found. Further analysis of the caribou cow locations is needed to determine if inferences can be made regarding change in distribution over time.

Threats and Stressor Factors

According to DENA (2009), potential detrimental influences on the caribou herd include loss of habitat due to climate and vegetation change, increased harvest in certain areas, disturbance of wintering areas, and inhibition of normal migration patterns.

The Denali Caribou Herd is primarily regulated by natural factors. Caribou survival is strongly connected to weather conditions. This relationship was evidenced by a decline in herd populations following a series of severe winters from 1988 to 1992. During this period cow winter survival dropped from 96% to 85% and calf recruitment fell to 5% (Adams and Roffler 2009). Calf birth weight, a factor strongly correlated with calf mortality, was found to decrease as the amount of snowfall during gestation increased (Adams 2005). Severe weather conditions can also lead to extremely abnormal caribou movements, as was observed in 1992. After a severe September snowstorm, the majority of the Denali herd headed north to lower elevations outside the park and preserve, up to 221 km from their normal winter range, mixing with caribou from other herds (Adams et al 2005; Figure 20). Denali caribou gradually returned to the park and preserve during the winter and spring.

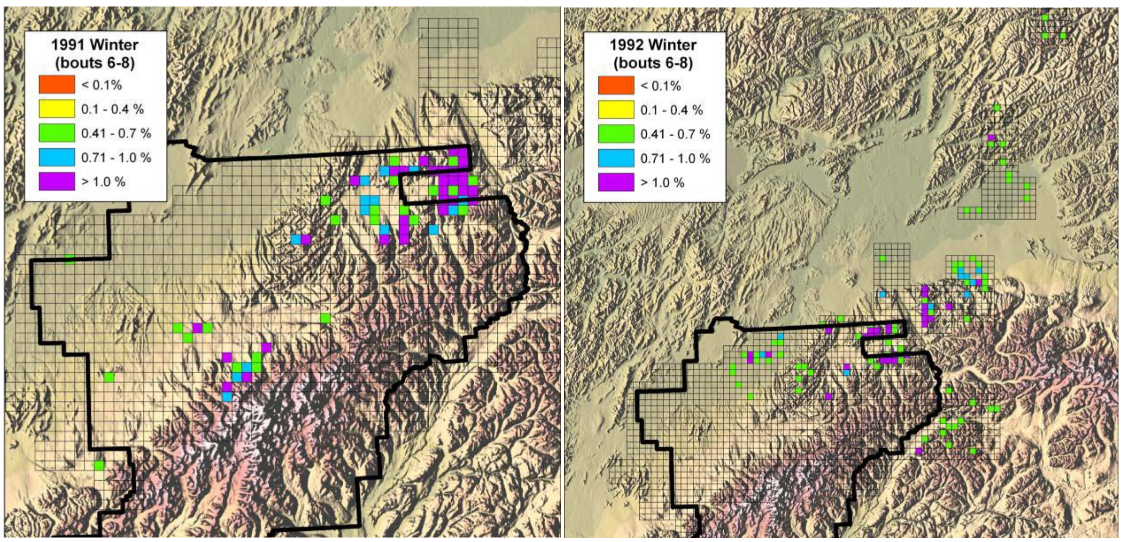


Figure 20. Winter distribution of female caribou during 1991 (left) and in 1992 (right) after the severe September snowstorm (Adams and Roffler 2010).

Predation is believed to be the primary cause of mortality in all Interior Alaska caribou herds, particularly for calves (Valkenburg et al. 2002). During a study of calf mortality in Denali, 39% of radio-collared calves died before they were 16 days old. Ninety-eight percent of these deaths were attributed to predation (Adams et al. 1995). Grizzly bears and wolves were responsible for 49% and 29% of all calf mortality respectively. Researchers noted that grizzly bear predation decreased as calves got older, with few bear kills after calves reached 10 days old, while wolf predation did not vary with calf age (Adams et al. 1995). Evidence suggests that predation risk may be related to winter weather conditions. Caribou may be forced to calve at lower elevations when snowpack persists at high elevations into the calving season, making them more vulnerable to predators (Adams et al. 1995).

Subsistence and sport harvest have not been a significant stressor on the Denali Caribou Herd since hunting is not allowed within most of their range in the park and preserve. Caribou hunting has been closed in GMU 20C since 1977 (DENA 2004). However caribou are vulnerable to hunting if they enter GMU 13E in the southeast portion of the park. Federal registration permit information has been summarized for GMU 13E for years 1991 through 2004 (Table 15). On average, approximately 4.5 caribou were harvested each year by Cantwell permits on GMU 13E park lands. It is unknown how many of the harvested caribou were from the Denali herd and how many were from the neighboring Nelchina herd.

Table 15. GMU 13E caribou harvest data, 1991-2004 by federal registration permits (DENA 2010b).

Year	Permits	Total Harvests by Cantwell Permits in GMU 13	Total Harvests by Cantwell Permits on 13E Park Lands
1991	84	22	9
1992	128	12	5
1993	45	4	1
1994	72	15	7
1995	84	8	7
1996	88	9	3
1997	100	2	1
1998	120	1	0
1999	129	16	7
2000	90	2	0
2001	102	27	15
2002	99	21	1
2003	94	7	1
2004	110	-	-

Data Needs/Gaps

A key information gap in Denali Caribou Herd research is bull survival and mortality patterns. Even though bulls comprise the majority of the take in harvested populations, little information can be found on bull survival patterns in the scientific literature (Adams and Roffler 2010). Additional data collection on bull survival, growth, and seasonal distribution began in 2007 in an attempt to address this gap (Adams and Roffler 2010). These studies will provide an improved understanding of bull populations for future natural resource condition assessment projects.

Overall Condition

All evidence suggests that the caribou population is stable, although it has not returned to the levels observed between 1986 and 1992. Calf:cow and bull:cow ratios have been steady for the last four to five years and calf recruitment rates have actually increased since the 1990s. Harvest pressure has remained minimal for several decades and is not currently considered a major threat to the Denali Caribou Herd.

Level of Confidence

The consistent monitoring of the Denali Caribou Herd since 1987 provides a relatively long record for determining trends and comparing recent herd population data to the last two decades.

The lack of comparable data prior to 1987 limits the available knowledge of the full range of natural variability that the Denali Caribou Herd experiences.

Sources of Expertise
The primary source of information used in the assessment is Adams and Roffler (2009, 2010).

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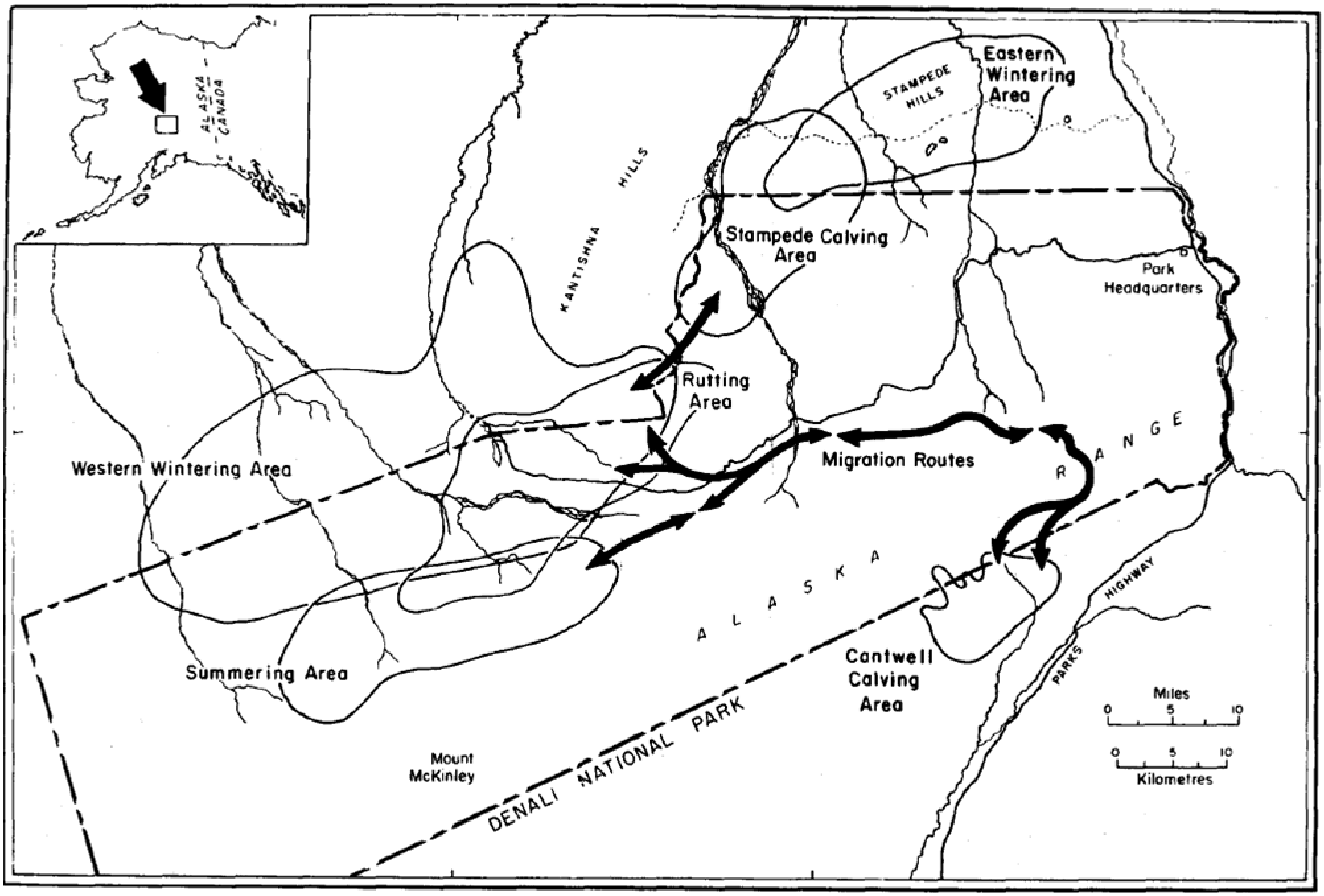


Plate 12. Seasonal caribou ranges in Denali National Park and Preserve, 1978-1980 (figure reproduced from Boertje 1984).

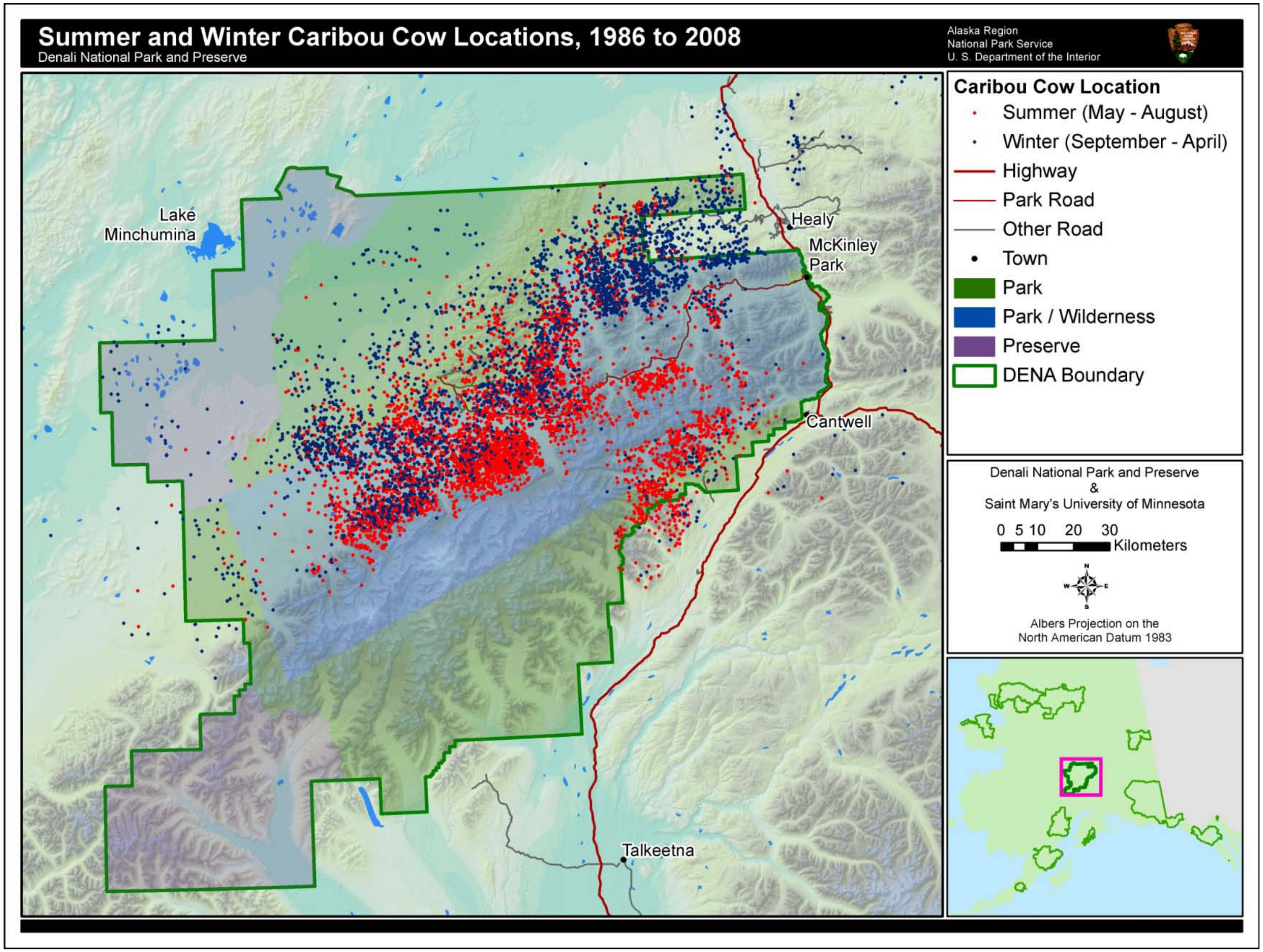
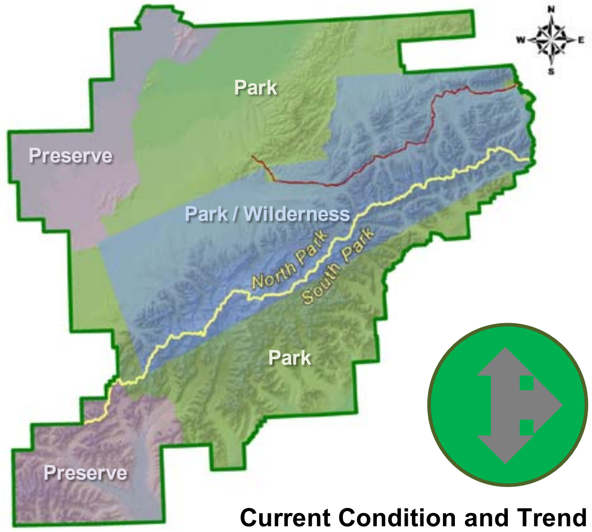


Plate 13. Denali Caribou Herd cow locations identified September 1986 through March 2008 (Adams 2010). Summer (May – August) locations in red and winter (September – April) locations in blue.

4.3 Dall's Sheep (*Ovis dalli*)



Current Condition and Trend

Description

Dall's sheep are considered one of the six keystone large mammal species of Interior Alaska. Denali's Dall's sheep have been a subject of great interest for wildlife managers and park visitors for many years. Their protection was one of the primary reasons Mount McKinley National Park was established in 1917 (Phillips 2009). Since Dall's sheep live at high altitudes and have very specific habitat needs, changes in sheep population and distribution are considered to be indicative of changes in climate and vegetation. Because of this and their importance in the naturally regulated predator-prey system of Denali, the Central Alaska Network has named Dall's sheep a vital sign for their monitoring program (Phillips 2009).

Photo 8. Dall's sheep at Denali National Park and Preserve (photo by Kevin Stark, SMUMN GSS, 2010).

Measures

Population Size
Distribution

Reference Conditions/Values

DENA (2009a) defines the reference condition for the Dall's sheep population as "within the range observed 1987-2007." However, this is difficult to establish given the inconsistency of surveys during this period. According to Phillips (2009), population estimates of Dall's sheep in the eastern part of Denali since 1934 have ranged from 1,104 to 2,280. Other sources suggest that the population within the wilderness boundary had fallen as low as 500 sheep in the mid 1940s and then increased to at least 3000 during the 1960s (Whitten 1975). Prior to surveys in 2008 and 2009, the most recent survey in 1996 documented 1,903 sheep in the eastern portion of

Denali. The most recent survey of western areas of the park and preserve in 1995 found 371 sheep (Phillips 2009).

Data and Methods

Aerial and ground surveys were conducted in 2008 and 2009 in eastern Denali to estimate sheep abundance and productivity (Phillips 2009). Seventeen aerial survey units have been established in the eastern portion of the park (Plate 14). As a result of poor weather conditions in 2008 and 2009, not all units could be surveyed each year. In 2008 all units except 6, 7, 12, and 13 were surveyed. In 2009 only units 9, 12, and 13 were surveyed. Unit 9 was the only unit surveyed both years while units 6 and 7 were the only units not surveyed during either year. Ground-based surveys were conducted on 9-10 July 2008 and 29-30 June 2009 in the following areas: Primrose Ridge, Mt. Wright, Igloo Mt., Sable Mt., Cathedral Mt., the west end of Polychrome Mt. above the Toklat bridge, and areas in the Alaska Range along the east branch of the Toklat River (Plate 15; Phillips 2009).

Observations of sheep migration have been recorded along the park road since 1939. Records include time of day, the location along the park road, the distance of the sheep from the road, and the number of sheep by sex and age class. Bus drivers also recorded Dall's sheep sightings along the park road from 2000 to 2005. These datasets were not analyzed as part of the condition assessment but could be used in the future to further assess Dall's sheep condition specific to this portion of the park and preserve.

Current Condition and Trend

Population Size

During 2008 and 2009 aerial surveys, 1,724 total sheep were observed within 15 survey units in Denali (Table 16, Plate 14; Phillips 2009). For unit 9, which was surveyed both years, only the higher number of sheep observed in 2008 is included in this number to avoid double counting. In the 1996 survey, 1,816 individuals were counted in these same survey units (Phillips 2009). During the ground surveys in 2008 and 2009, 177 and 136 sheep were observed respectively (Table 17; Phillips 2009). Productivity estimates from these ground counts were 40 lambs:100 ewes in 2008 and 38.6 lambs:100 ewes in 2009. These numbers are slightly lower than the ratio of 45 lambs:100 ewes observed in the 1996 survey, but within the range of 30-77 lambs:100 ewes observed in previous ground surveys at Denali (Phillips 2009). The recent productivity estimates are similar to those reported for other populations in the Central Alaska Range east of Denali (Arthur 2003, Scotton 1997).

Lamb productivity may have been underestimated in 2008 because of difficulty classifying a large nursery group observed south of Mt. Wright due to shrub cover and distance from the observers. This could have caused an inaccurately high ewe count, which would result in an underestimate of productivity (Philips 2009). These classification challenges also make it difficult to calculate a meaningful sex ratio for 2008, but the sex ratio in 2009, based on ground surveys, is approximately 41.4 rams:100 ewes.

Table 16. Aerial Dall's sheep survey results, Denali National Park and Preserve, 2008-2009 (from Phillips 2009).

Year	Unit	Date	Ewe -like	Lambs	Sub-rams	Full curl rams	Unknown ram	Unknown sheep	Total	General area
2008	1	15-Jul	201	37	33	4	0	1	276	Mt. Healy
	2	15-Jul	0	0	9	2	19	1	31	Primrose, Mt. Wright
	3	25-Jul	0	0	0	0	0	0	0	Sushana
	4	15-Jul	0	0	1	5	2	0	8	Jenny Creek
	5	25-Aug	189	38	60	8	0	1	296	Fang Mt.
	8	15-Jul	97	21	22	7	8	5	160	Double Mt.
	9	25-Jul	213	50	78	22	0	4	367	Cathedral, Sable, & Igloo Mts.
	10	20-Aug	34	6	6	2	36	0	84	Wyoming Hills
	11	26-Jul	38	11	15	3	0	0	67	Polychrome
	14	15-Jul	75	23	22	6	0	2	128	West Upper Toklat River
	15	25-Jul	41	15	22	3	0	0	81	Mt. Sheldon
	16	25-Jul	1	0	6	3	0	0	10	Thorofare Mt.
	17	25-Jul	0	0	0	0	0	0	0	Mt. Galen
	total		898	202	281	66	65	14	1526	
2009	12	13-Jul	84	17	17	8	0	0	126	Polychrome Glaciers
	13	13-Jul	48	12	8	4	0	0	72	Divide Mt.
	9 (recount)	17-Jul	181	56	68	24	0	0	329	Cathedral, Sable, & Igloo Mts.
	total		313	85	93	36	0	0	527	
2008-2009	Total traditional survey units completed		1030	231	306	78	65	14	1724	

Table 17. Dall's sheep ground survey results, Denali National Park and Preserve, 2008–2009 (from Phillips 2009).

Year	Ewes	Lambs	Year-lings	Unknown Ewe-like	<1/2 curl rams	½ - ¾ curl rams	¾ - 4/4 curl rams	>4/4 curl rams	Unknown rams	Unknown sheep	Total
2008	41	29	15	31	18	12	14	5	3	9	177
2009	70	27	9	1	7	12	7	1	2	0	136

Distribution

Dall’s sheep have very specific habitat needs that include natural mineral licks, birthing areas, steep slopes and rocky outcrops for grazing and protection in the summer, and overwintering areas with light snow and accessible forage near rocky escape terrain (Phillips 2009). In 2008 and 2009, Dall’s sheep were found at elevations ranging from approximately 900 to 1800 meters, with an average elevation of 1500 meters (DENA 2008, DENA 2009b). Locations of Dall’s sheep observed during the 2008 and 2009 aerial surveys are depicted on Plate 14.

Threats and Stressor Factors

DENA (2009a) identifies the following as potential threats to the Dall’s sheep population: possible loss of habitat due to climate and vegetation change, potential for increased harvest in certain areas, disturbance in wintering areas, and inhibition of normal migration patterns.

Much of the suitable Dall’s sheep habitat falls within the wilderness boundary where no hunting is allowed. However subsistence hunting is permitted in the 1980 ANILCA additions to Denali and sport hunting is permitted in the preserve areas in the south and northwest. Sheep within these areas are vulnerable to human harvest within the limits of state and federal hunting regulations. Two hunting guides hold concession permits to conduct guided hunting for Dall's sheep in the southwest portion of Denali National Preserve (DENA 2003). According to Denali’s subsistence management plan (DENA 2004), Dall’s sheep are not frequently used by local subsistence communities.

Wolves, wolverines, grizzly bears, coyotes, and golden eagles prey on Dall’s sheep in Interior Alaska (Scotton 1997). A study in the Central Alaska Range just east of Denali found that 90% of lamb mortality was due to predation (Arthur 2003). Coyotes and golden eagles were the primary predators, responsible for 40% and 30% of calf deaths respectively. All adult ewe deaths during this four-year study were from predation, mainly by wolves. Although Dall’s sheep do not comprise a majority of any predator species’ diet, cumulative changes in predator-prey dynamics throughout the ecosystem as a whole can affect the sheep population. For example, Arthur (2003) suggests that Dall’s sheep are likely impacted by changes in snowshoe hare population, because lambs and snowshoe hares are both prey for coyotes and golden eagles.

Data Needs/Gaps

Regular surveys utilizing a consistent protocol are needed to better understand the Dall’s sheep population status and trends within Denali. Efforts are underway within CAKN to develop a Dall’s sheep monitoring protocol that will address this need (Phillips 2009). No recent data or information could be found on the status of Dall’s sheep south of the Alaska Range within Denali.

Research is also limited on factors that affect the Denali sheep population (predation, weather, human disturbance, nutrition, etc.). Although information is available on the effects of harvest and causes of mortality in other parts of Interior Alaska, it may not necessarily apply to the naturally regulated Denali population.

Overall Condition

Although comparisons with past results are difficult given the inconsistency of Dall’s sheep surveys, Phillips (2009) concluded that results of the 2008-2009 survey suggest that sheep numbers within the eastern part of Denali "have not changed significantly since the mid-1990s." Based upon this limited information, condition of Dall's sheep is considered good. A recent trend cannot be determined at this time due to the lack of consistent long-term monitoring data.

Level of Confidence

The level of confidence is low. Variations in survey techniques and large time gaps between surveys make it difficult to identify change in population size and distribution. Phillips (2009) strongly cautions against any determination of trend based on survey results.

Sources of Expertise

The primary source of information for the Dall's sheep condition assessment is Phillips 2009.

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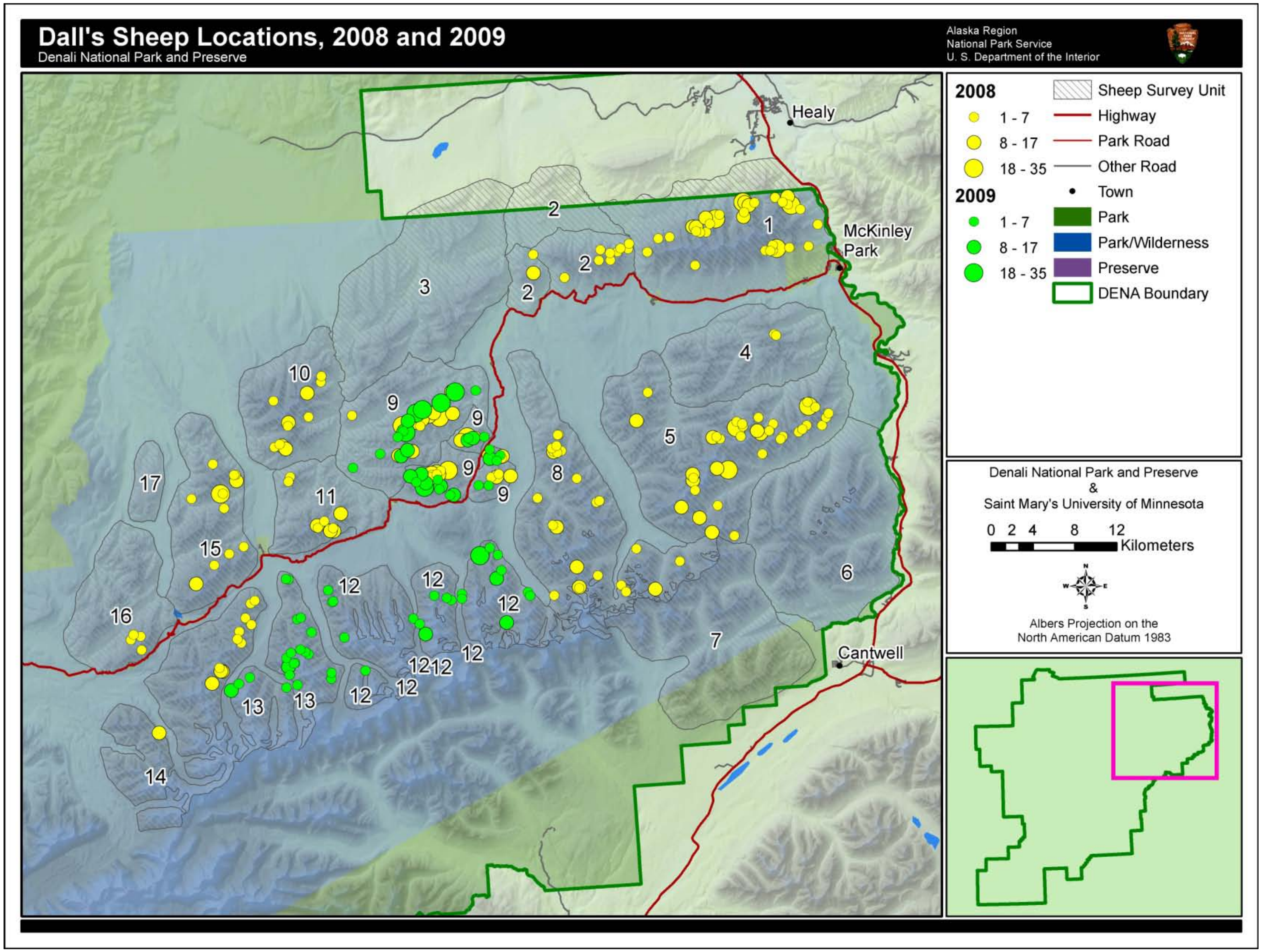


Plate 14. Dall's sheep locations and survey units, 2008 and 2009 (DENA 2008, DENA 2009b, NPS 2010).

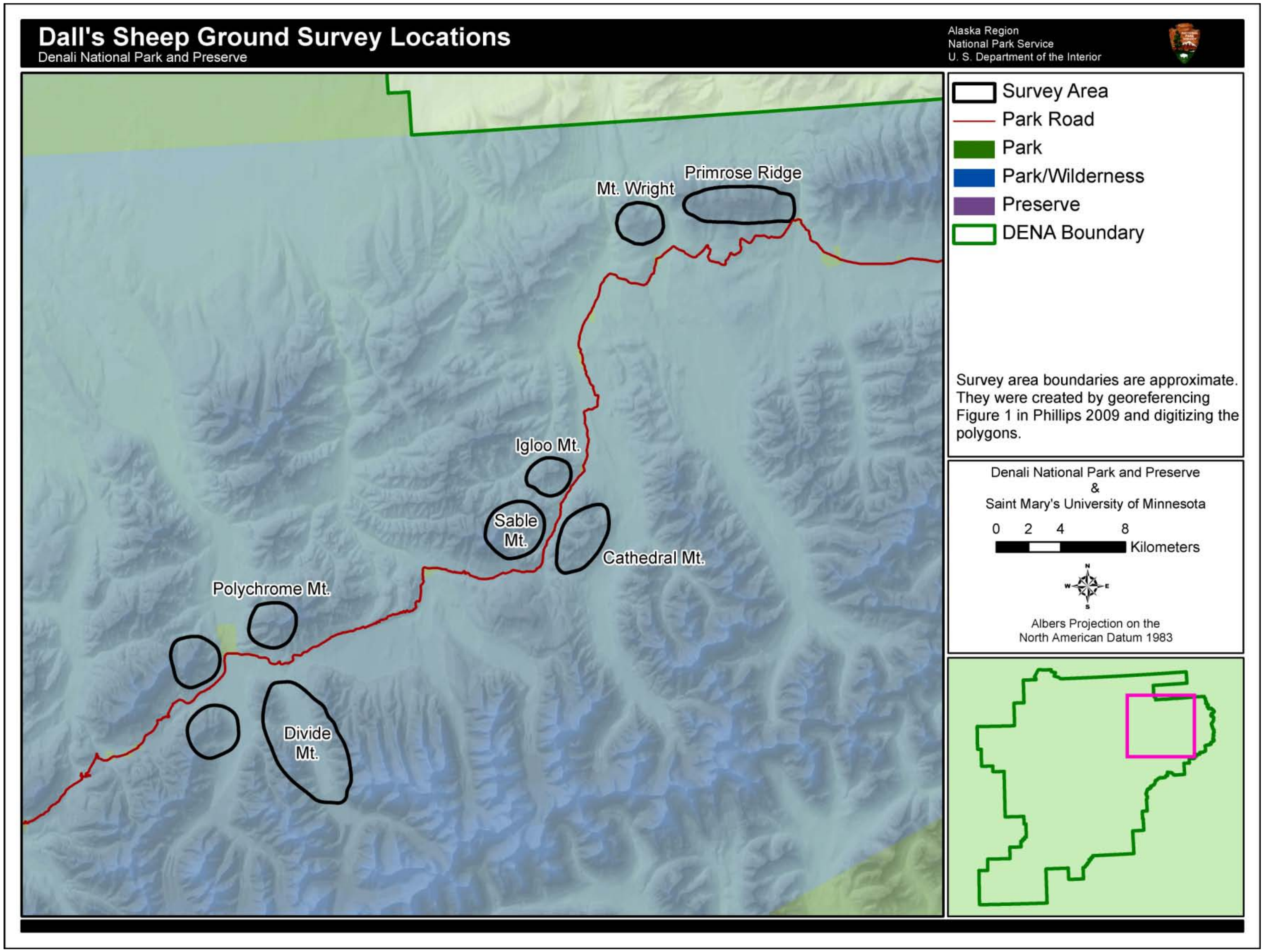
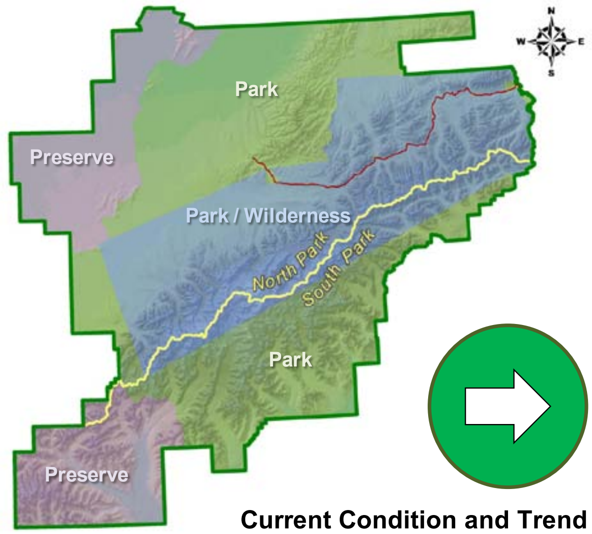


Plate 15. Dall's sheep ground survey locations (Phillips 2009, NPS 2010).

4.4 Moose (*Alces alces*)

Description

Moose have been identified as indicators of long-term habitat change because “they require large quantities of resources from their habitat year round, and populations have the potential to respond dramatically to long term changes in resource conditions” (Burch et al. 2004). Moose populations in Denali are particularly important to understand because they are a prominent prey species, providing food for wolves and bears (Fox 1996, Mech et al. 1998). Fauna distribution and abundance has been identified as one of the top three vital signs for CAKN, and moose population surveys at DENA are part of the CAKN vital signs monitoring program.



Current Condition and Trend

Photo 9. Moose at Denali National Park and Preserve (photo by Kevin Stark, SMUMN GSS, 2010).

Within Denali, moose tend to live in forested areas that are close to lakes, marshes, or other bodies of water (DENA 2010a). During the summer, their diet consists of grasses, forbs, aquatic vegetation, shrubs, evergreen needles, and deciduous leaves. Some Denali moose migrate to more favorable range in winter, while others remain in one home range year around. Winter habitat for moose is highly dependent on willow forage, and as snows deepen wintering moose establish well-worn trails and trampled areas within and between willow patches. Moose are generally solitary but aggregate in small groups during the breeding season in late September and early October (Van Ballenberghe 2004).

The Denali population faces many natural and anthropogenic pressures that potentially affect their distribution and behavior. These include weather, predation by wolves and bears, and human development (DENA 2010a).

Measures
Population size
Distribution

Reference Conditions/Values
DENA (2009a) has defined the reference condition for moose as herd size and demography within the range observed from 1987 to 2007. Results of population surveys from this time period are included in the Current Condition and Trend section below.

Data and Methods
Aerial surveys of moose populations have been conducted by various researchers since 1974. Survey methods have changed over time, but most follow methods developed by the ADF&G (DENA 2009a). Multiple surveys have occurred over a large area on the north side of the Alaska Range. Other, smaller surveys are regularly conducted in the Cantwell and Yentna regions (Plate 17) to monitor populations impacted by subsistence harvest (DENA 2009a). Radio collaring and tracking of moose have also consistently occurred within the park and preserve since these survey methods were pioneered by U.S. Forest Service (USFS) biologist Victor Van Ballenberghe in the early 1980s (Van Ballenberghe 2004).

The most recent moose survey occurred from 3 November through 25 November 2008 (Owen and Meier 2009a). For this survey, 312 sample units were selected from a statewide grid developed by ADF&G. Each unit is two minutes of latitude by five minutes of longitude, and approximately 15.3 square kilometers in size. Survey units are classified into a low or high density stratum based on preliminary flights, designation in previous surveys, or habitat characteristics. The high density stratum comprises those units where five or more moose are expected to be found. Low density units are those in which fewer than 5 moose are expected to be found. In 2008, 103 high density and 209 low density units were surveyed. The entire study encompassed an area of 10,004 km^2, of which 48.7% was surveyed (Owen and Meier 2009a). The units surveyed and moose locations from 2008 are depicted on Plate 16. Estimated population, population density, calf:cow ratio, and bull:cow ratios were calculated based on survey observations.

Several studies of the Denali park road's impact on wildlife in the late 1990s looked at the distribution of moose in areas of human development, particularly the park road, and any effects development may have on their behavior (Yost 1998, Burson et al. 2000, Belant et al. 2006). A study by Miquelle et al. (1992) explored sexual segregation in moose, including differences in distribution and habitat use by bulls and cows with calves.

Current Condition and Trend

<u>Population size</u>
In 2008, the moose population was estimated at 1,279 (±135) across the north side survey area, with an overall population density of 0.13 moose/ km^2 (Owen and Meier 2009a). The estimated densities in the high and low density strata were 0.37 and 0.03 moose per square kilometer respectively (Owen and Meier 2009a). The 2008 population estimate is higher than the previous survey estimate in 2004, but lower than estimates from 1986 -1999 (Figure 21).

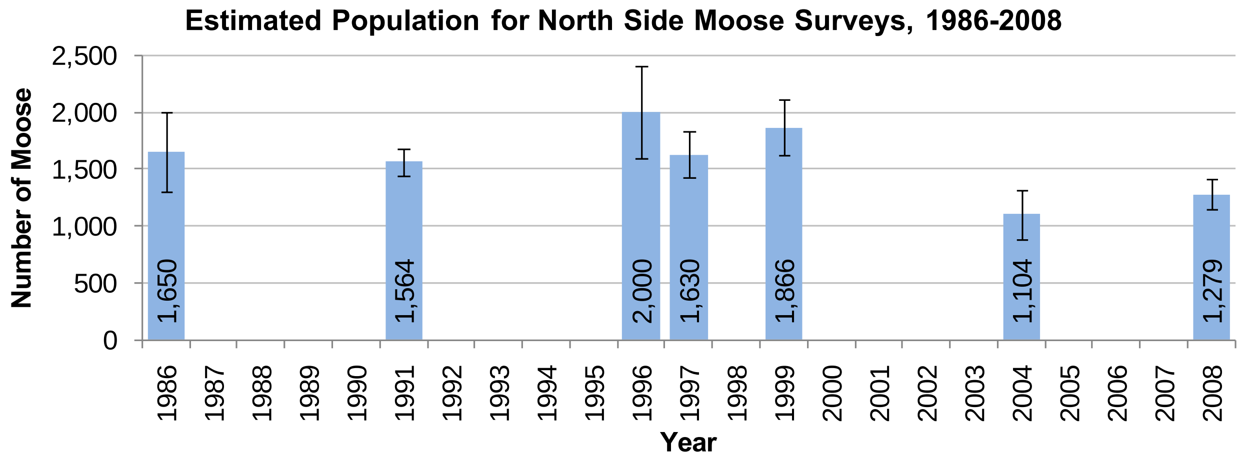


Figure 21. Estimated population of moose (+/- 90% confidence intervals) for north side moose surveys, Denali National Park and Preserve, 1986-2008 (Owen and Meier 2009a). Note that areas surveyed each year were not identical (see Table 18).

Calf:cow ratios, bull:cow ratios, and estimated density are summarized in Table 18 for surveys occurring on the north side from 1986 to 2008. In 2008, the calf:bull:cow ratio was 24:54:100 (Owen and Meier 2009a). The bull:cow ratio observed in 2008 is the lowest observed in surveys from 1986 to 2008. The 2008 calf:cow ratio was within the range of values observed from 1986 to 2004. Surveyors estimated that a majority of cows (77%) were without calves, while 22% had one calf, and 1% of cows had two calves (Owen and Meier 2009a).

Table 18. Moose cohort ratios and estimated populations (90% confidence intervals), and densities for north side moose surveys, Denali National Park and Preserve, 1986-2008 (Owen and Meier 2009a).

Year	Calves/ 100 cows	Bulls/ 100 cows*	Estimated population	Density Estimate moose/km^2	Area Surveyed square km	Source
1986	23	75	1650 ± 347	0.19	10,024	Meier 1987
1991	23	81	1564 ± 123	0.22	6,952	Meier et al. 1991
1996	30	56	2000 ± 402	0.13	13,504	Fox 1997
1997	22	63	1630 ± 204	0.23	7,068	Belant and Stahlnecker 1997
1999	22	69	1866 ± 244	0.24	7,068	Belant et al. 1999
2004	39	88	1104 ± 219	0.11	10,004	Owen and Meier 2005
2008	24	54	1279 ± 135	0.13	10,004	Owen and Meier 2009

* 1996 ratio includes the Lakes and Flats Regions (see Fox 1997)

The 2008 survey also discussed the results from two smaller regions of the north park area that could be directly compared to previous studies. These are referred to as the East analysis area and the Kantishna-South analysis area (Plate 17). Table 19 summarizes results for the East analysis area and Table 20 summarizes results for the Kantishna-South area. The population measures in these two areas are similar to those found in the park overall, although density estimates are consistently higher in the East analysis area and bull:cow ratios are notably higher in the Kantishna-South area.

Table 19. Moose cohort ratios, estimated populations, and densities (90% confidence intervals) for north side East area moose surveys, Denali National Park and Preserve, 1986-2008 (Owen and Meier 2009a).

Year	Calves/ 100 cows	Bulls/ 100 cows	Estimated population	Density Estimate moose/km^2	Source
1986	18	44	416 ± 149	0.53	Meier 1987
1987	23	37	319	0.58	Dalle-Molle 1987
1991	14	55	272 ± 43	0.34	Meier et al. 1991
2004	29	52	240 ± 37	0.26	Owen and Meier 2005
2008	13	36	304 ± 30	0.34	Owen and Meier 2009

Table 20. Moose cohort ratios, estimated populations, and densities (90% confidence intervals) for north side Kantishna-South area moose surveys, Denali National Park and Preserve, 1986-2008 (Owen and Meier 2009a).

Year	Calves/ 100 cows	Bulls/ 100 cows	Estimated population	Density Estimate moose/km^2	Source
1986	28	91	424 ± 123	0.27	Meier 1987
1991	11	132	395 ± 69	0.25	Meier et al. 1991
2003	9	105	276 ± 72	0.13	Owen 2004
2004	37	148	133 ± 64	0.08	Owen and Meier 2005
2008	38	73	228 ± 55	0.13	Owen and Meier 2009

The Cantwell and Yentna survey areas are shown on Plate 17. Unlike the majority of the north park survey area, hunting is allowed in large portions of these regions. In 2005, both the Yentna and Cantwell regions were surveyed in their entirety (Owen and Meier 2006). In the Cantwell area, 257 moose were observed with a calf:bull:cow ratio of 19:47:100. The overall density was 0.25 moose/km^2. Eighty-two percent of cows were without calves, 17% had one calf, and 1% of cows had two calves present. In the Yentna area, 41 moose were observed in a survey of 93% of the entire area, and the population was estimated at 42 (± 4 moose at 90% confidence interval). The overall density was extremely low (0.02 moose/km^2) with a calf:bull:cow ratio of 11:40:100. An estimated 93% of cows were without calves, 3.6% had one calf, and 3.8% of cows had two calves present. While the Cantwell numbers are somewhat similar to those from the north park area, the density and calf:cow ratios for the Yentna population are dramatically lower than those from north area surveys. A 1996 density estimate for the Yentna area of 0.5 moose/km^2 shows that moose density there had declined substantially from surveys conducted in 1984, 1992, and 1996 (Owen and Meier 2006).

The Cantwell and Yentna areas were surveyed again in 2008. As in 2005, all survey units in the Cantwell area were surveyed. A total of 255 moose were observed, a number nearly identical to the 2005 survey (Owen and Meier 2009b). The calf:cow ratio was significantly higher, at 28.5

calves:100 cows compared to 19 calves:100 cows in the previous survey. The bull:cow ratio of 40 bulls:100 cows was slightly lower than the 2005 ration of 47 bulls:100 cows (Owen and Meier 2009b). Table 21 shows the results of the 2008 Cantwell moose survey summarized by land management area. The Cantwell Traditional Use Area (TUA) is a part of the 1980 additions to Denali National Park in which local residents are allowed to hunt and conduct other subsistence activities.

Table 21. Results of 2008 Cantwell area moose survey by land ownership (DENA 2009b).

Bulls			Cows			Total	
Yearling	Med	Large	Lone	1 Calf	2 Calves	Moose	Land Status
4	10	10	49	12	0	97	Cantwell TUA
2	0	0	4	6	1	21	Adjacent State Land
1	1	3	7	2	0	16	New Park Not In TUA
11	13	6	50	19	1	121	Old Park Wilderness
18	24	19	110	39	2	255	Total

The Yentna area was surveyed in 2008 as part of an ADF&G aerial survey of GMU 16B south of Denali. Fifty moose were observed in 47 of the 121 survey units, producing a population estimate of 117 ± 69 moose for the entire survey area. The calf:bull:cow ratio was 18:57:100 (Owen and Meier 2009b). These numbers suggest a significant increase in moose numbers in the Yentna area, while the calf:cow ratio indicates an increase in calf recruitment since 2005.

Distribution

Plate 16 depicts moose locations observed during the 2008 surveys. No information is provided in recent reports regarding overall change in moose distribution over time.

Yost (1998) studied the distribution of moose along the park road and found two areas of high density, one in the east and one in the west. These are likely attributable to habitat availability, as willow and other shrubs are common in these areas but occur less frequently at the higher elevations in between. This suggests that moose distribution could be assessed based on habitat availability. Since preferred browse species are largely absent above 1100 m elevation, moose will rarely be found at such sites. Taller willow stands are particularly important for cows with calves as they provide cover and some protection from predation.

A study of sexual segregation of moose conducted in Denali found significant differences in the way the sexes utilize available habitat (Miquelle et al. 1992). During the spring and early summer females with calves remain solitary and prefer forested habitats in an effort to avoid predation while bulls are found in areas with high forage biomass. Sexual segregation was greatest in the winter when males remained in areas of high forage biomass and reduced travel distances. This is likely a survival strategy, since bull moose appear more vulnerable to winter starvation due to the greater energy costs associated with their size and lower fat reserves, particularly after the fall rut (Miquelle et al. 1992).

Threats and Stressor Factors

The park has identified harvest, climate change, front country development, and habitat fragmentation both in and outside the park and preserve as potential threats to the moose population (DENA 2009a). Earlier researchers (Fox 1996) noted additional stressors including weather, predation by wolves and bears, road traffic, visitor use, and poaching.

Since ADF&G harvest numbers are calculated by game management unit (GMU) and Denali includes portions of several different GMUs, no total harvest numbers could be found for the area within the Denali boundaries alone. Federal registration permit information has been summarized for GMU 13E for years 1991 through 2004, which includes portions of the southeast park (Table 22). On average, approximately five moose were harvested each year by federal subsistence users on GMU 13E park lands.

Table 22. GMU 13E moose harvest data, 1991-2004 by federal registration permits (DENA 2010b).

Year	Permits	Total Harvests by Cantwell Permits GMU 13	Total Harvests by Cantwell Permits on 13E Park Lands
1991	57	16	9
1992	50	6	2
1993	40	4	2
1994	27	3	2
1995	35	10	5
1996	34	6	5
1997	47	11	7
1998	51	7	3
1999	50	11	8
2000	42	2	2
2001	44	18	14
2002	50	6	0
2003	39	8	4
2004	42	-	4

The majority of Denali is located in GMU 20C. According to ADF&G (2008), hunting is “a minor factor affecting population dynamics” in this region. However there is some concern that harvest reporting is poor, resulting in an underestimate of harvest levels (ADF&G 2008). The only area of GMU 20C adjacent to DENA where moose harvest is likely to have any significant effect is the so-called "wolf townships" or Stampede corridor area that forms a notch in the northeast boundary of the park (DENA, Meier, pers. comm. 2011). This area is popular for moose hunting due to its relatively easy access and open habitats. Within GMU 20C, UCU units 502, 605, and 607 represent most of this area. Between 1983 and 2003, 682 moose were recorded as harvested in these three units, for an average of 32 moose per year (NPS 2006).

According to Gasaway et al. (1992), evidence suggests that predation by wolves and bears is the primary factor contributing to low-density moose populations. It is likely a key factor in calf mortality. Research during the 1980s found that in southcentral Alaska, brown bears were responsible for 79% of moose calf deaths during their first six weeks of life (Ballard and Miller 1990). A study conducted in the Sustina headwaters near Denali showed that a 60% reduction in the density of brown bears resulted in a 78% reduction in summer calf mortality (Ballard and Miller 1990). In another study from interior Alaska (Gasaway et al. 1992) predation was found to be the leading cause of death among yearlings and adults as well, with 89% of deaths due to grizzly bear and wolf predation.

Several studies addressing the impacts of human development on Denali wildlife suggest that moose are not significantly affected by the park road or other developed areas. Yost (1998) found that moose densities along the road were similar to those found in backcountry control areas. There was some evidence that moose may be avoiding the 200 meters closest to the road, with bulls showing a slightly higher sensitivity to traffic. It is difficult to say however if this observation is a direct impact of the park road, as results may be skewed by the amount of suitable habitat near the road. Burson et al. (2000) concluded that a decrease in sightings of moose from the park road since the 1970s was most likely not caused by increasing traffic but rather was the result of a decrease in the moose population and an increase in vegetation near the road screening moose from view.

A study of the impacts of additional developed areas (campgrounds, park offices, staff housing, etc.) found that moose distribution did not seem to be affected by human development (Belant et al. 2006). This evidence suggests that the "limited and predictable" nature of human activities within the park has allowed moose to become habituated to human presence. The authors note that any changes in the type or distribution of human activities in the park "could adversely affect moose distribution" (Belant et al. 2006).

Data Needs/Gaps

More research on the seasonal movements of moose within DENA would help in understanding whether or not survey timing influences the distribution and density of moose (Fox 1996). Additional information on how the various stressors (harvest, predation, weather conditions, and visitor use) impact the Denali moose population specifically would also be useful.

Overall Condition

According to DENA (2009a), the condition of the moose population in Denali is declining; however, this determination was made before the most recent aerial survey in 2008 found a slight population increase in the north side survey area. The most recent survey results suggest that the north side moose population may have stabilized. The apparent rebound in moose numbers in the Yentna survey area may be a result of decreased hunting pressure, as the state of Alaska has restricted moose hunting in that and adjoining areas to a "Tier 2" subsistence permit system, or to active predator control activities in areas adjacent to Denali National Preserve in GMU 16B (DENA, Meier, pers. comm. 2011). Moose numbers in the lightly harvested Cantwell area of Denali National Park remained constant between 2005 and 2008, with calf:cow ratios in 2008 suggesting that the population may be growing. Overall, the park-wide condition of moose populations appears to be favorable and stable.

Level of Confidence

Surveys with similar methodology have occurred in various portions of Denali north of the Alaska Range since 1986, providing a dataset for comparison of current condition to the 1987 to 2007 reference period. Although the scarcity of surveys during some years makes it difficult to determine detailed population trends, enough information is available to support an overall statement of current condition.

Sources of Expertise

The primary source of information for this assessment is Owen and Meier (2009a), which includes tables summarizing results of previous surveys in the park.

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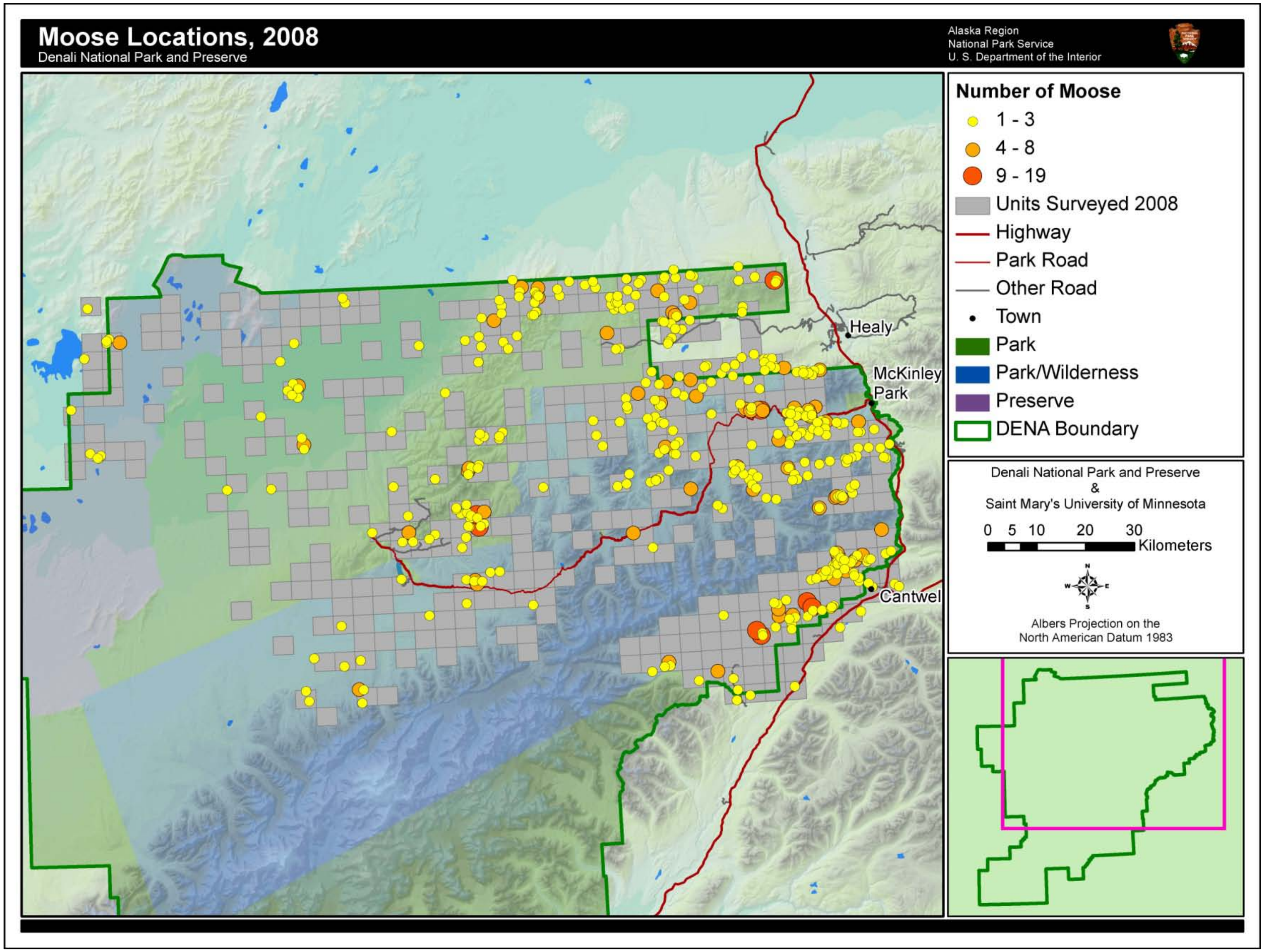


Plate 16. Moose: units surveyed and locations, 2008 (DENA 2008, NPS 2010).

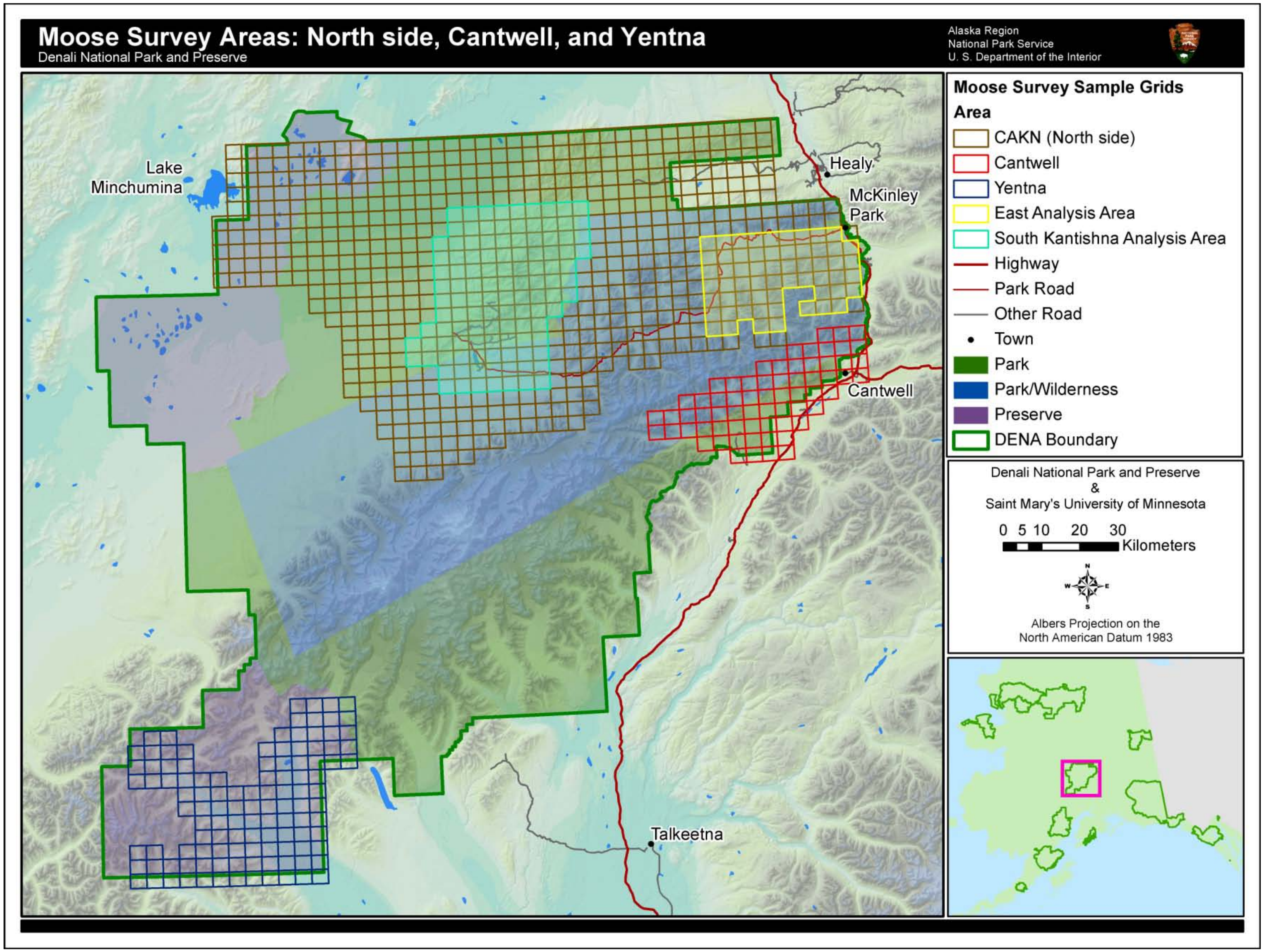
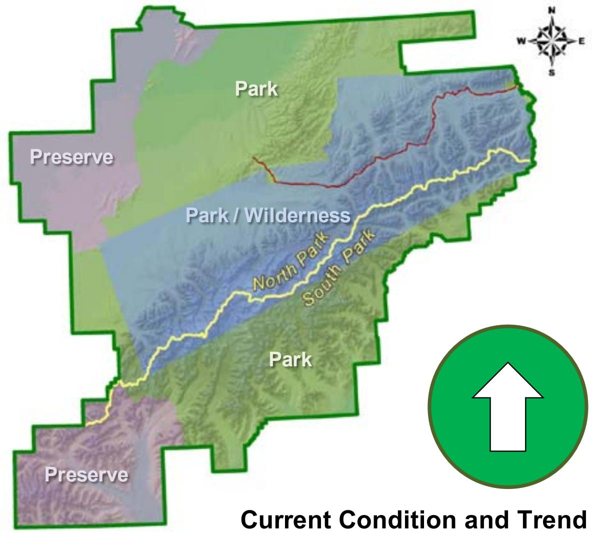


Plate 17. Moose survey areas: North side (including South Kantishna and East analysis areas), Cantwell, and Yentna (NPS 2010).

4.5 Trumpeter Swans (*Cygnus buccinator*)



Description

The trumpeter swan is one of two swan species found in Denali National Park and Preserve and is the only swan species that nests in the park and preserve (McIntyre 2006). Its 1.5 meter length and two meter wingspan earns it the honor of the largest species of waterfowl in North America and one of the largest waterfowl species in the world (USFWS 2010a, McIntyre 2006). Trumpeter swans are found in the wetlands and drainages of the northwestern part of Denali and all along the southern boundary. During an aerial survey in 2000, trumpeter swans were officially observed within the wilderness boundary for the first time in the survey's history (Figure 23).

Photo 10. Trumpeter swans in Denali (photo by R. Winfree, in McIntyre 2006).

Alaska's trumpeter swans belong to the Pacific Northwest population. Swans arrive at their Alaska breeding grounds from mid-April to early May to begin one of the longest nesting seasons among North American birds (McIntyre 2006). These swans are known to live 24 years in the wild, often returning to the same nesting area with the same mate for many years. Cygnets remain with their parents throughout the summer, partly for protection from predators. Evidence suggests that nesting swans are more successful at raising cygnets in areas with abundant invertebrate and/or aquatic plant populations (McIntyre 2006). At the end of the nesting season, trumpeter swans leave Denali and migrate to their wintering grounds along the Pacific Coast, including southeastern coastal Alaska, coastal and interior British Columbia, and western Washington (McIntyre 2006).

Trumpeter swans were once scarce in Denali and throughout North America. European settlement and overhunting reduced the known population to fewer than 70 swans near Yellowstone National Park in 1932 (USFWS 2010a). However this number did not include the Alaska breeding population, which was not discovered until 1954. While the abundance of trumpeter swans has greatly increased since the early 1960s, the population has not yet rebounded to its original size or distribution across North America (McIntyre 2006).

Measures
Population size
Distribution

Reference Conditions/Values
Aerial surveys of trumpeter swans in Alaska began in 1968 and have been conducted every five years since 1975. This provides sufficient baseline data for evaluating population condition and trends. The initial survey in 1968 found a large population statewide, and subsequent surveys have documented an increase in trumpeter swan numbers and distribution (McIntyre 2006).

Data and Methods
U.S. Fish and Wildlife Service biologists conducted the first statewide trumpeter swan census in 1968 as part of an overall assessment of the species which was listed as threatened under the Endangered Species Act of 1966 (McIntyre 2006). The survey found nearly 3,000 swans across the state, with 43 observed in the Denali region. The discovery led to the removal of the trumpeter swan from the Endangered Species List. This survey has been repeated every five years since 1975 to monitor summer productivity and stability of the population. In 2005, surveyors flew over all 128,325 km^2 of potential trumpeter swan habitat in Alaska (Conant et al. 2007). There are 11 delineated trumpeter swan survey units that are based on terrain features such as drainages and mountain ranges. The four units that contain portions of Denali National Park and Preserve are Gulkana, Cook Inlet, Lower Tanana, and Kuskokwim (Plate 18).

Aerial survey teams consist of a pilot-biologist and a primary observer. The survey occurs when cygnets are at least four to six weeks old, ensuring that the immature swans can be seen and counted, and before any pre-migratory movements occur (Conant et al. 2007). Surveyors fly 150 meters above the ground until a nest is located, then the pilot circles around the nest until the brood is accurately counted. More information on survey protocol can be found in Conant et al. (2007).

Current Condition and Trend

<u>Population Size</u>
The overall population of trumpeter swans in Alaska is following a logistic growth curve, with total population increasing since 1968 and population density increasing since 1975 (Conant et al. 2007). In 2005 a record high 23,962 swans were observed, a 38% increase over the 2000 survey. Reproductive success in 2005 was above average, with an increase in average brood size (3.1), and total number of broods leading to a 100% increase in number of cygnets over 2000 results (Conant et al. 2007). As a result, the percentage of cygnets in the 2005 population was 27.2%, surpassing the survey's average of 25.4% (Groves 2006). Given the surprising continual increase in Alaska trumpeter swan populations, scientists are unable to predict if or when the population will stabilize or possibly decrease (Conant et al. 2007).

The number of trumpeter swans summering in Denali has increased since the survey began in 1968 (Figure 22; McIntyre 2006). A summary of results from USFWS surveys is included in Table 23. This table includes only the survey units that fall partly within the park and preserve boundary.

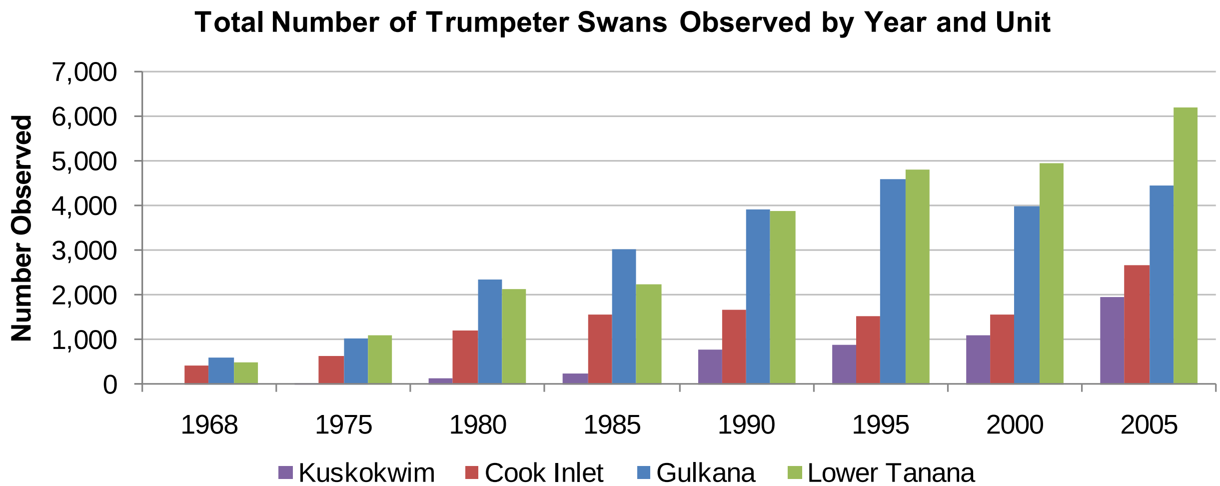


Figure 22. Total number of trumpeter swans observed in survey units containing land in DENA, 1968-2005 (Conant et al. 2007).

Table 23. Trumpeter swan survey results for units including land in DENA (From Conant et al. 2007).

Unit	Year	In Pairs	As Singles	In Flocks	Total White	Cygnets	Total Swans
Gulkana	1968	288	31	81	400	190	590
	1975	556	43	155	754	284	1,038
	1980	1,026	42	632	1,700	660	2,360
	1985	1,736	143	595	2,474	533	3,007
	1990	2,142	225	776	3,143	778	3,921
	1995	2,332	280	965	3,577	1,002	4,579
	2000	2,520	280	683	3,483	503	3,986
	2005	2,440	252	510	3,202	1,228	4,430
Cook Inlet	1968	224	19	50	293	124	417
	1975	340	36	60	436	181	617
	1980	608	38	186	832	369	1,201
	1985	800	66	454	1,320	241	1,561
	1990	904	79	162	1,145	516	1,661
	1995	838	91	269	1,198	330	1,528
	2000	938	57	219	1,214	331	1,545
	2005	1,470	196	310	1,976	694	2,670
Lower Tanana	1968	224	21	94	339	137	476
	1975	518	21	185	724	388	1,112
	1980	746	16	585	1,347	773	2,120
	1985	1,202	113	426	1,741	503	2,244
	1990	2,070	179	559	2,808	1,072	3,880
	1995	2,268	219	987	3,474	1,315	4,789

Table 23. Trumpeter swan survey results for units including land in DENA (From Conant et al. 2007) (continued).

Unit	Year	In Pairs	As Singles	In Flocks	Total White	Cygnets	Total Swans
	1985	1,202	113	426	1,741	503	2,244
	1990	2,070	179	559	2,808	1,072	3,880
	1995	2,268	219	987	3,474	1,315	4,789
	2000	2,788	227	1,026	4,041	901	4,942
	2005	3,054	305	1,040	4,399	1,786	6,185
Kuskokwim	1968	--	--	--	--	--	--
	1975	20	6	4	30	7	37
	1980	60	0	22	82	63	145
	1985	122	0	62	184	55	239
	1990	386	21	141	548	233	781
	1995	454	42	134	630	248	878
	2000	662	40	177	879	226	1,105
	2005	1,016	69	338	1,423	535	1,958

Distribution

Trumpeter swan locations in or near Denali during each survey year are shown in Figure 23. In general, trumpeter swans in Alaska are occupying habitat in higher densities and expanding their range. Conant et al. (2007) notes that swan density is still increasing in the best habitat in the Kuskokwim unit and that peripheral habitat use is increasing in both the Kuskokwim and Lower Tanana units. According to McIntyre (2006), over the past 30 years the distribution of trumpeter swans has expanded to pond and lake habitats at higher elevations in the northwestern portion of Denali. Conant et al. (2007) predicts that climate warming may create new habitat for swans, allowing distribution to continue expanding.

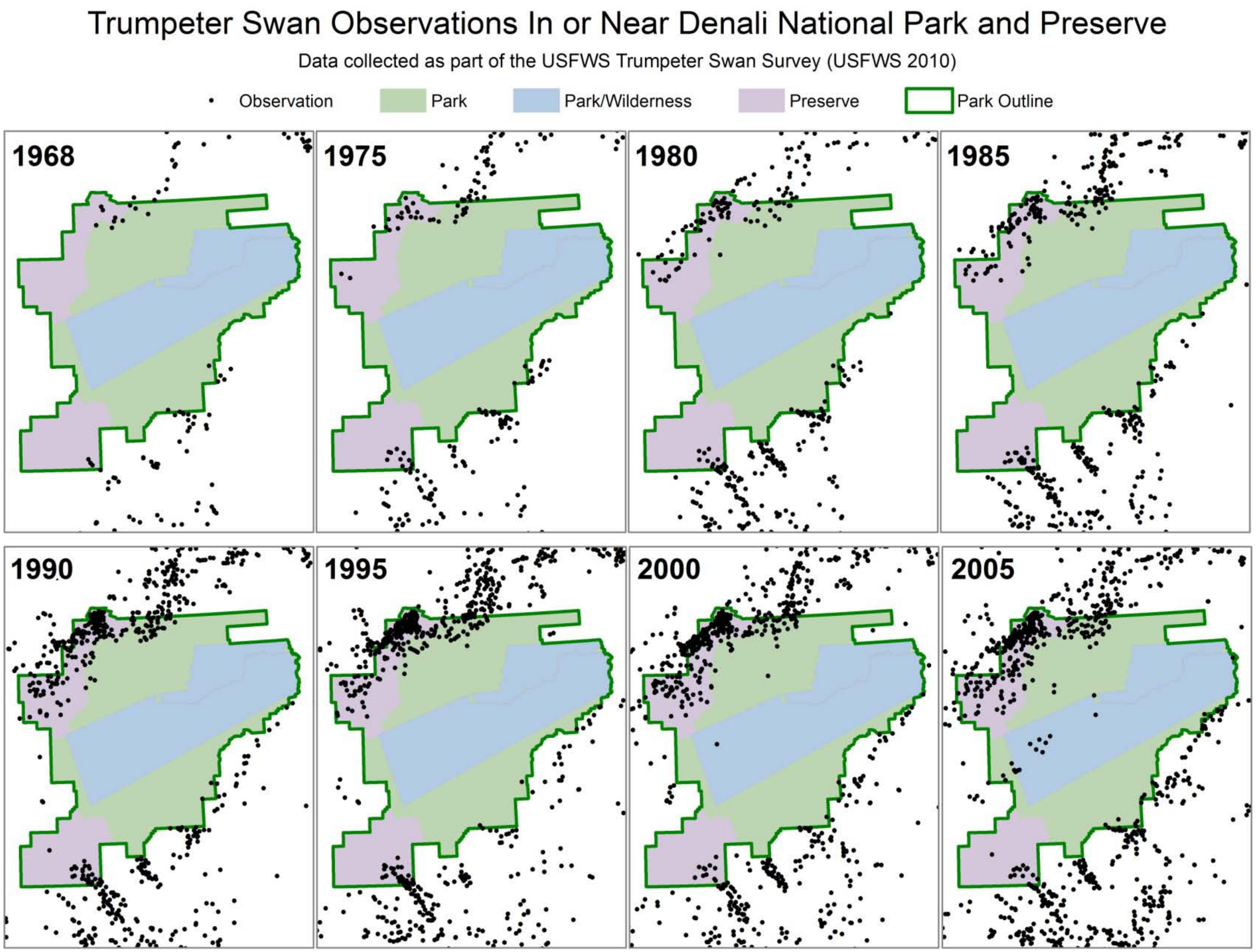


Figure 23. Trumpeter swan observations in or near DENA during the USFWS surveys, 1968-2005 (USFWS 2010b, NPS 2010).

One area where trumpeter swan distribution is of concern is south of the Alaska Range. In the past, a relatively high number of swans were observed along the Yentna River within the Denali boundary and in the Kahiltna and Tokositna drainages just to the south of the park and preserve, which may be important staging areas during migration (McIntyre 2001). Survey data indicated that fewer swans were observed in the upper reaches of the Tokositna River from 1995-2005 compared to 1975-1985. Long-term park employees are concerned that an increase in low-flying sight-seeing aircraft traffic is displacing swans in this area (McIntyre 2006).

Threats and Stressor Factors

The NPS has expressed concern about the effects of low-level aircraft traffic associated with flight seeing in areas on the south side of the Alaska Range (McIntyre 2006). Fewer nesting swans were found on the south side of the Alaska Range from 1995 to 2005 than from 1975 to 1985 (McIntyre 2006). More research is needed to understand how the trumpeter swan responds to aircraft traffic.

Climate change is a concern for trumpeter swans because they rely on aquatic habitats, and lake drying has been documented in Denali (CAKN 2008). In addition, the increase in numbers and mobility of people living in Alaska, as well as an increasing number of tourists also creates stress on swan habitat (Conant et al. 2007).

Since the Denali swan population leaves the park and preserve during the winter, it is impacted by events occurring outside the park and preserve boundary. Many trumpeter swans winter on grounds in southwestern British Columbia and northwestern Washington, where they are threatened by lead poisoning (Conant et al. 2007). Although lead shot has been banned in Washington and Canada, trumpeter swans contract lead poisoning from spent shot that has accumulated in their winter habitat for decades (McIntyre 2006). Ingesting one or two lead pellets is enough to kill a swan (McIntyre 2006). Large numbers of trumpeter swans began dying from lead poisoning in December 1999, and evidence of deaths continued through at least the winter of 2005-2006 (McIntyre 2006). The U.S. Fish and Wildlife Service, the Washington Department of Fish and Wildlife, and the Canadian Wildlife Service are working together to identify areas contaminated with lead shot and to create a strategy for clean-up (McIntyre 2006).

The Alaskan trumpeter swan population is also threatened by loss of habitat at their wintering grounds. Human encroachment and urbanization in the Pacific Northwest appear to be displacing swans from some of the best available aquatic habitat (Conant et al. 2007). Climate change may also have a negative effect on winter habitat.

Data Needs/Gaps

Aerial surveys by the USFWS should continue every five years so that population trends can be monitored to ensure effective management of the species. Research is clearly needed south of the Alaska Range to determine the impacts of aircraft traffic on trumpeter swans there. Conant et al. (2007) recommends the development of a comprehensive trumpeter swan management plan for both the Alaska summering areas and the Pacific wintering grounds.

Overall Condition

In general, population numbers and distribution of trumpeter swans in Denali are increasing. There is some concern that aircraft use in the southern parts of the park and preserve may be displacing some trumpeter swans. The species is believed to be near carrying capacity in Alaska and was removed from the Audubon Alaska Watchlist in 2010 (Kirchhoff and Padula 2010). Despite the improved condition, the species continues to appear on the National Audubon Society Watchlist due to the swan's vulnerability to human disturbance, habitat alteration, and lead poisoning (McIntyre 2006, National Audubon Society 2010).

Level of Confidence

The consistency in survey methodology since 1968 for monitoring trumpeter swan populations allows for a relatively high level of confidence in detecting change in population size and distribution.

Sources of Expertise

The primary sources of information for this condition assessment are results from the USFWS trumpeter swan surveys (Conant et al. 2007) and an article by McIntyre (2006).

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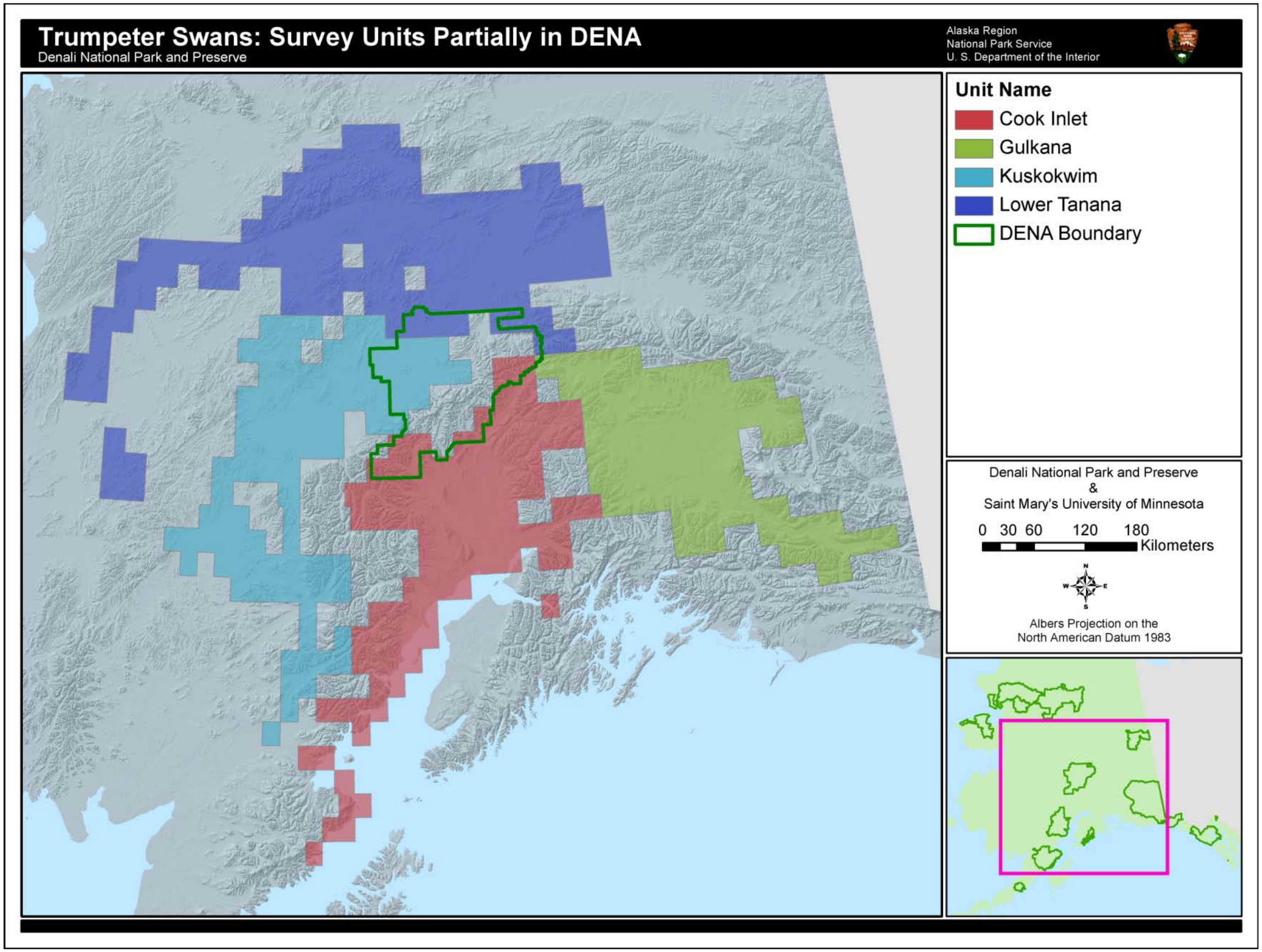
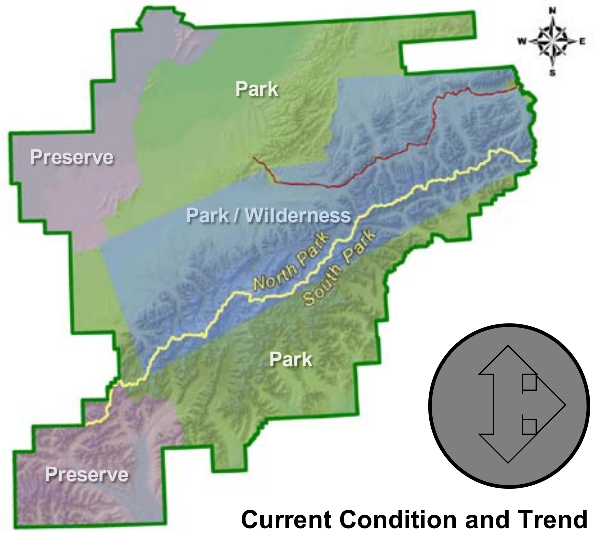


Plate 18. USFWS Trumpeter swan survey units which partially cover DENA (green outline) (USFWS, D. Groves pers. comm. 2010, and NPS 2010).

4.6 Breeding Birds (Passerine Birds)



Current Condition and Trend

Description

Birds make up more than 75% of the terrestrial vertebrates in Denali and are good indicators of ecosystem health on a larger scale because of their high body temperature, rapid metabolism, and high ecological position in most food webs (McIntyre and Paulson 2009, Peitz et al. 2002). Of all the land birds that occur in CAKN, members of the order Passeriformes, or passerines, are relatively easy and economical to detect and a single survey method can cover many common species (McIntyre and Paulson 2009). Passerines include a wide variety of species (e.g., flycatchers, thrushes, warblers, sparrows) that occupy many different habitats over many environmental gradients and may represent unique response variables in relation to changes in vegetation (Hutto and Young 2002, Jones and Bock 2002). These passerine bird communities are strongly tied to vegetation structure and composition (Roland and McIntyre 2006). This condition assessment will focus on passerine birds when specific results for this Order are available.

Measures

Diversity
Distribution
Frequency of occurrence

Reference Conditions/Values

According to DENA (2009) reference condition for breeding birds is “to be determined”. No comprehensive inventory of bird species has been conducted in Denali (DENA 2009). Currently, there are 119 species of birds known to breed (or nest) in Denali, and the park does not have the resources to study all 119 species. Twenty-eight of these species are year-round residents and 91 are migratory (McIntyre 2007).

Data and Methods

Various monitoring protocols have been used for breeding birds in Denali. The two survey protocols with the longest available datasets on a wide variety of bird species in the park and preserve are the North American Breeding Bird Survey (BBS) and the Christmas Bird Count (CBC). Both of these datasets follow protocols developed for the purpose of monitoring birds on a continental scale. Of these two programs, only the BBS data provide insights into breeding birds. Due to a change in observers in 2000 and concerns about the completeness of survey data prior to 2000, the conclusions that can be drawn from these data sources regarding change over time are limited.

The two BBS routes (Savage and Toklat) are part of the continent-wide BBS, which began in 1966 and is coordinated by the USGS and the Canadian Wildlife Service. The standard BBS survey route is approximately 24.5 miles long with survey points every half mile, resulting in fifty survey points (USGS 2001). At each survey point, all birds seen and heard within a quarter mile radius during a three minute interval are recorded. Data are available for the Toklat route for years 1982, 1983, 1986, 1987, 1991, and 1993 to the present (USGS 2010). Data are available for the Savage route for years 1986, 1987, 1989, 1991, and 1993 to the present (USGS 2010). The routes are depicted on Plate 19.

The Denali CBC is part of the international CBC which started in 1900 and is coordinated internationally by the National Audubon Society and locally by community members. Multiple volunteers survey a 15-mile radius on one day between 14 December and 5 January. The number of each species and the total number of survey hours are recorded each year. Data for the CBC is available for years 1967 to 1969 and 1993 to the present (National Audubon Society 2010). While this survey does not occur during the breeding season, it may provide useful information regarding winter birds in the area. According to DENA (2009), the CBC is the only ongoing bird project to focus on resident and wintering birds in the area.

Additional land bird monitoring has occurred through the NPS Inventory and Monitoring Program. In 1991, Denali was selected as a prototype park for the program (Boudreau and Timmons 2002). Referred to as the Long Term Ecological Monitoring (LTEM) Program, initial data collection for land birds was conducted from 1993 to 2001 in coordination with a Monitoring Avian Productivity and Survival (MAPS) project and from 1993 to 2001 by the Alaska Bird Observatory using point counts (DENA 2009). The point count transects were generally limited to spruce forest habitats accessible from the main park road (Boudreau and Timmons 2002). Sample sites for the MAPS project are depicted on Plate 20 and transects used for the Alaska Bird Observatory's point counts are shown on Plate 21. In 2001, the monitoring effort was revised and changed to the Passerine Monitoring Project, which later became part of the CAKN Vital Signs Monitoring Program (DENA 2009).

The revised surveys were integrated with the vegetation monitoring program with the objective of identifying relationships between the physical environment, vegetation, and songbird distributions, as well as detecting any fluctuations in these distributions in response to ecological change over time (McIntyre and Paulson 2009). From 2001 to 2008, sampling was conducted on Roland et al.'s (2003) minigrid sampling design (McIntyre and Paulson 2009). Sampling occurred on minigrids comprised of five rows of five points, each 500 meters apart. The minigrids were spaced in a macro-grid framework with 10 km between each minigrid (Roland and McIntyre 2006). Utilizing this randomized site selection procedure provides unbiased data about the status and trend of park resources over large spatial scales (McIntyre and Paulson 2009). Each point was sampled for ten minutes and included detection via visual, singing, aerial, and calling methods. The time interval (0 to 3 min, >3 ≤5 min, >5 ≤8 min, and >8 ≤10 min) and distance interval (10-m intervals up to 100 m, 25-m intervals to 150 m, and >150-m) were recorded for each observation (McIntyre and Paulson 2009). Minigrids sampled between 2002 and 2008 are depicted on Plate 22. Analyses of data collected from 2002 to 2008 suggested that some assumptions of distance sampling were not being met, and a revised protocol was implemented in 2009. The revised protocol uses a repeat sampling method that will be used on four roadside survey routes along the Denali park road and on a subset of minigrids off the road (DENA, McIntyre, pers. comm. 2010).

McIntyre (2007) compared bird observations made between 2001 and 2006 to historic bird observations made by Joseph Dixon (1926 and 1932) and Adolph Murie (1922-1962). The contemporary observations were from the BBS along the park road, off-road point transect surveys, and other fieldwork by Denali naturalists. McIntyre (2007) reported primarily on changes in whimbrel *(Numenius phaeopus)* and orange-crowned warbler *(Vermivora celata)* distribution and abundance, but other species were also included.

Additional research projects have been conducted on breeding birds in Denali. Due to the limitations of project scope and the focus of this assessment on breeding bird diversity, density, and distribution, these additional research projects are not summarized as part of the NRCA. These additional projects include a breeding ecology study of merlins (*Falco columbarius*), short-term nesting studies of northern hawk owls (*Surnia ulula*), and monitoring for H5N1 Avian Influenza in Arctic warblers (DENA 2009). Trumpeter swans and golden eagles have been monitored extensively in or near Denali and are discussed in separate sections of this assessment.

Photo 11. From left to right: Orange-crowned warbler (photo by K. Whitten, in McIntyre 2007), whimbrel (photo by W. Elder, in NPS 2010a), and northern hawk owl (DENA 2010).

Current Condition and Trend

<u>Diversity</u>
The species richness per year is summarized for the BBS in Figure 24 and for the CBC in Figure 25. Most years the Toklat BBS route had higher species richness than the Savage BBS route. The number of species reported in recent years is within the range of values reported since data collection began.

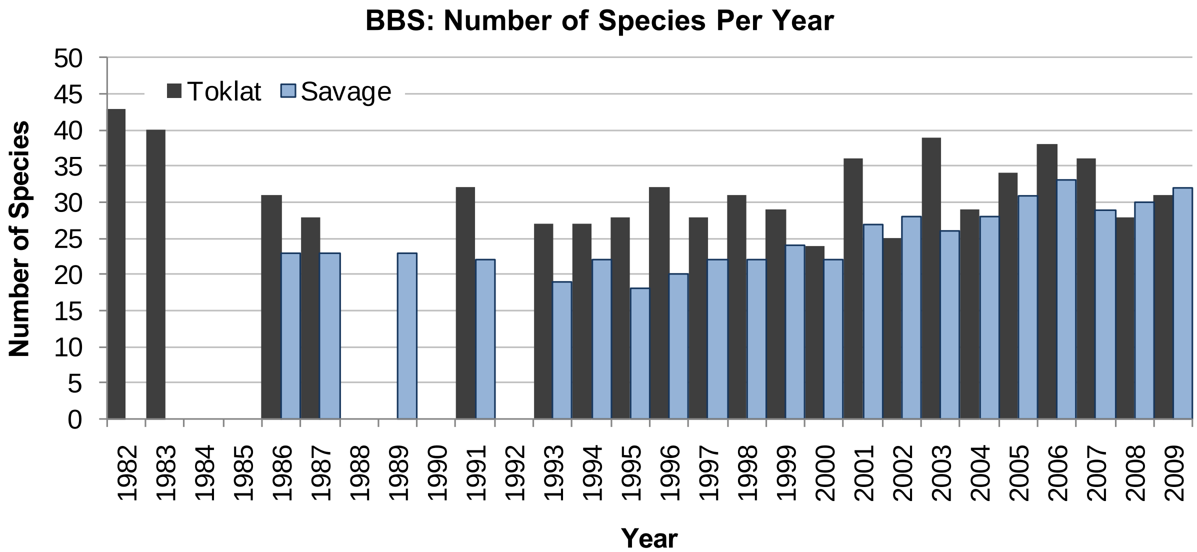


Figure 24. Breeding bird surveys: Number of species per year, 1982-2009 (USGS 2010).

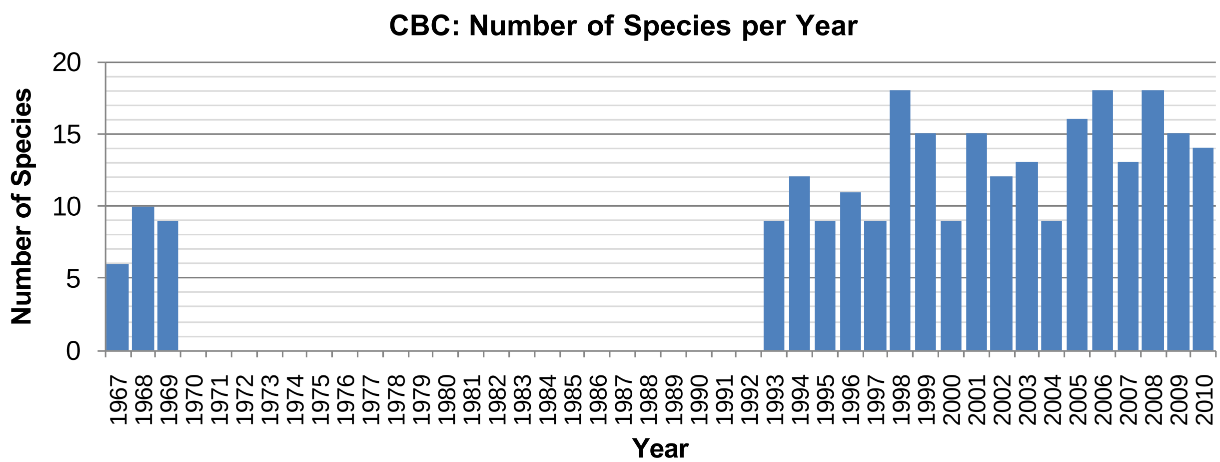


Figure 25. Christmas bird count: Number of species per year. 1967-1968, 1993-2010 (National Audubon Society 2010).

<u>Distribution</u>

McIntyre (2007) found that initial comparisons of historic bird observations and bird observations from 2001 to 2006 suggest that the distribution and abundance of several species has changed within the last century (Table 24; McIntyre 2007). For example, observers historically reported whimbrels to be common breeders along what is now the Denali park road. Recently, whimbrels have rarely been observed within a half mile of the road. Conversely, orange-crowned warblers were rarely reported in historic accounts but were "one of the most common species encountered" during recent surveys (McIntyre 2007).

Table 24. A sample of species that have either increased or decreased in abundance, shifted their distribution, or exhibited no change in abundance or distribution between historic observation (1922 to 1962) and contemporary observations (2001 to 2006) in Denali National Park and Preserve, Alaska (McIntyre 2007).

Species that have decreased in abundance or shifted their distribution	**Species that have increased in abundance or shifted their distribution**	**Species that exhibited no change in abundance or distribution**
• American Golden Plover *(Pluvialis dominica)* • Red-necked Phalarope (*Phalaropus lobatus)* • Bank Swallow *(Riparia riparia)* • Northern Wheatear *(Oenanthe oenanthe)* • Lapland Longspur *(Calcarius lapponicus)* • Rusty Blackbird *(Euphagus carolinus)*	• Wilson's Snipe *(Gallinago delicata)* • Black-billed Magpie *(Pica hudsonia)* • Ruby-crowned Kinglet *(Regulus calendula)* • Savannah Sparrow *(Passerculus sandwichensis)* • Lincoln's Sparrow *(Melospiza lincolnii)*	• Merlin (*Falco columbarius)* • Golden Eagle (*Aquila chrysaetos*)

Frequency of Occurrence

The number of individual birds observed during the Toklat and Savage BBS is summarized in Figure 26. A change in observer is a possible reason for the increase in abundance observed in 2001. The number of birds observed in recent years is within the range of values observed since data collection began.

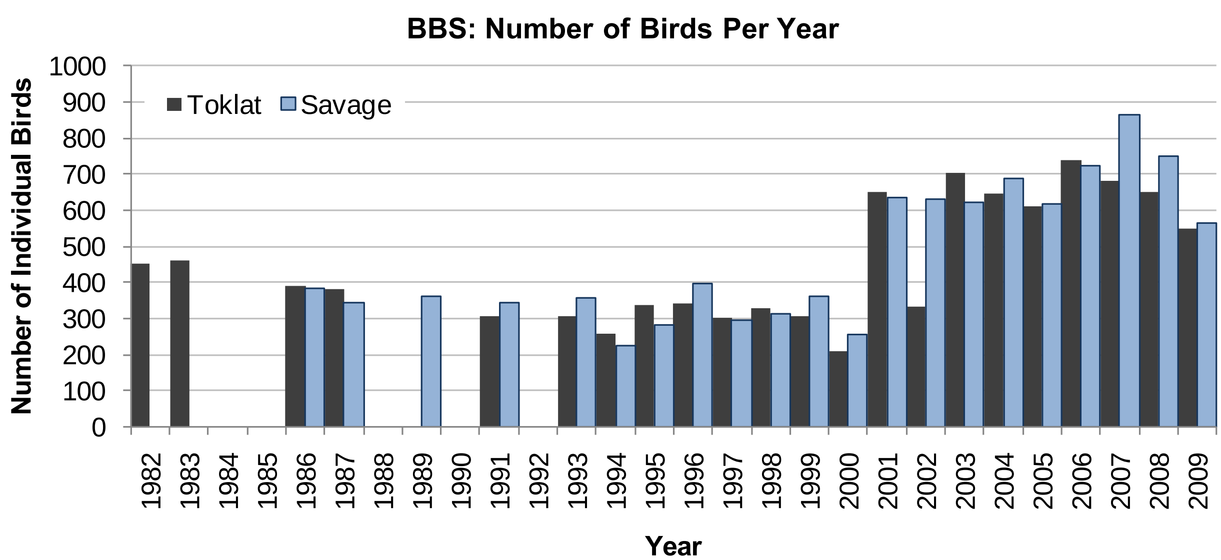


Figure 26. Breeding bird surveys: Number of birds per year, 1982-2009 (USGS 2010).

The total number of birds observed per survey hour each year during the CBC is depicted in Figure 27. The years refer to the end year of the CBC. The number of birds observed in the CBC ending in 2010 was within the range of values reported since the count began.

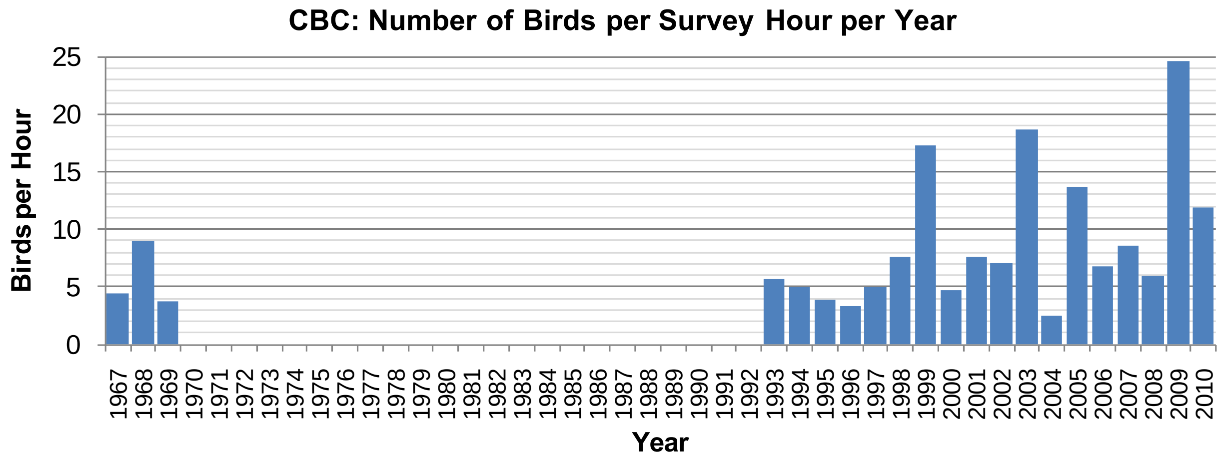


Figure 27. Christmas bird count: Number of birds per survey hour per year (Audubon Society 2010).

Several species from the Audubon Alaska Watchlist 2010 have been observed during BBS over the past decade. These observations are shown in Table 25. One species of concern, the varied thrush (*Ixoreus naevius*), appears to be increasing in numbers on the Savage route.

Table 25. Occurrence of species on the Audubon Alaska Watchlist (Kirchoff and Padula 2010) during the Denali BBS. Species in bold are also considered "birds of conservation concern" in Alaska by the USFWS (2008).

Route/Species	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Toklat										
American golden-plover	1	2	3	1	1	1	4	2	0	2
Blackpoll Warbler	0	0	0	1	0	0	0	0	0	2
Green-winged teal	5	1	0	0	0	0	2	1	0	1
Greater white-fronted goose	0	2	0	0	0	0	8	0	2	0
Surfbird	0	0	0	1	0	0	0	0	0	0
Varied thrush	0	0	0	0	0	1	0	1	0	0
Wandering tattler	0	0	2	0	0	0	0	1	0	0
Whimbrel	0	2	0	1	0	0	0	1	0	1
Savage										
Blackpoll warbler	0	0	0	1	4	0	1	0	1	0
Olive-sided flycatcher	0	0	0	0	0	0	0	0	1	0
Surfbird	0	0	0	0	0	0	0	0	0	1
Varied thrush	5	5	3	0	5	6	9	27	15	17
Whimbrel	0	0	1	0	0	0	0	0	0	0

Threats and Stressor Factors

DENA (2009) identified the following stressors for breeding birds: habitat change in the park and preserve, loss of wintering habitat, loss of lakes and ponds, and lead poisoning on wintering grounds. Other stressors include trophic mismatches resulting from a warming climate (e.g., seasonal bird behavior is out of sync with earlier growing seasons), changes and loss of habitat along migration routes, and barriers to migration including communication towers, buildings, and feral and domestic cats (DENA, McIntyre, pers. comm. 2010).

Researchers have noted that active layer depth (the depth to which frozen soils melt during the summer) is a strong predictor of vegetation patterns within the park (Roland and McIntyre 2006). Bird abundance and distribution, in turn, is greatly influenced by vegetation structure and composition. If active layer depth increases from melting permafrost as a result of climate change, the vegetation patterns could be altered, affecting bird habitat (Roland and McIntyre 2006).

<u>Data Needs/Gaps</u>
DENA (2009) noted the need for a park-wide bird inventory to assess the presence, distribution, and breeding status of all species within the park. This is particularly important given the rapid population declines of several species that occur in the park (e.g., blackpoll warbler, rusty blackbird) and the potential negative impacts of climate change on wetland and alpine birds (DENA 2009). Most bird research has occurred during the breeding season, resulting in a lack of knowledge about the ecology of resident bird species (DENA 2009).

A new survey protocol is currently under development (DENA, McIntyre, pers. comm. 2009). This method will provide estimates of relative abundance and occupancy on a park-wide scale using both on-road and off-road surveys. The on-road surveys involve conducting repeated surveys along the park road from mile 0 to the end (about 180 points). These points are sampled at least three times during the breeding season and used with the occupancy model approach to estimate probability of detection, relative abundance and presence. The off-road surveys are in progress, and researchers are developing an occupancy modeling approach for these surveys.

<u>Overall Condition</u>
According to DENA (2009), the current condition of breeding birds in the park is unknown. Recent reports of abundance and species richness observed during the BBS and CBC counts are within the range of values reported since the beginning of data collection. McIntyre (2007) suggests that the distribution and abundance of many species has changed since historic observations.

Level of Confidence
As a result of resource constraints as well as the size and remoteness of Denali, it is extremely difficult to assess the abundance and distribution of the birds (McIntyre 2007).

Sources of Expertise
This assessment relied primarily on McIntyre 2007, McIntyre and Paulson 2009, and BBS data from USGS (2010).

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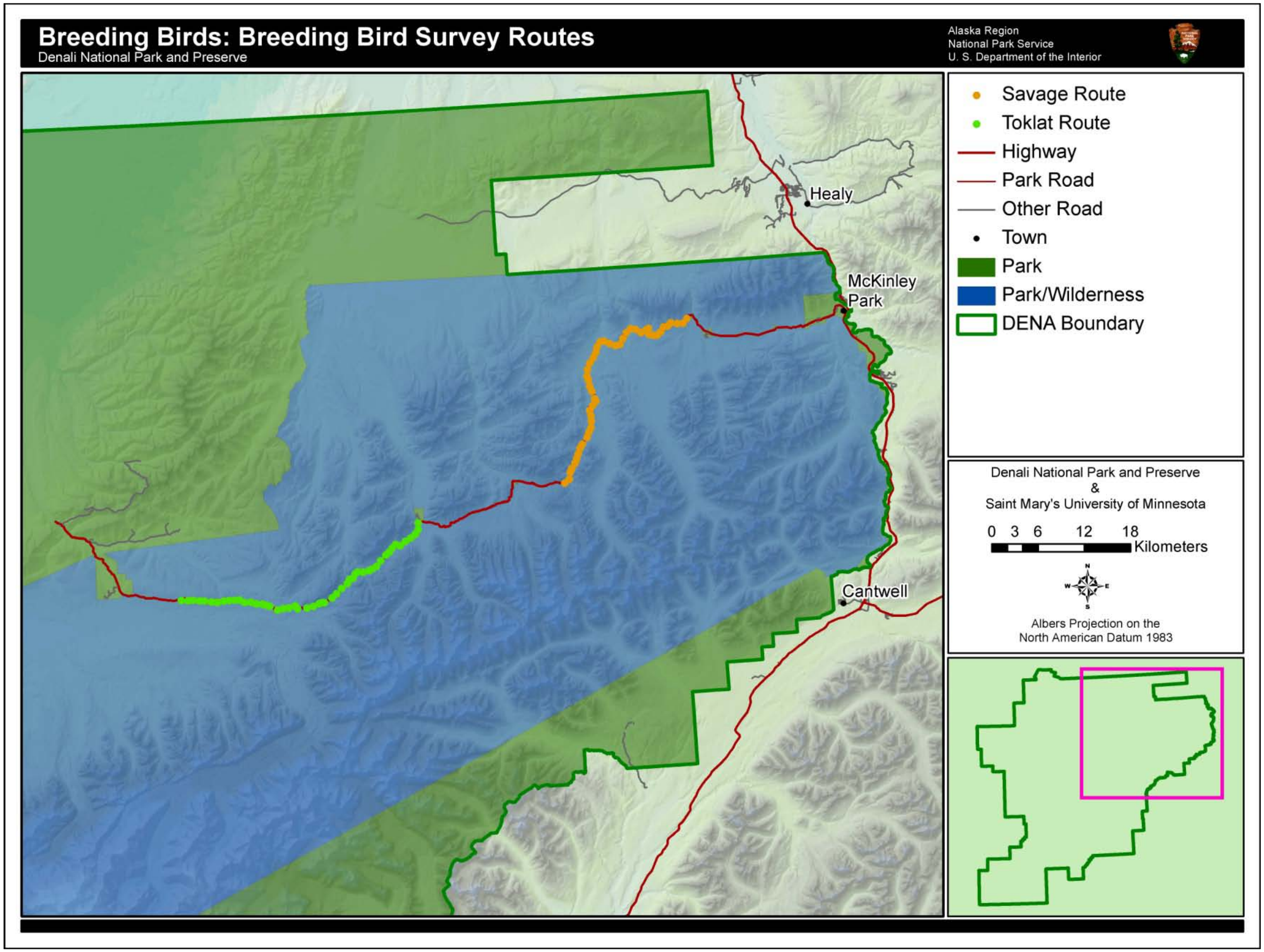


Plate 19. Breeding Birds: Savage and Toklat breeding bird survey routes (McIntyre 2010a).

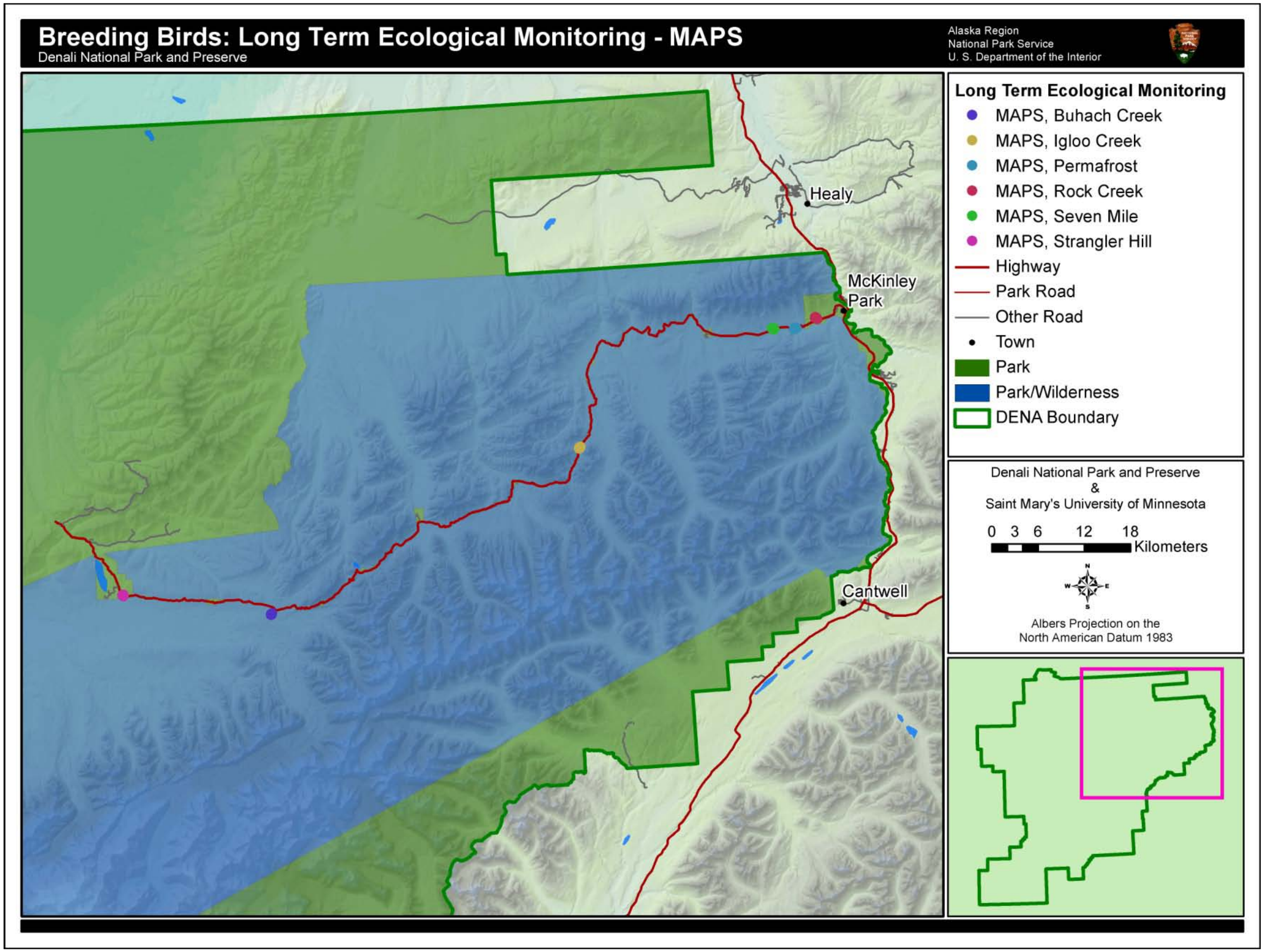


Plate 20. Breeding birds: Long term ecological monitoring sites for the MAPS program (NPS 2010b).

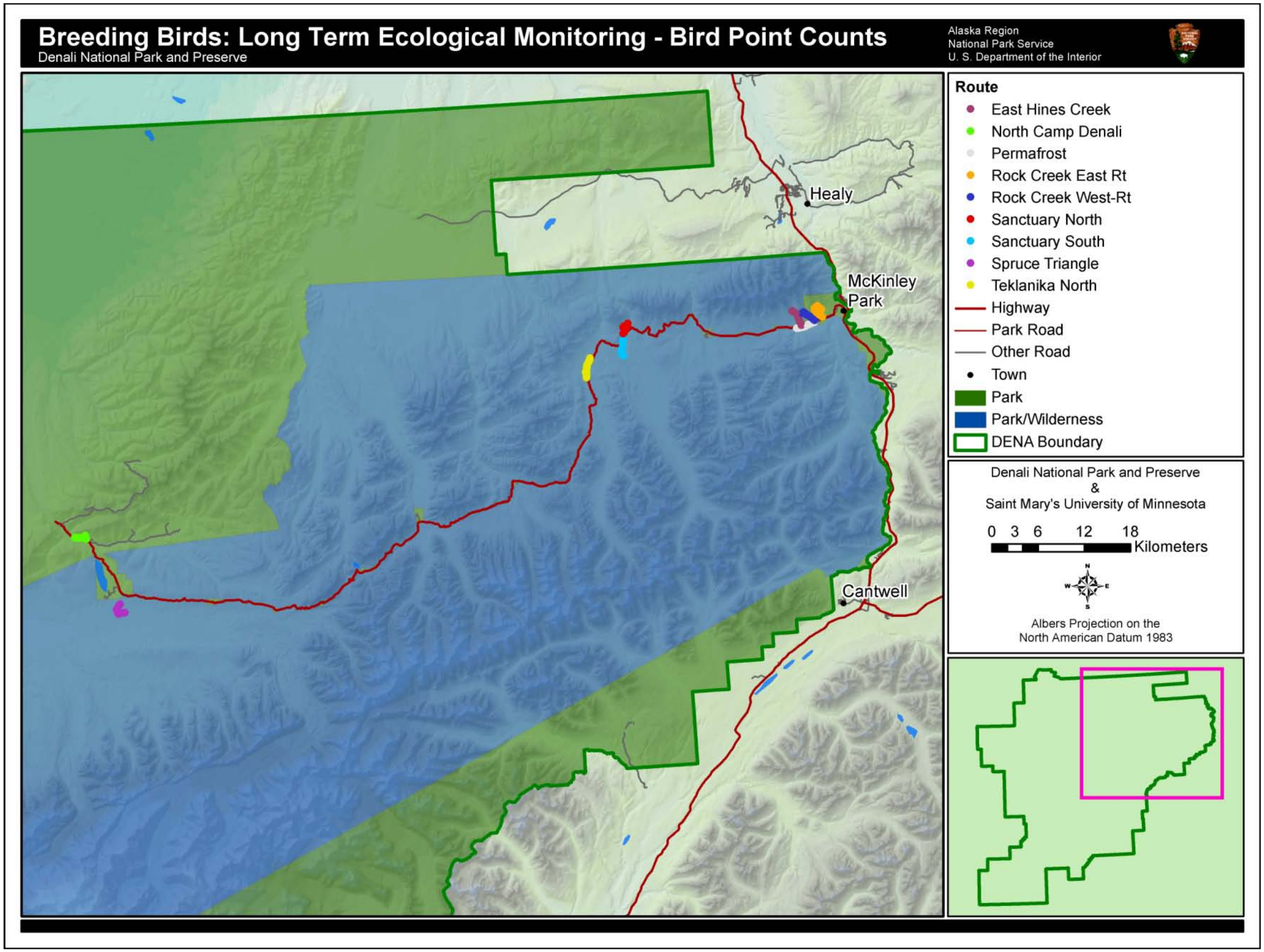


Plate 21. Breeding birds: Long term ecological monitoring point count sites (NPS 2010b).

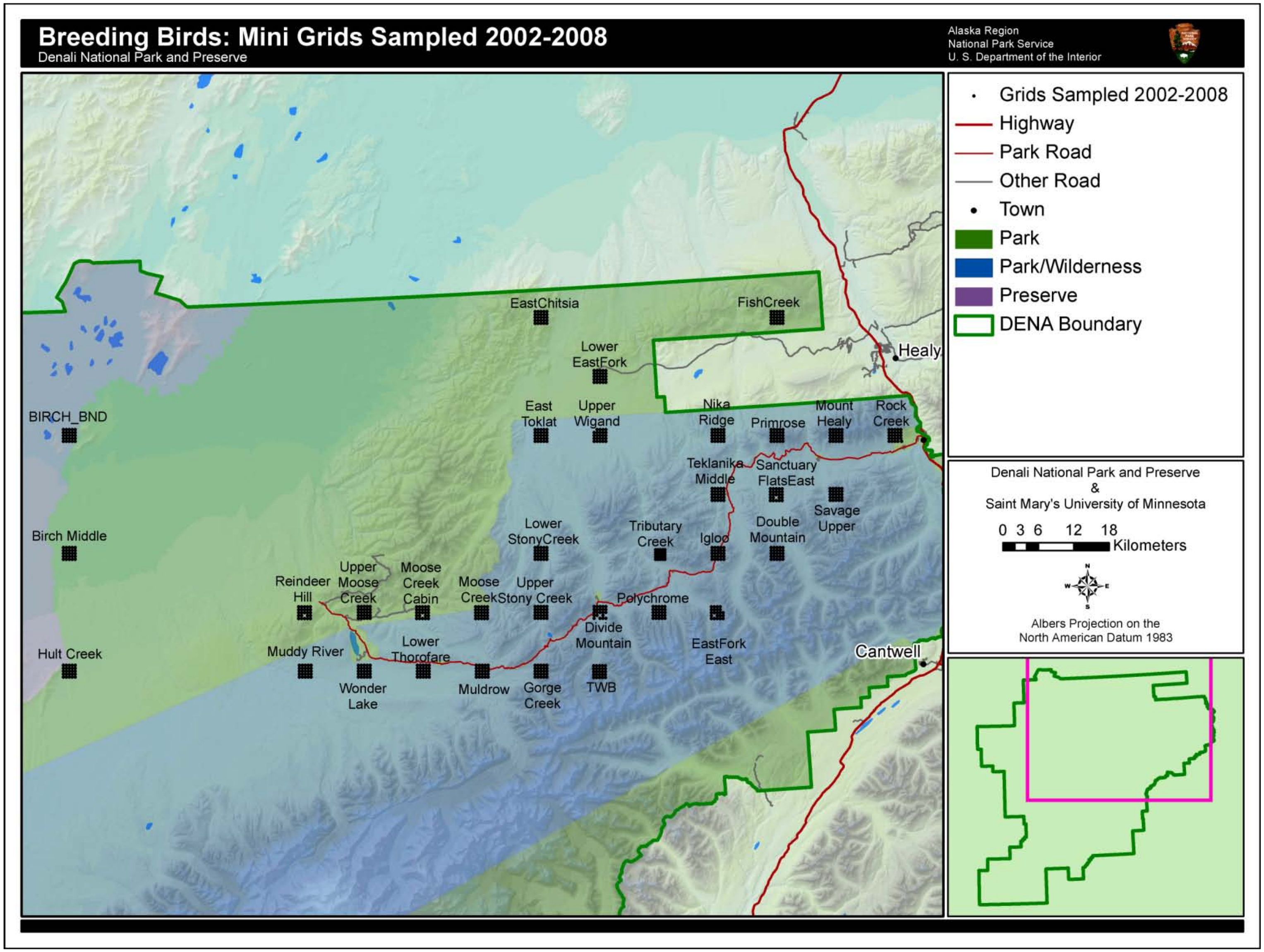
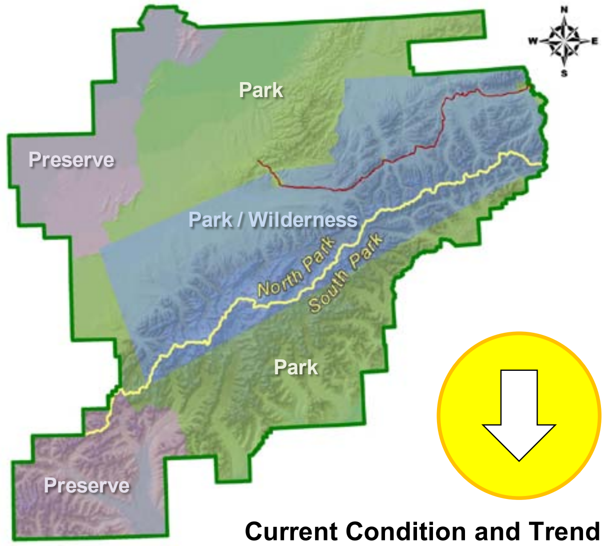


Plate 22. Passerines: All mini grids sampled 2002-2008 (McIntyre 2010b).

4.7 Wolves (*Canis lupus*)



Current Condition and Trend

Description

Wolves are one of the six keystone species of large mammal in Interior Alaska and are a top predator in Denali National Park and Preserve (Meier 2005, 2009). The enabling legislation and management objectives of Denali specifically mention the protection of wolf populations and habitat. Wolves in Denali prey mostly on ungulate species but also on beaver, snowshoe hare, and salmon. Evidence shows that wolves tend to prey on very young or very old animals, particularly moose, caribou, and Dall's sheep (DENA 2009a). As predators of ungulate species, wolves are very important to the park and preserve ecosystem. They have a significant impact on ungulate population size, which directly affects subsistence harvest opportunities and indirectly affects vegetation patterns (Mech et al. 1998, Meier 2009).

Photo 12. Wolf pup along the park road (photo by Kent Miller, in DENA 2010a).

Denali is one of a very few places in the world where wolf mortality is not primarily caused by humans and, as such, it provides researchers with the opportunity to study wolf population dynamics in a relatively pristine environment (DENA 2009a). Wolf data from Denali and other Alaska parks has proved valuable in developing scientific models of predator/prey systems. In addition, regular monitoring of wolves helps park managers minimize human disturbance, particularly at sensitive den sites (Meier 2009).

Measures

Population size
Distribution

Reference Conditions/Values

Wolves within Denali National Park and Preserve have been regularly monitored since 1987. This 25 year record represents the best information upon which to base natural variability and reference condition of the Denali wolf population. This is supported by DENA (2009b) which recognizes that population size and demography of wolves "within the range observed from 1987-2007" is the desired condition for this species. Prior to 1987 research efforts were widely distributed, often anecdotal in nature and inconsistent in study design.

Data and Methods

Wolf populations have been monitored using radiocollars and GPS collars since 1986. Each year 15 to 20 wolf packs occupying land within the Denali boundary are monitored (Meier 2009). Non-collared wolf packs are located using snow tracking, and one to three wolves per pack are captured and collared. GPS collars record the location of the wolf once per day. Radio-collared wolves are usually located twice per month using aircraft equipped with tracking antennae. Since the study began, surveyors have collected information on 350 different wolves (DENA 2009a). A summary of wolf monitoring and results is included as Table 26.

Table 26. Spring and Fall wolf monitoring and results, Denali National Park and Preserve, 1986-2010 (Mech et al. 1998, Meier 2009, 2010).

Year	Number of Packs Monitored		Total Wolves in Packs Monitored		Combined Area of Monitored Packs (km^2)		Estimated Density: Wolves / 1000 km^2		Population Estimate Inside the Park	
	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
1986	4	4	26	22	7,380	8,180	3.5	2.7	61	46
1987	8	9	37	70	12,125	13,150	3.1	5.3	53	92
1988	14	14	69	121	15,355	14,670	4.5	8.2	78	142
1989	13	11	98	127	16,810	15,240	5.8	8.3	101	144
1990	10	11	106	136	13,930	13,930	7.6	9.8	131	169
1991	13	13	111	137	14,275	14,275	7.8	9.6	134	166
1992	15	15	103	120	13,620	13,620	7.6	8.8	131	152
1993	12	12	68	93	9,900	9,900	6.9	9.4	119	162
1994	10	12	61	72	11,145	11,145	5.5	6.5	95	112
1995	12	11	59	80	12,120	12,045	4.9	6.6	84	115
1996	11	11	69	104	12,640	12,776	5.5	8.1	94	141
1997	11	12	78	75	13,080	12,808	6	5.9	103	101
1998	12	12	61	68	13,121	12,578	4.6	5.4	80	93
1999	13	15	69	80	12,699	12,699	5.4	6.3	94	109
2000	17	18	71	112	14,378	14,554	4.9	7.7	85	133
2001	16	18	87	91	13,802	13,802	6.3	6.6	109	114
2002	15	14	73	86	13,026	12,226	5.6	7	97	121
2003	18	11	75	84	11,682	11,682	6.4	7.2	111	124
2004	14	14	78	78	16,061	14,630	4.9	5.3	84	92
2005	15	15	66	106	14,630	15,367	4.5	6.9	78	119
2006	15	17	103	111	15,367	17,439	6.7	6.4	116	110
2007	16	20	93	147	17,439	17,757	5.3	8.3	92	143
2008	20	14	99	86	17,757	16,607	5.6	5.2	96	89
2009	16	15	65	80	16,607	16,607	3.9	4.8	68	83
2010	12		59		17,061		3.5		60	

Current Condition and Trend

Population Size

Over the past twenty-five years, the estimated wolf population density in the spring has fluctuated between 3.1 and 7.8 wolves per 1000 km^2 (Figure 28). Fall population densities show an even wider range of 2.7 to 9.8 wolves per 1000 km^2. All estimates of population density in recent years have been within values observed from 1987 to 2007, although they are increasingly at the low end of the range. The most recent survey in spring of 2010 found an estimated population density of 3.5 wolves per 1000 km^2, the lowest number reported since 1987 (Meier 2010). As of 2009, researchers could not identify a clear reason for the recent low density estimates, but have no reason to believe that wolf density will not return to the higher rates previously observed (Meier 2009). The estimated number of individual wolves in Denali has fluctuated from 46 to 169 since 1986 (Figure 29). The spring 2010 survey estimated the wolf population at 60 individuals, the lowest level reported since 1987.

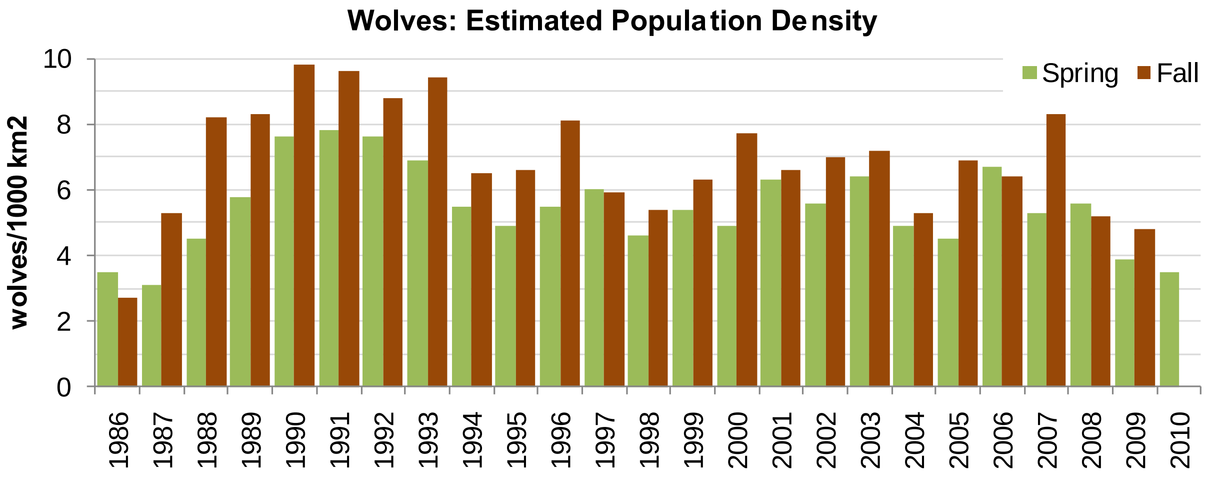


Figure 28. Wolf density estimates, Denali National Park and Preserve, 1986-2010, spring and fall estimates (Mech et al. 1998, Meier 2009, Meier 2010).

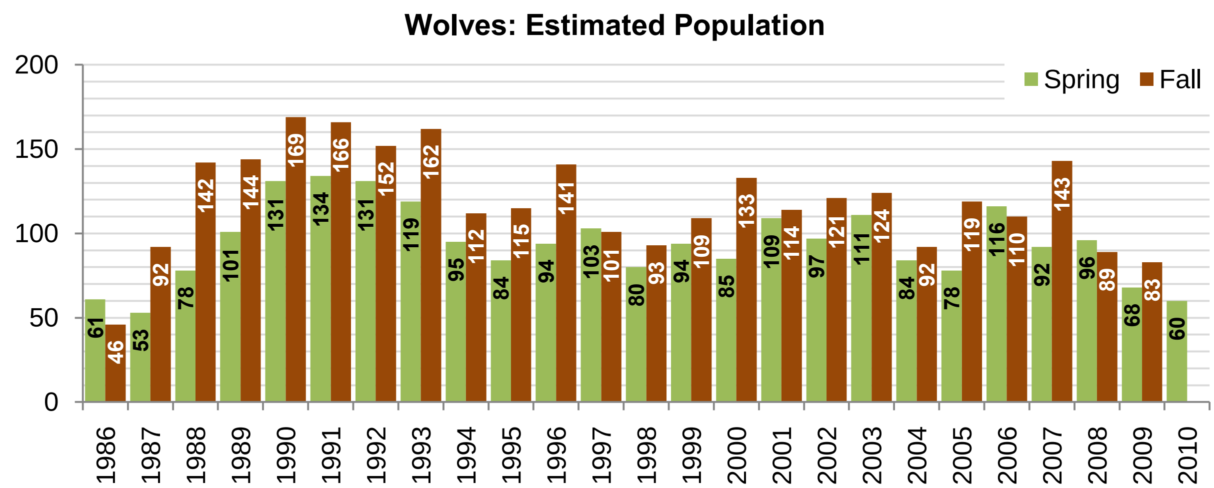


Figure 29. Estimated spring and fall wolf population in Denali National Park and Preserve, 1986-2010 (Mech et al. 1998, Meier 2009, Meier 2010).

During the late 1980s and early 1990s, data was gathered on wolf pup numbers to estimate wolf productivity. The best pup counts were from the air during fall (Table 27). Pups in some packs were also counted in early summer and a comparison of these numbers with fall counts indicated that average pup survival over summer was 91% or greater (Mech et al. 1998).

Table 27. Wolf pup observations for all Denali-area packs during fall aerial surveys, 1987-1993 (Mech et al. 1998).

Year	Fall pup numbers
1987	28
1988	64
1989	52
1990	53
1991	53
1992	54
1993	37

Distribution

Radiotracking of collared wolves in spring 2010 documented 59 wolves in 12 packs over a range of 17,061 km^2 north of the Alaska Range and generally within the park and preserve boundaries (DENA 2010d). Wolf pack territories delineated in 2010 are depicted in Figure 30. Wolf locations obtained through radio and GPS collars are depicted on Plate 23 and Plate 24. Known wolf den locations mapped from 1992 to 1994 are depicted on Plate 25. Several additional and more recent den locations likely exist in the park and preserve, but have not been mapped.

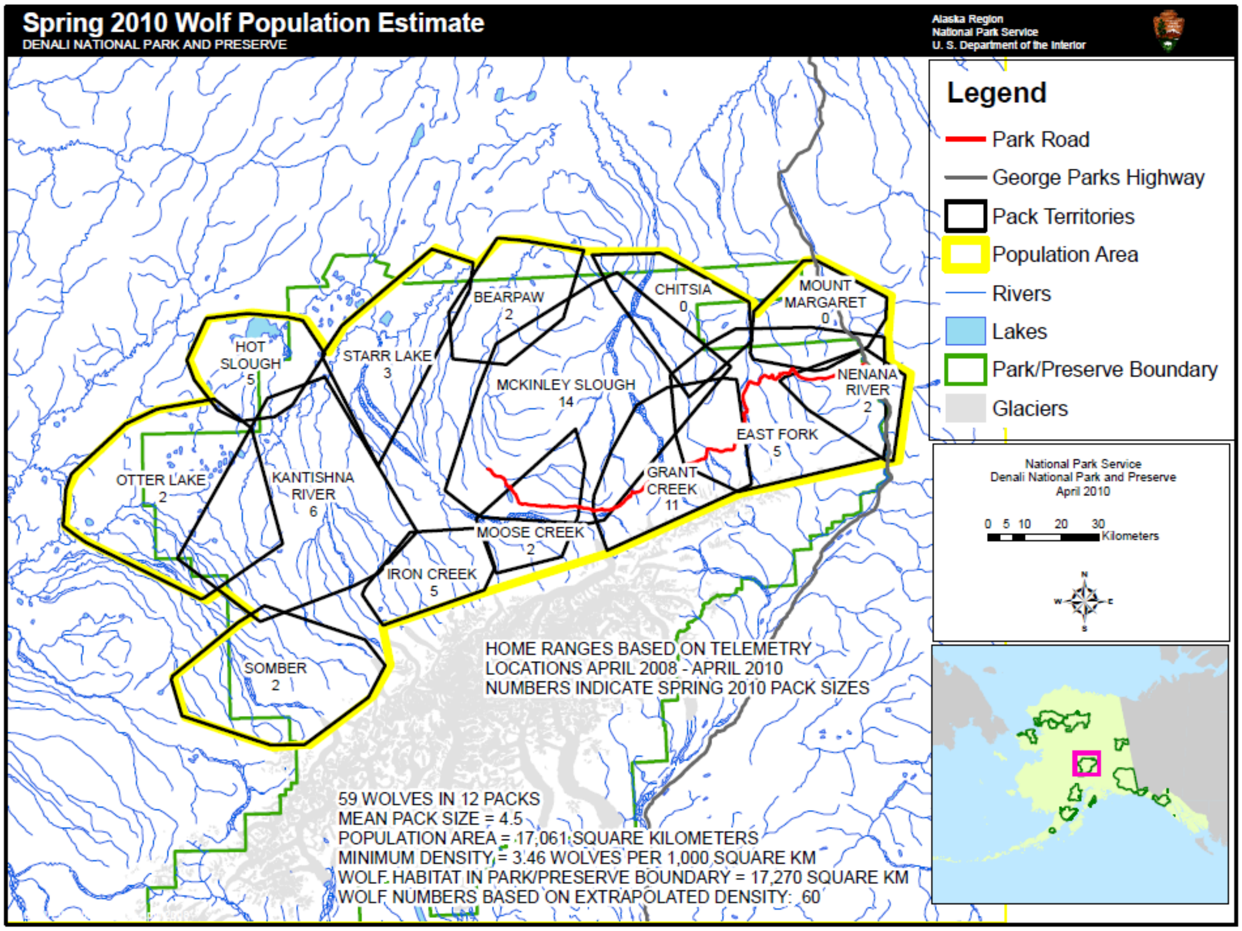


Figure 30. Wolf pack territories and population estimate for Denali National Park and Preserve, 2010 (from Meier 2010).

Wolf distribution is driven by the location of prey species. Haber (2007) conducted an extensive investigation of the seasonal distribution and movements of wolf packs in Denali. In the eastern portion of the park and preserve where sheep and moose are available throughout the year, wolf packs typically remain in the same territories year round (Haber 2007). In the central region of Denali, wolves are more dependent on caribou for prey and migrate northeast with the caribou in the winter (Haber 2007). Competition between these migratory packs and resident packs often leads to conflict, sometimes resulting in wolf fatalities (Haber 2007).

Threats and Stressor Factors

DENA (2009b) identifies the following as potential threats to the wolf population: predator control activities near the park, excessive harvest, and lack of public sympathy. While there is no hunting or trapping within the wilderness boundary, subsistence hunting and trapping are allowed in the 1980 ANILCA park additions and both sport and subsistence harvest occur in the Denali National Preserve areas. Meier (2009) suggests that rates of wolf mortality due to humans have increased in recent years. From March 2003 to March 2009, 35% of radiocollared wolves that died were killed by humans. This is a significant increase from 1986 to 1994 when only 14% of radiocollared wolf deaths were human-caused (Meier 2009). Over the years, legal subsistence hunting within park and preserve boundaries has consistently accounted for only 10% of human-caused deaths of radiocollared wolves.

In 2010, the Alaska Board of Game voted to eliminate areas closed to wolf harvest just outside Denali's northeastern border (Figure 31; DENA 2010b). It is expected that this will increase the number of Denali wolves vulnerable to legal hunting and trapping. These previously closed areas are sometimes utilized by the packs with territories along the park road, raising concerns that increased harvest pressure could impact wolf viewing opportunities at Denali (DENA 2010b).

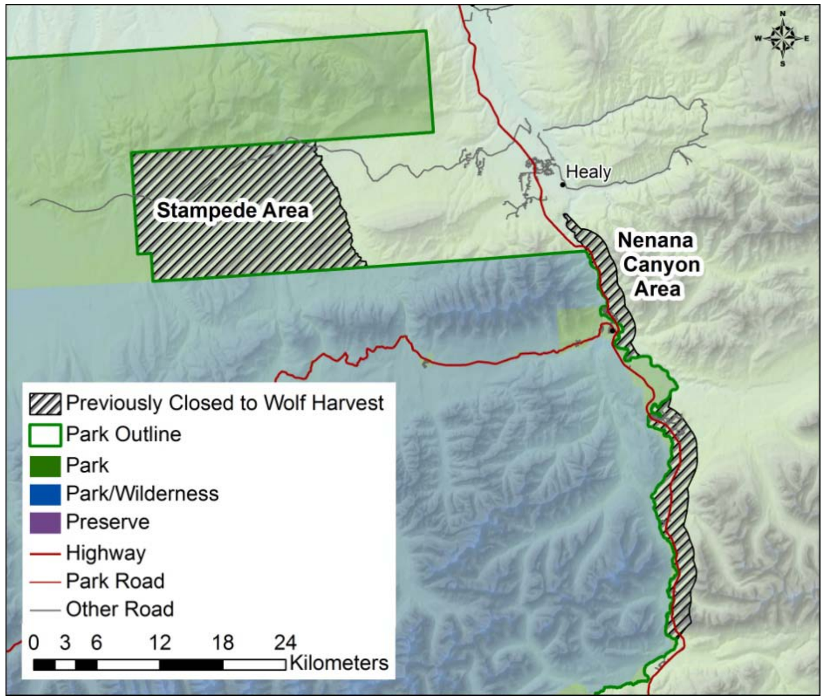


Figure 31. Areas near the DENA boundary opened to wolf harvest in 2010 (NPS 2010).

There is some concern about the impact that predator control activities outside the park and preserve may be having on the Denali wolf packs. Wolves occasionally venture outside the park and preserve boundaries, particularly during the winter, in search of prey. Denali borders three ADF&G active predator control areas: the Nelchina basin area to the southeast, the Cook Inlet area directly south, and the McGrath area to the west (Plate 26). In the Nelchina basin area (GMU 13), the wolf population was reduced by approximately 40% between 2001 and 2009 (ADF&G 2009a). Aerial hunting has been allowed since winter 2007 and 51 wolves were harvested through aerial shooting in GMU 13 during the 2008-2009 hunting season (ADF&G 2009b). Aerial shooting has also been allowed in the Cook Inlet area (GMU 16) since 2005 (ADF&G 2006). The wolf population in GMU 16B has been reduced by about 60% since 2004 (ADF&G 2007, 2009c).

Wolf-human interactions are a safety concern at Denali, for both visitors and the wolves themselves. Several cases have been reported in the park and preserve where wolves have approached hikers or entered campgrounds while people were present (McNay 2002). However all these behaviors were classified as nonaggressive and investigative or scavenging. There were no human injuries although some damage to property was reported (McNay 2002).

The leading cause of wolf mortality in Denali according to Mech et al. (1998) and Meier (2009) is intraspecific conflict, which occurs when neighboring wolf packs come into contact. From 2003-2009, at least 30% of wolf deaths were caused by other wolves. Conflict is most likely to occur during the winter when wolves venture outside their regular territories in search of prey (DENA 2009a). Other natural causes of wolf mortality include avalanche, starvation, drowning, old age, and disease (DENA 2009a). Confirmed cases of the dog louse *Trichodectes canis* and another coat abnormality of unknown origin have been documented in wolves in or near Denali (Meier 2009). Presence of other diseases has been detected during testing by the ADF&G, but the diseases do not appear to significantly impact the wolf population in Denali (Meier 2009). One disease that is of special concern to park management is canine parvovirus (CPV) because of the potential effects it would have on the survival of wolf pups. Blood samples from wolves captured in Denali show that in some years approximately half the population is exposed to CPV (Meier 2009).

Weather also influences wolf populations, especially during the winter season. When winters are mild, prey species have a better chance of escaping wolves (Mech et al. 1998, DENA 2009a). High wolf numbers are often observed after severe winters when ungulates are more vulnerable to predation (Meier 2005).

Data Needs/Gaps

Given the recent decline in wolf density and increasing harvest pressure outside park and preserve boundaries, more research is needed on how factors outside the park affect the wolf population. A new graduate research project on the impact of harvest on wolf viewing within Denali has recently begun and should help to address this data need (DENA, Meier, pers. comm. 2010). Although some information regarding pup production can be inferred from spring and fall population counts, no recent data has been collected specific to reproductive success of wolves in Denali. New data collected could be compared to existing pup production data from 1986 to 1993.

Overall Condition

According to DENA (2009b), the current condition of wolves is stable. However, in spring of 2010, the lowest estimated density of wolves since 1987 was reported (3.5 wolves/1000 km^2). While this density is still within the range observed from 1987 to 2007, it seems to indicate a declining trend within the Denali wolf population. No information has been found reporting change in overall wolf distribution over time. The population decline to levels among the lowest recorded since 1987, combined with the potential for increased hunting pressure near the park and preserve boundary, results in a condition assessment of moderate concern with a declining trend.

Level of Confidence

Wolves have been consistently monitored in Denali since 1986, providing a relatively long record for comparison with recent wolf population data. The lack of comparable data prior to 1987 limits the available knowledge of the full range of natural variability which wolf populations experience.

Sources of Expertise

The primary source of information for determining the current condition of wolf populations in Denali is Meier 2009.

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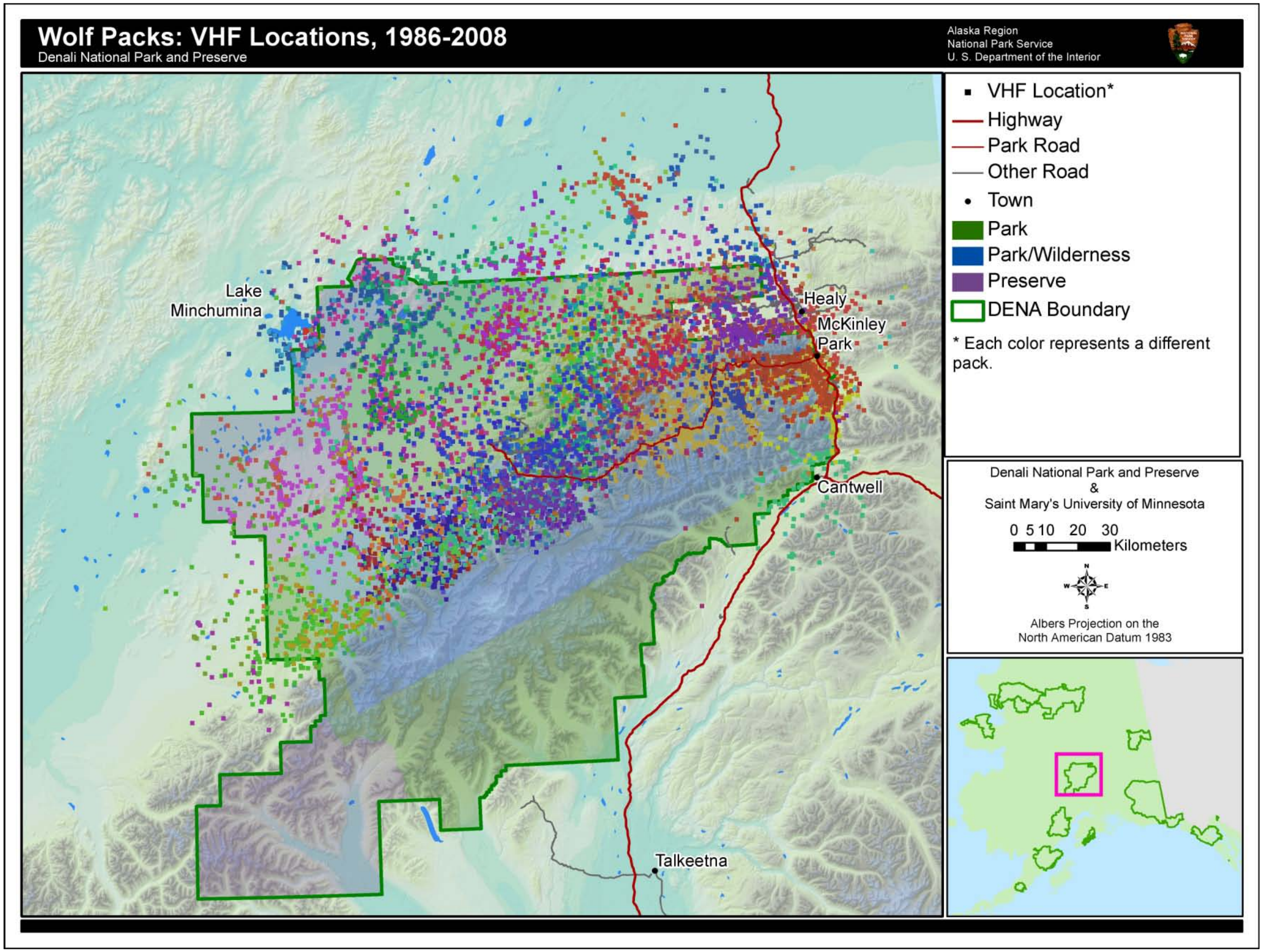


Plate 23. Wolf Packs: VHF radio collar locations, 1986-2008 (NPS 2010, DENA 2009c)

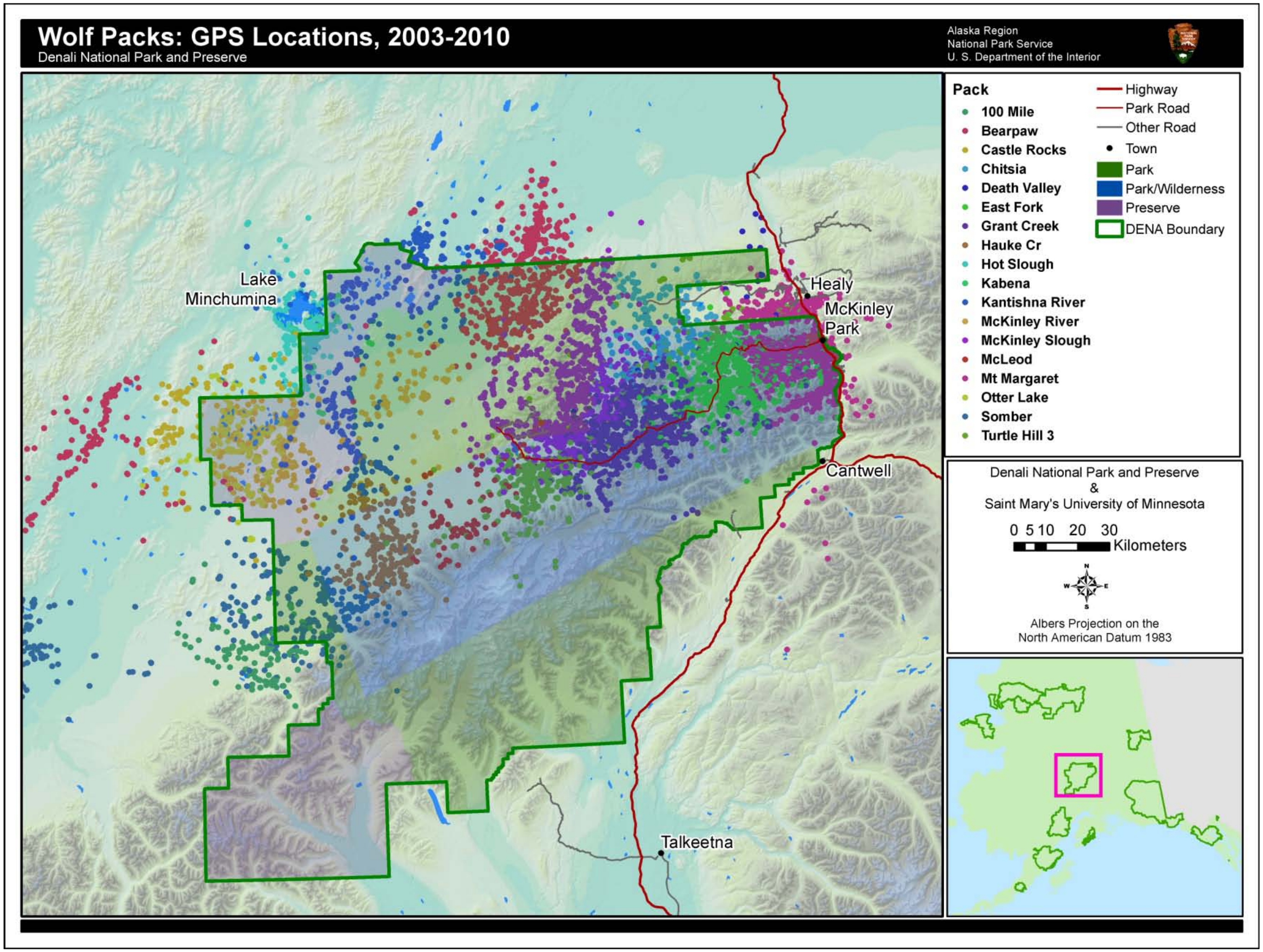


Plate 24. Wolf packs: GPS locations, 2003-2010 (NPS 2010, DENA 2009d, DENA 2010c).

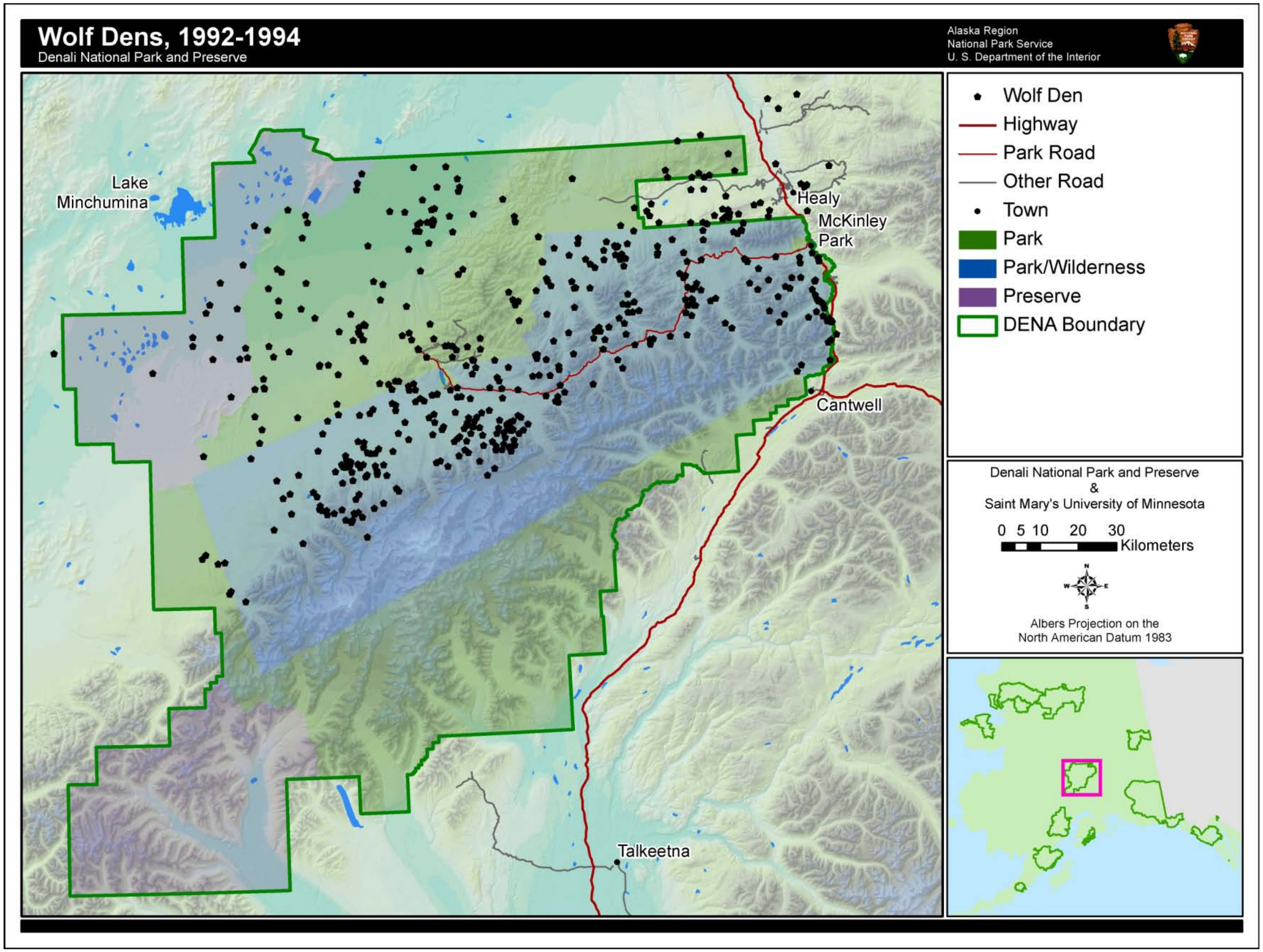


Plate 25. Wolf dens, 1992-1994 (NPS 2010, DENA 2008).

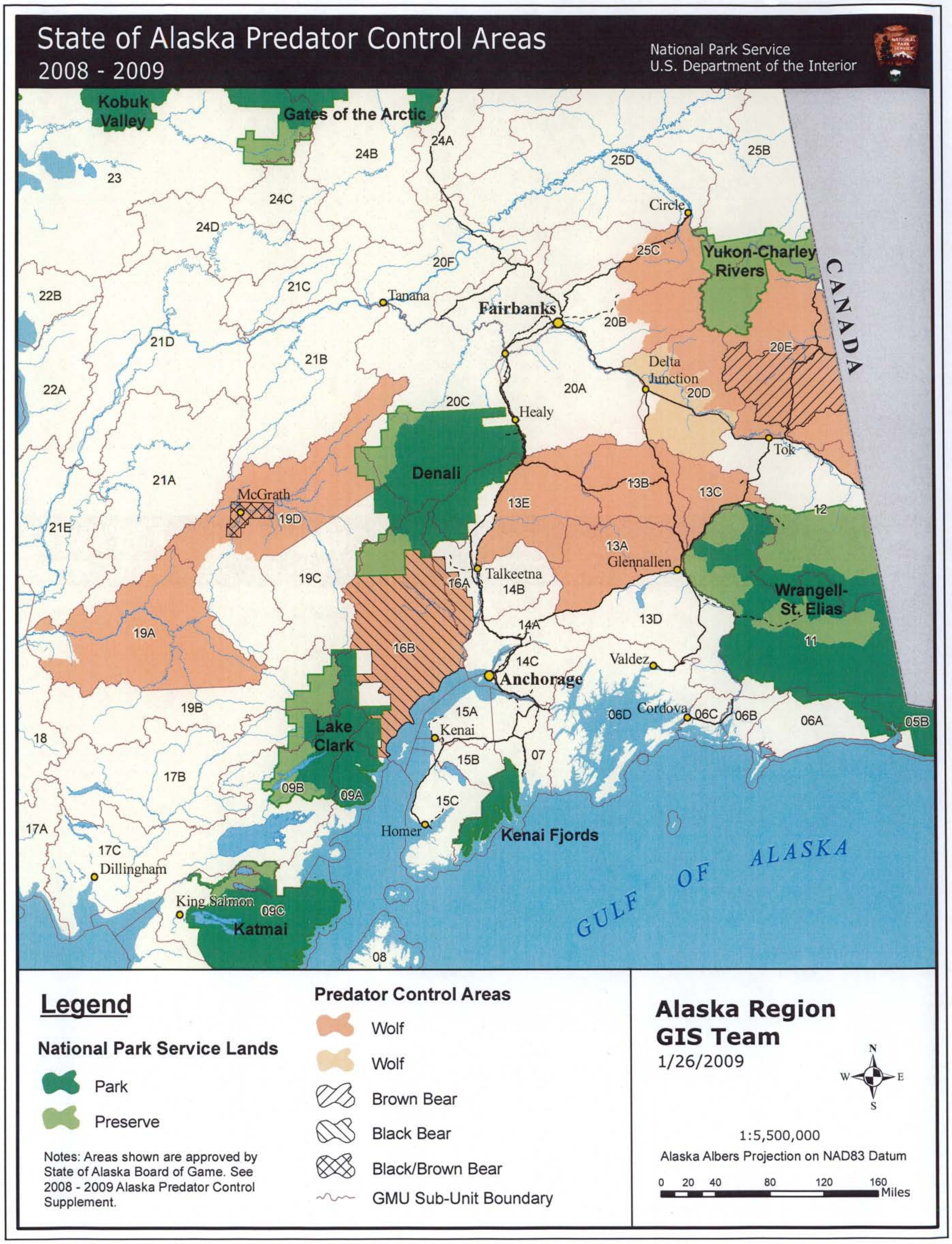
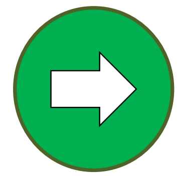


Plate 26. State of Alaska Predator Control Areas, 2008-2009 (NPS 2009).

4.8 Grizzly Bears (*Ursus arctos*)



Current Condition and Trend

Description

Grizzly bears are an important component of both the ecology and the public appeal of Denali National Park and Preserve. Grizzlies are considered “an integral part of the naturally functioning predator-prey system” of Denali (Keay 2001) and are one of the resources the park and preserve is mandated to protect (Owen and Mace 2007). They are also one of the “big five” mammal species that visitors come to Denali hoping to see. In addition, the relatively long life-span of grizzly bears make them good indicators of long-term habitat change (MacCluskie and Oakley 2005), and they are therefore a key component of CAKN’s vital signs monitoring program.

Photo 13. Grizzly bear in Denali (photo by Kevin Stark, SMUMN GSS, 2010).

Grizzlies in Denali feed on salmon, berries, grasses, roots, caribou, and moose, and roam widely throughout the Park in order to forage. While meat is probably the most important food source for bears when it is available, vegetation is preferred during the summer, with berries forming the bulk of their diet starting in late July (DENA 2010a). Since hunting is only allowed in portions of Denali, it has not been a significant threat to the grizzly population. However the impacts of other human activities within the park and preserve and human development outside its boundaries are of concern (Keay 2001).

Measures
Population size
Distribution

Reference Conditions/Values
DENA (2009a) desires to maintain the population size and demography within the range that was observed from 1987 to 2007. Prior to the establishment of Denali in 1917, hunting, trapping, and limited bear harvesting occurred, but currently there are no records or indications of poaching in the park and preserve (Keay 2001). Previous population density estimates are available from studies in Denali (Murie 1981 and Dean 1987) and adjacent to the park and preserve (Miller et al. 1997).

Data and Methods
Grizzly bear populations have been intensively studied in Denali National Park and Preserve since 1988 (Owen and Mace 2007). From 1991 to 1998, bears were radio-tagged and located at least monthly during the non-denning season (Keay 2001). The study area is depicted in Figure 32. Sixty-one percent of the population was marked and bear density, survival rates, reproductive rates, and age structure were estimated.

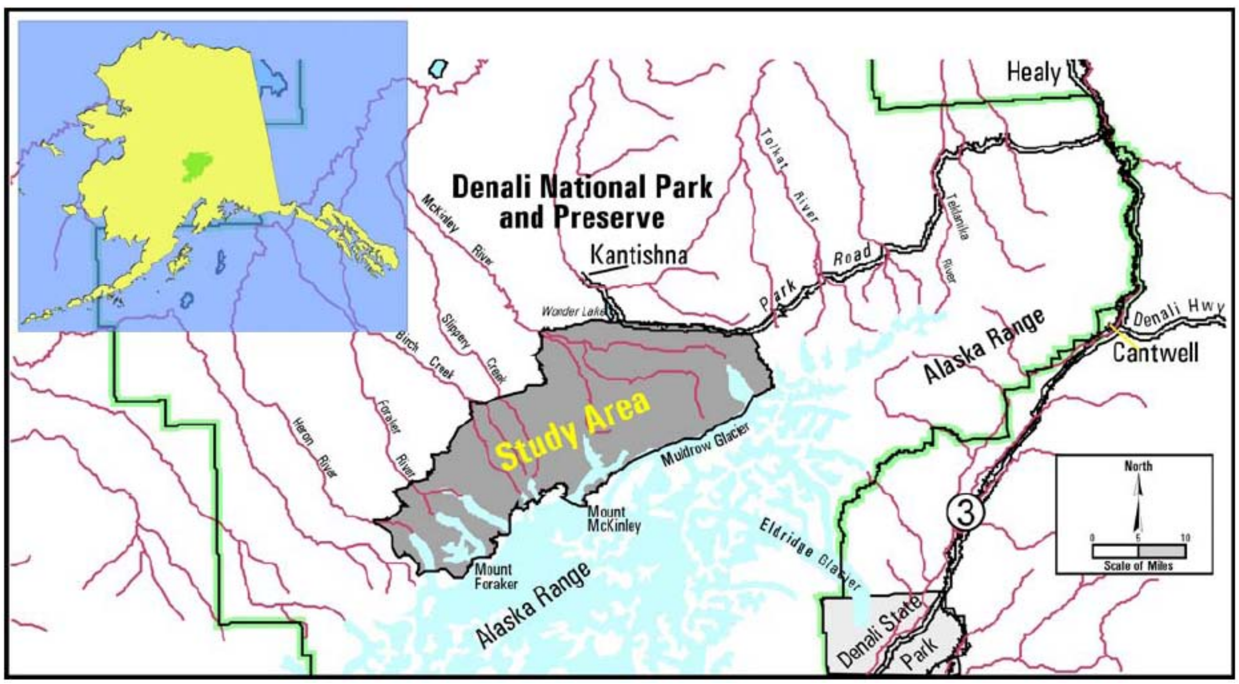


Figure 32. McKinley Slope grizzly bear study area, Denali National Park and Preserve, Alaska, 1991-1998 (Keay 2001).

Following the 1991 to 1998 study, monitoring of grizzly bears continued, and updated estimates of various population metrics for female grizzly bears were reported in Owen and Mace (2007). Owen and Mace used the same radio-collar sample as Keay (2001) with six additional years of data collected 1999-2005 as well as earlier data collected from 1988 to 1991. Bear monitoring using radio-collars has continued in this area. Spatial locations of radio-collared grizzly bears collected from 1991 to 2009 are included on Plate 27.

From May through September 2006, 17 grizzly bears were monitored using GPS collars to investigate the relationship between behavior and the main park road (Mace et al. 2009). The study area was located primarily along the park road corridor. The bear locations obtained during this study are shown on Plate 27.

Belant et al. (2006, 2010) investigated resource selection by female brown and black bears on the south side of the Alaska Range. The study area included portions of Denali but also extended outside of the park and preserve boundary. Over the three years of the study, from 1998 to 2000, a total of 31 female grizzly bears were monitored using GPS collars. Eleven were captured in May of 2000, and five additional female grizzly bears were captured in June of 2000. Grizzly bear locations for the 16 bears collared during the 2000 season are depicted on Plate 27. This study focused on diet and body composition and does not address population metrics or speak to change in grizzly bear distribution over time.

DENA (2008) reports population estimates for the north and south regions of the park and preserve. The estimate for the north side is based on Keay (2001). The southern region estimate was based on preliminary analysis from Earl Becker of USGS (Becker and Quang 2005).

In 2009, study efforts shifted to bears along the northern boundary of Denali (Plate 27). Sixteen bears have been fitted with GPS collars as of 2010. No data for this study are available at this time because the collars are scheduled to remain on until 2012 (DENA, Owen, pers. comm. 2010).

Current Condition and Trend

<u>Population size</u>

In 2008, there were estimated 300-350 grizzly bears in Denali north of the Alaska Range. This estimate was based on densities from a radiocollaring study area near Wonder Lake which was extrapolated to all grizzly bear habitat (DENA 2008). In 1995, Keay (2001) estimated the grizzly bear population density in the northern part of Denali to be 27.1 bears/1000 km^2 (95% C.I. = 25.1-30.2) or a density of 34.7 bears/1000 km^2 in forage producing habitat. This population density of grizzly bears is similar to densities recorded within Denali in 1981 (Murie) and in 1987 (Dean), but higher than the nearby harvested Susitna population estimates from 1985 (Miller) (Keay 2001).

Although there are no population size estimates for the portion of Denali south of the Alaska Range, it is estimated that this area has a population density of 28 grizzly bears/1000 km^2 (Becker and Quang 2005). A slightly higher density of grizzly bears in the southern part of Denali may result from an abundance of streams that support salmon populations (DENA 2008).

In 2001, evidence suggested that the Denali population of grizzly bears was at its carrying capacity and stable, because the population density was high, the survival rates of independent bears were high, and the park and preserve had seen 80 years of little human disturbance (Keay 2001). During monitoring from 1991 to 1998, five breeding females were lost from the population and eleven were added, which suggests population growth. However, this indication of population growth conflicted with observed survival and reproductive rates, which indicated the grizzly bear population was declining at a rate of approximately two percent each year (Keay

2001). From 1991 to 1998, Keay found the adult survival rate was 0.970 for females and 0.983 for males. The subadult survival rate was 1.000 for females, and 0.943 for males. The estimated survival rate for dependent two year olds was 0.785, with yearling and cub survival rates of 0.455 and 0.341, respectively. Rates of reproduction varied from 0.071 to 0.382 depending on the age of the female (Keay 2001).

Owen and Mace (2007) used data from 1988 to 2005 radio-collar surveys to estimate grizzly bear vital rates, including productivity, mean litter size, and adult female and cub mortality. The mean litter size was 2.03 cubs/litter, and over 60% of litters had two cubs. Productivity increased with the maturation of the mother but began declining once females reached the age of 20. The average birth rate was 0.6954 (obtained by multiplying the reproductive rate of 0.3477 by the average litter size of 2). Survival rates were calculated for four classes of grizzly bears: adult females (6+ years old), independent subadult females (2 to 5 years old), yearlings (1 year old), and cubs (< 1 year old). The mean survival rates of these four classes are 0.9572 (adult female), 0.9309 (subadult female), 0.5983 (yearling), and 0.3514 (cub) (Table 28). High yearling and cub mortalities in Denali are generally attributed to starvation or predation, although these deaths have not been directly investigated in the field. Data show that the average birth rate is only slightly higher than observed cub mortality rates. The vital statistics produced by this study suggest that the northern Denali grizzly population is likely regulated by density dependent factors (Owen and Mace 2007).

Table 28. Vital rates of grizzly bears in Denali National Park and Preserve, Alaska, 1988-2005 (Owen and Mace 2007).

Parameter	Estimate				
	Sample Size	Point Estimate	Lower 95% CI	Upper 95% CI	SE
Adult survival	39/251*	0.96	0.94	0.98	0.01
Subadult survival	20/42	0.96	0.82	1.00	0.04
Yearling survival	54/39	0.60	0.46	0.74	0.07
Cub survival	148	0.35	0.28	0.43	0.04
Age first parturition	fixed	6.0			
Litter sex ratio	fixed	50:50			
Reproductive rate[b]		0.35	0.29	0.43	0.04
Maximum age	fixed	35			
Lambda		0.9963	0.9617	1.0268	0.0166

*Number of Individuals sampled/years monitored

[b] Reproductive rate for female cubs only

Owen and Mace (2007) used these vital rates to estimate population trend (lambda), where a lambda value below 1.0 is considered a declining trend. Their estimate of lambda was 0.9963 (CI = 0.9716-1.0268). Within the 95% confidence intervals, grizzly bear population could either be declining at a rate up to 3.8% annually or increasing at a rate up to 2.7% annually, but it is more likely declining than increasing.

Distribution

Grizzly bear locations collected as part of the 1991 to 2009 radio-collar monitoring work by the NPS, the 2006 road study (Mace et al. 2009), and by Belant et al. (2010) in 2000 are depicted on Plate 27. These locations reflect the area of study and do not illustrate the complete distribution of grizzly bears within the park and preserve. No published analysis of change in bear distribution within Denali over time has been found.

Mace et al. (2009) documented the varying types of habitat use, including mountain, tundra, and river channel. Results indicate that female grizzles utilize mountainous areas more than males, while male grizzlies moved throughout tundra and river channel habitat more than females, especially during the late season (Mace et al. 2009). Information about grizzly bear resource selection on the south side of the Alaska Range can be found in Belant et al. (2010).

Threats and Stressor Factors

DENA (2009a) identifies stressors on the grizzly bear population as human interactions with the bears, predator control activities near the park and preserve, excessive harvest, and a lack of public sympathy.

Bear observations by humans documented from 1985 to 2006 are depicted on Plate 28. This includes both black and grizzly bear observations. The spatial data do not indicate the type of bear-human encounter. More analysis of the Bear–Human Information Management System (BHIMS) database is needed to determine what can be concluded about the impact of bear-human interaction in Denali. According to Keay (2001), "human activities have had virtually no impact on grizzly bear population dynamics in the study area for at least 80 years." Although backcountry visitor use has increased steadily over time, there were no translocations or management kills of nuisance bears in the study area during or prior to Keay's study. Albert and Bowyer (1991) noted that bear-human interactions could be minimized by restricting the use of campgrounds in riparian areas during seasons that these areas are heavily used by bears. They also caution against any further development in heavily used bear habitat.

Research from various locations outside of Denali has shown that roads can have a negative effect on wildlife populations by causing a loss or alteration of habitat and by preventing wildlife movement (Mace et al. 2009). However, a 2006 study along the main park road suggests that these conclusions may not apply to Denali. Data collected during the study indicated that bears were not significantly affected by the park road since they still traveled during periods of high traffic and did not alter their movements to avoid human activity (Mace et al. 2009). Some changes in behavior, however, were documented, including faster movements when crossing the road (Table 29) and a tendency to rest farther away from the road. Their findings show that some bears find vehicular traffic bothersome while others do not. Earlier studies also found that Denali's grizzlies were not significantly impacted by the park road (Yost 1998, Burson et al. 2000).

Table 29. Movement speed (m/hr) of grizzly bears during one hour steps before road crossing, while crossing the road, and immediately after crossing the road in Denali National Park and Preserve, 2006 (Mace et al. 2009).

Movement relative to road	Movement speed (m/hr)	*n*	SD
Pre-crossing	700	364	690
Road crossing	985	444	756
Post-crossing	611	328	691

Disease does not seem to be a major factor within the DENA grizzly population (Keay 2001). In 1994, just one of seventeen females captured tested positive for infectious canine hepatitis while none of the five cubs captured tested positive for the disease. Only one of twelve female bears tested for canine distemper in 1991-92 tested positive for the disease. These numbers are similar to or lower than other Alaskan grizzly populations (Keay 2001).

According to Keay (2001), the mortality of many dependent bears from starvation or poor physical condition suggests that nutrition plays a role in the low survival rates of young bears. At least six bears, most of which were in poor physical condition, were consumed by other bears during Keay's study. Yost (1998) noted that low spring cub numbers in 1997 appeared to be associated with the failure of berry crops in 1996 due to drought.

Concern has been growing over the impact that predator control activities outside the park and preserve may be having on the Denali grizzly population. Denali borders three ADF&G active predator control areas: the Nelchina basin area to the southeast, the Cook Inlet area directly south, and the McGrath area to the west (see Plate 26 in the previous section). While efforts in these areas have primarily focused on wolves and/or black bears, grizzly bear hunting regulations have been dramatically liberalized in recent years. In the Cook Inlet area, bear limits were increased from one bear every four years to one per year in 2004, and to two bears per year in 2005 (ADF&G 2007). According to the ADF&G, "There is no indication from available scientific data that state-sponsored wolf or bear control programs have created conservation concerns for wolf or bear populations on either a statewide or local basis" (ADF&G 2007). The current north study area will provide an opportunity to investigate the effects of predator control activities on bear populations in DENA (DENA, Owen, pers. comm. 2010).

<u>Data Needs/Gaps</u>

Periodic aerial surveys are needed to better understand the distribution, abundance, and status of grizzly bears in Denali and to identify important concentration areas (Keay 2001). This need will be addressed by a grizzly bear monitoring protocol currently being developed by CAKN (DENA 2008). The data from these surveys could be used to identify priority habitat areas and movement corridors that are at risk from human development. More research is needed to better understand the impact of human activities, both in and outside the park and preserve, on the grizzly population (Keay 2001). Given the potential for decline of the population, it is also important to better understand the high mortality rates among cubs and yearlings. Studies have suggested these rates are high due to density dependent regulation, but this theory has yet to be confirmed in the field (Owen and Mace 2007).

Overall Condition

Condition of grizzly bears in DENA is considered good with a stable trend (DENA, P. Owen, pers. comm. 2010). Results from Owen and Mace (2007) indicate that the population is either stable or at a slow decline. If the bear population is currently experiencing a slow decline, it is unknown if this is a concern or a natural fluctuation. Keay (2001) indicates that grizzly bear populations may fluctuate mildly, but the population is likely stable in the long term. Information regarding change in grizzly bear distribution over time has not been found.

Level of Confidence

There is a long history of study related to grizzly bear populations in Denali. As one of the top level predators in the park and preserve, there is much interest in this species and public awareness is high. Current data indicates that population levels are either stable or in slight decline. However, all evidence suggests that grizzly bears are in good condition within Denali.

Sources of Expertise

The primary sources used to determine condition are Owen and Mace (2007) and Keay (2001).

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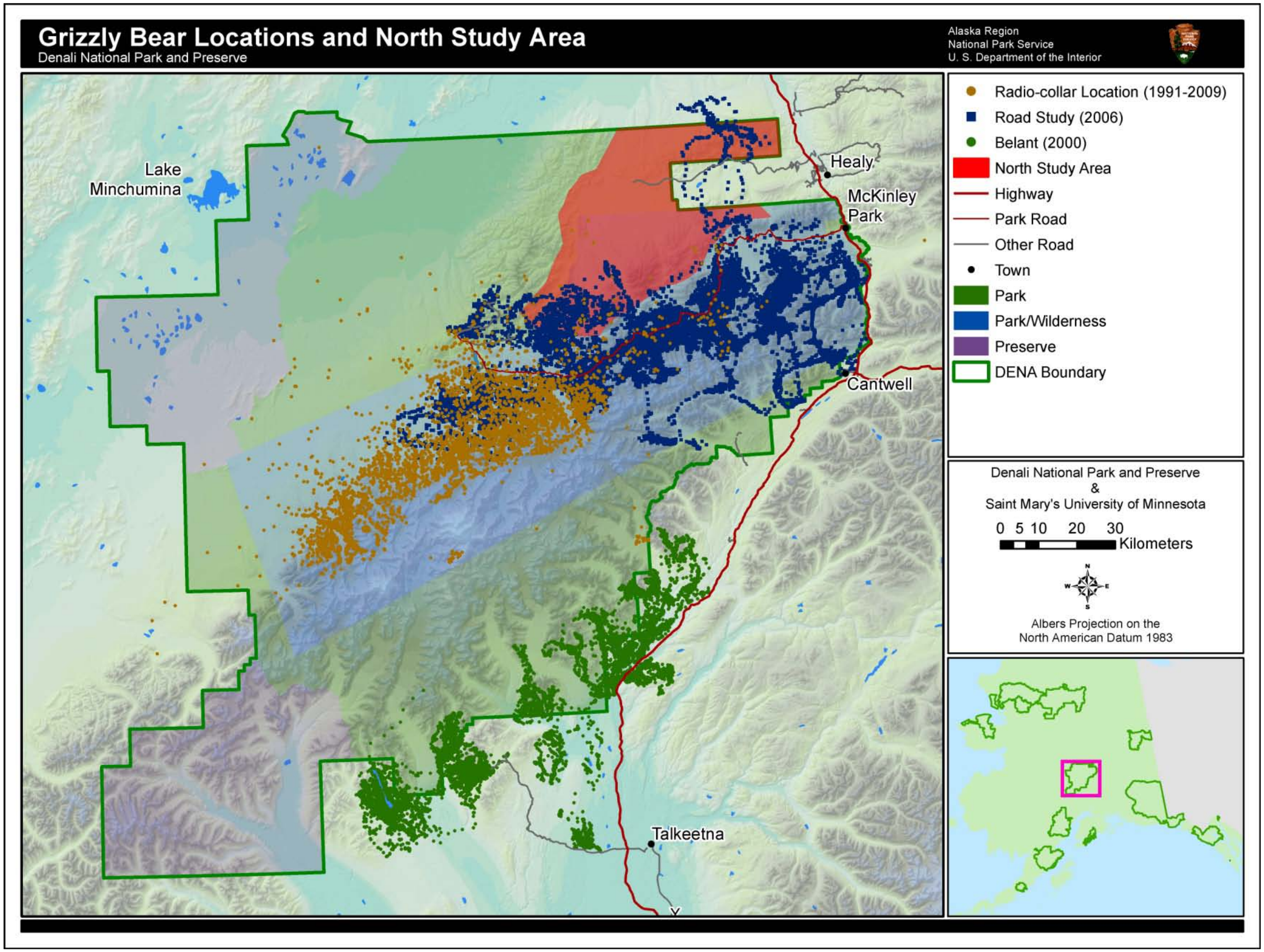


Plate 27. Bear locations identified during three different studies and the current north study area (DENA 2006, DENA 2009b, DENA 2010b, c, d, & e, NPS 2010).

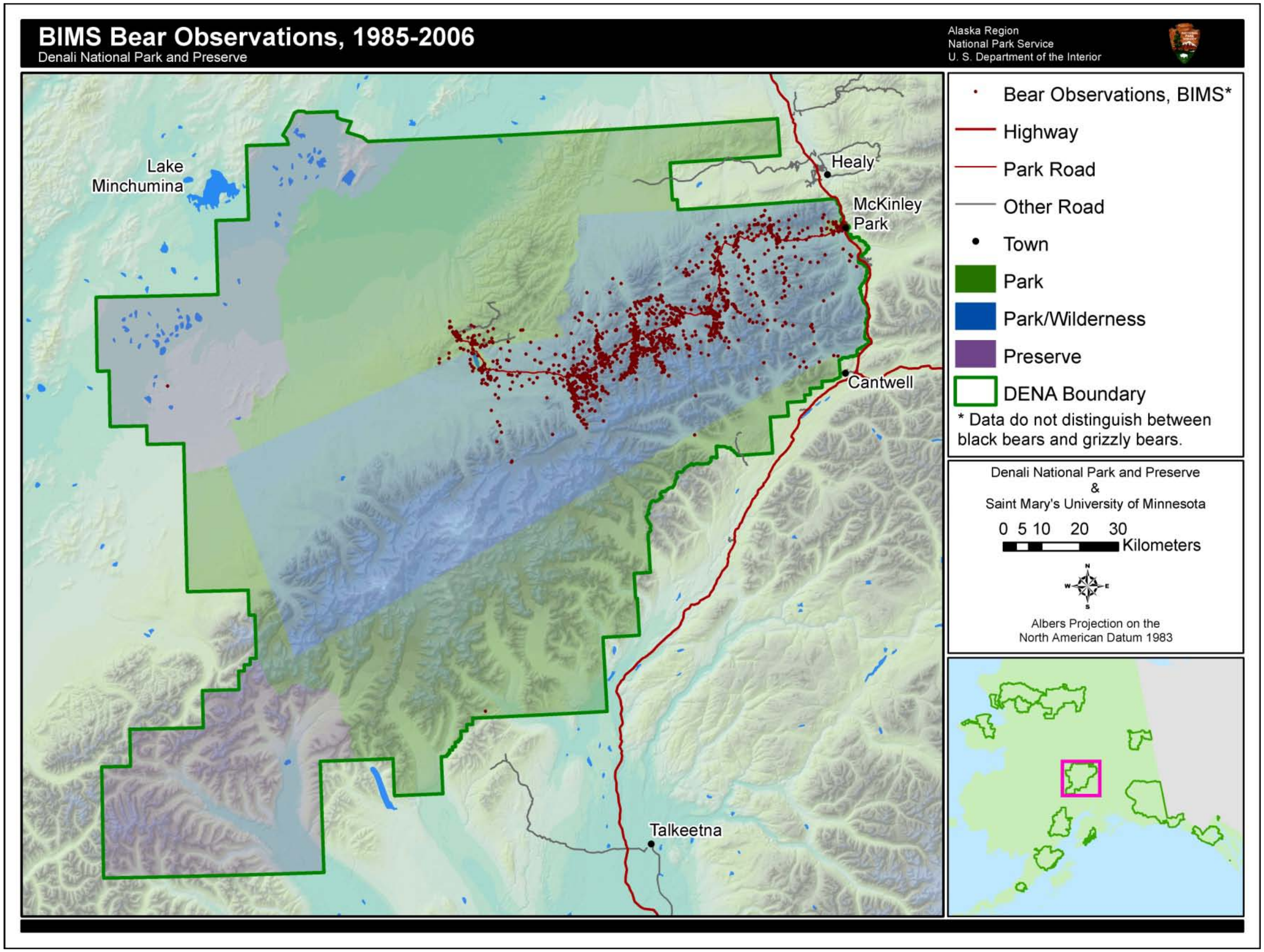
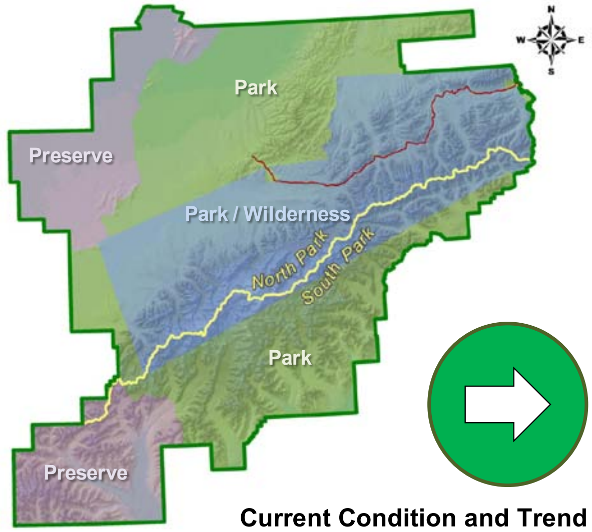


Plate 28. Bear observations reported in BHIMS, 1985-2006 (NPS 2010). Data includes both black and grizzly bears.

4.9 Golden eagles *(Aquila chrysaetos)*



Current Condition and Trend

Description

Golden eagles are commonly found in mountainous habitats characterized by shorter vegetation and large open areas that are optimal for aerial hunting (McIntyre 2009). Little was known about the species within Denali until a large nesting population was found in the northeastern region of the park in 1987. The birds nest in relatively high densities here, making it one of the best places to watch and study golden eagles in North America (McIntyre 2009).

Golden eagles are an important component of the Denali ecosystem and have been identified as a vital sign by the Central Alaska Network I&M Program, because “they are a high trophic level predator that responds quickly to changes in their habitat and prey supplies” (McIntyre 2009). Golden eagles prey primarily on arctic ground squirrel (*Spermophilus parryii*), snowshoe hare (*Lepus americanus*), hoary marmot (*Marmota caligata*), and willow ptarmigan (*Lagopus lagopus*). Research has shown that golden eagle reproductive success in Denali is greatly influenced by the abundance of snowshoe hare and willow ptarmigan (McIntyre and Adams 1999).

Photo 14. A golden eagle nest at Denali (left, NPS photo) and two nestlings (right, photo courtesy of M. Collopy) (McIntyre et al. 2006a).

Long-term studies at Denali currently provide the only contemporary data on the reproductive success of a large migratory population of golden eagles in northwestern North America (McIntyre 2009). These data are similar to a long-term data set for a resident golden eagle population at the Snake River Birds of Prey National Conservation Area in southern Idaho, allowing comparisons to be made between a migratory and a resident eagle population. Research at Denali has focused on the nesting population, leaving much to be learned about juvenile and other non-breeding golden eagles in the region (McIntyre et al. 2008).

Measures

Population size
Distribution
Reproductive success

Reference Conditions/Values

The reference condition for the Denali golden eagle population has been identified as within the range of natural variability observed from 1987-2007 (DENA 2009). Nesting area surveys were conducted every year during this time period.

Data and Methods

Prior to the late 1980s, most knowledge regarding Denali's golden eagle population was based on anecdotal observations from early twentieth century authors Joseph Dixon and Adolph Murie. In 1987, a nesting population inventory resulted in an increase in known nesting territories from around 15 to over 60 (McIntyre 2009). This discovery triggered the implementation of a long-term monitoring program in the northeastern part of the park in 1988 (Figure 33).

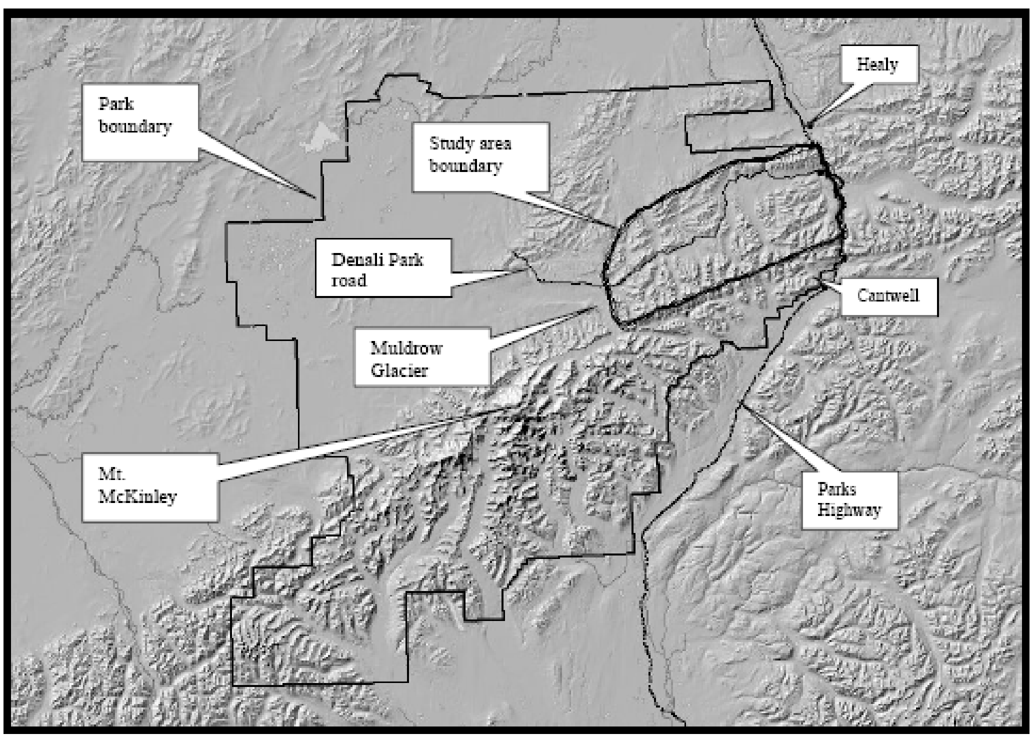


Figure 33. General location of study area for Golden eagle monitoring project, Denali National Park and Preserve, Alaska (McIntyre 2005).

Since 1988, NPS biologist Carol McIntyre has conducted two standardized aerial surveys and additional foot surveys in Denali annually to assess occupancy of nesting territories and also a series of reproductive measures. The first part of this survey involves documenting occupancy of nesting territories and breeding activities within those territories. These observations are made in mid to late April after most clutches are complete but before there are many nest failures. The second survey occurs in mid-July when most chicks are nearing fledging age but have not yet left the nest (McIntyre 2009). From these data, nesting territory occupancy, laying rate, success rate, and fledgling production are calculated. Fledgling production is further divided into three measurements: fledglings per territorial pair, fledglings per laying pair, and fledglings per successful pair to allow for comparison with other studies. Steenhof (1987) suggests that raptor studies should focus on these productivity measurements based on the territorial population, yet many studies still do not include them (McIntyre 2005).

Results from these annual assessments can be compared to average rates from previous surveys and to rates from other study areas across North America. Details regarding the survey protocol are available in McIntyre 2009.

In addition to annual surveys of nesting territory occupancy and reproductive success, research was conducted in the late 1990s and early 2000s investigating the movements and survival of juvenile golden eagles from Denali (McIntyre et al. 2006b, McIntyre et al. 2008). During this time McIntyre and Collopy (2006) also studied the post-fledging dependence period of young Denali golden eagles.

Current Condition and Trend

<u>Population size</u>
In 2008, 75 territorial golden eagle pairs were observed in the northeastern study area. Thirty-four of these pairs successfully reproduced, resulting in 52 fledglings. These numbers are down slightly from the 2006 and 2007 surveys, but the number of territorial pairs is similar to numbers from 2004-2005 and higher than the 20-year average of 67.4. McIntyre (2005) suggests that territorial populations of golden eagles in Denali have either a high adult survival rate, or that non-territorial adults are abundant and replace territorial birds that die. Survival and turnover rates of the territorial eagles cannot currently be determined as an understanding of the population dynamics of territorial eagles is incomplete (McIntyre 2005). In contrast, the survival rate of juvenile golden eagles from Denali is relatively low. The average first-year survival rates for two cohorts during the late 1990's were just 0.34 ± 0.10 and 0.19 ± 0.07. These numbers are much lower than the 0.92 first-year survival rate of a non-migratory golden eagle population in California (McIntyre et al. 2006b).

McIntyre (2005) could not determine exactly how many subadult eagles were in Denali's territorial population, because they are identified based on their plumage, which was not visible to the surveyor without flushing the birds off their nests. Very few subadult golden eagles were observed during nest visits or aerial surveys, which infers that adults dominate the territorial population (McIntyre 2005). During the later part of the nesting season, subadults are seen in the study area, but are not considered part of the territorial population. The presence of these subadults is higher in years when snowshoe hare are abundant (McIntyre 2009).

Distribution

The distribution of golden eagle nesting territories in the northeastern study area is shown in Figure 34. Golden eagle distribution across the remainder of Denali is not entirely understood due to limited survey data. An aerial survey of the south side of the park and preserve in 2000 found 24 golden eagle nesting territories in the Kichatna, Yentna, Kahiltna, and Tokositna River drainages. Eleven of these territories were occupied at the time of the survey (McIntyre 2001).

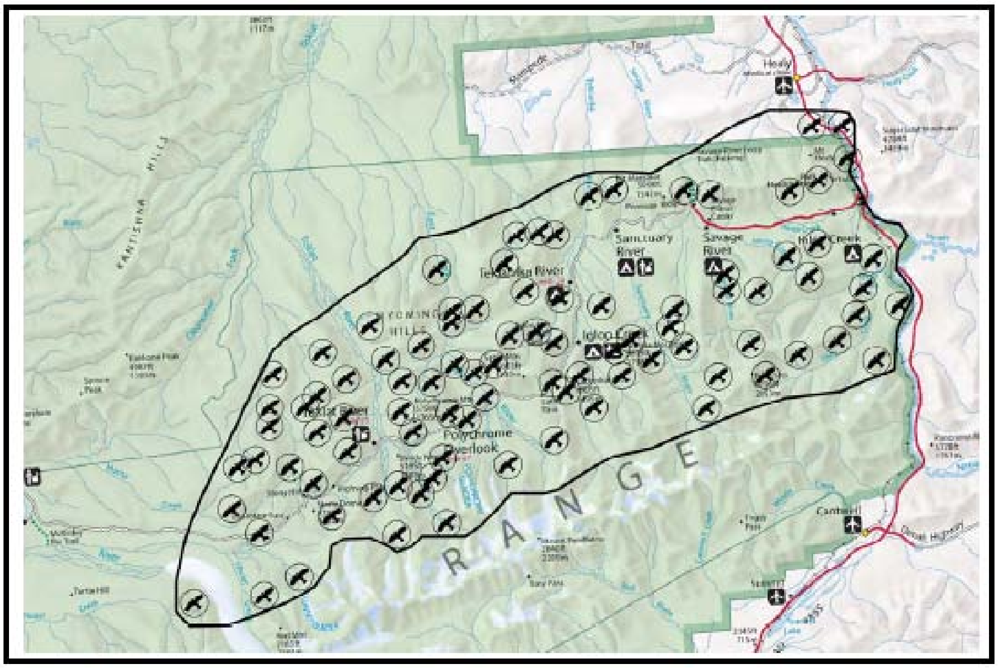


Figure 34. Golden eagle monitoring project study area in the northeastern corner of Denali National Park and Preserve, Alaska. The eagle symbols within the open circles show the approximate distribution of Golden eagle nesting territories within the study area. The study area is approximately 2,100 km^2 (McIntyre 2009).

In autumn, most golden eagles leave interior Alaska and head southeast, migrating through western Canada and wintering as far away as northcentral Mexico. In the spring, the eagles return north, travelling through western Canada to their Alaska nesting and summering grounds. The seasonal movements of juvenile golden eagles from Denali studied by McIntyre et al. (2008) are shown in Figure 35. Juveniles from the Denali population travel thousands of kilometers during their first year of life (McIntyre et al. 2008). This differs from the behavior of golden eagles in the lower regions of North America who migrate short distances or remain in the same territory year-round. Most juveniles from Denali are sedentary in the winter season, but they move frequently during the summer and many spend their first summer in areas hundreds of kilometers north of Denali (Figure 35; McIntyre et al. 2008).

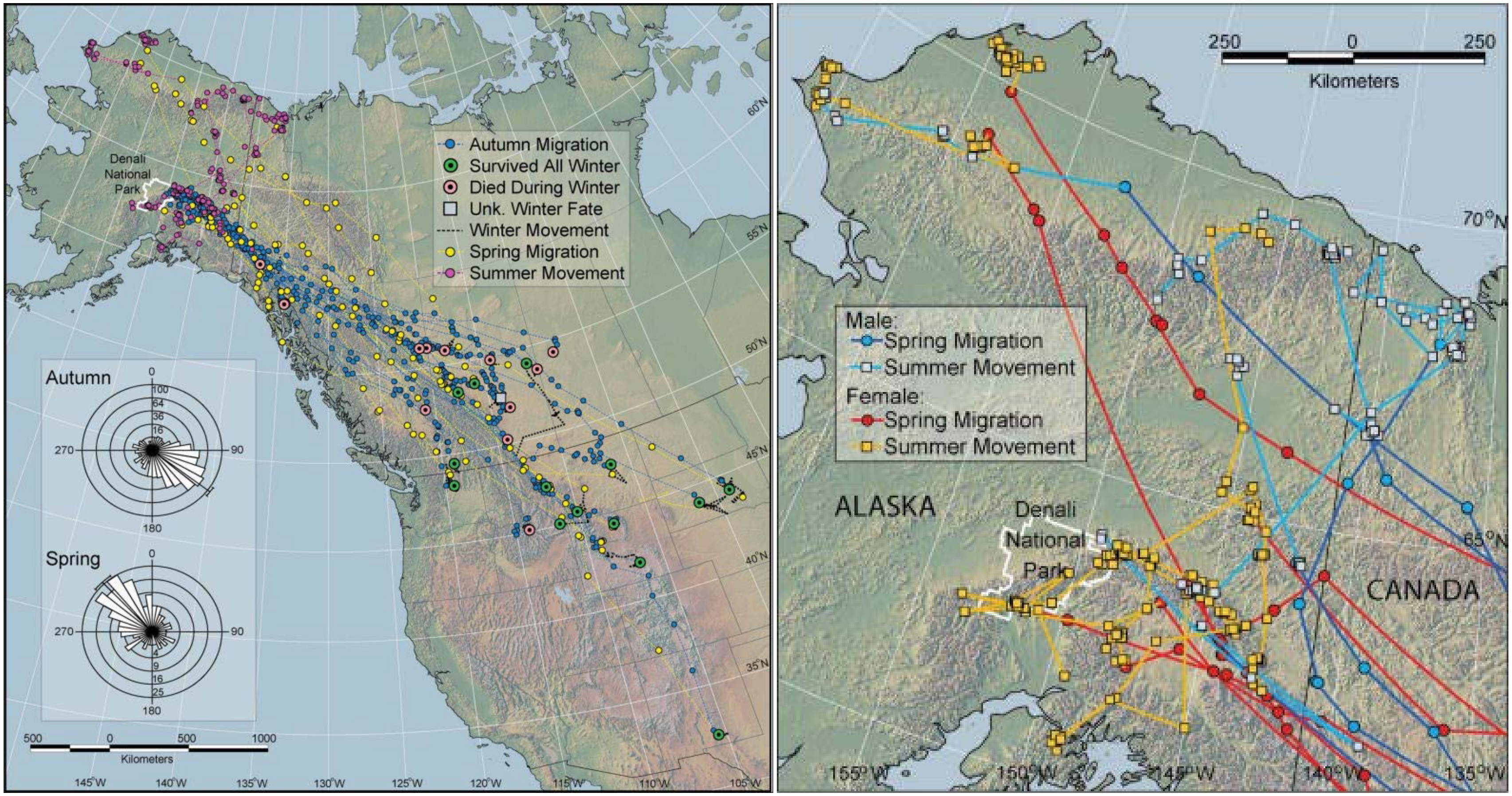


Figure 35. Movements of juvenile Golden eagles from Denali National Park and Preserve, Alaska, during their first year of independence, as determined by satellite telemetry (left; McIntyre et al. 2008). Spring migration and summer movements of 12 radiotagged juvenile Golden eagles from Denali National Park and Preserve, Alaska (right). Note movements to northern Alaska and the apparent difference between movements of males and females in relation to latitude and distance to Denali National Park and Preserve (McIntyre et al. 2008).

Reproductive Success

The number of nesting territories occupied and the number of laying pairs, successful pairs, and fledglings produced in Denali have been recorded annually since 1988. These results can be found in Table 30.

Table 30. Summary of Golden eagle nesting area occupancy and reproductive success, Denali National Park and Preserve, Alaska, 1988-2008 (McIntyre 2009).

Year	Nesting territories surveyed	Nesting territories occupied	Laying pairs	Successful pairs	Fledglings
1988	69	60	45	35	50
1989	69	58	51	43	70
1990	73	58	47	34	53
1991	76	62	43	37	56
1992	83	69	39	18	25
1993	85	69	30	20	28
1994[a]	66	56	20	9	11
1995[a]	66	55	27	19	25
1996[a]	69	62	27	24	30
1997	82	69	48	35	58
1998	83	66	35	22	33
1999	83	72	54	42	69
2000	84	70	53	34	49
2001	81	67	43	22	29
2002	83	73	10	4	4
2003	84	71	25	13	19
2004	82	73	32	16	20
2005	86	76	42	28	38
2006	89	81	64	52	79
2007	89	81	59	46	72
2008	86	75	51	34	52

[a] Study area size was decreased in 1994, 1995, and 1996 following recommendations of two U.S. Fish and Wildlife Service raptor biologists who suggested that it would be more cost-efficient to limit surveys to a smaller study area. This proved to be a poor recommendation for several reasons and surveys of the entire study area resumed in 1997.

In 2006 and 2007, nesting territory occupancy was similar to most previous years, but production of fledglings was well above average. The high fledgling production was attributed to an increasing snowshoe hare population within the park and preserve (McIntyre 2005). Figure 36 shows the relationship between annual golden eagle laying rate and the number of snowshoe hare detected each field day. McIntyre (2006) concluded that more eagles laid eggs and raised more fledglings in years when the snowshoe hares were abundant. This trend is particularly evident in 2006, when the number of laying pairs, successful pairs, and fledgling production were the highest ever recorded in the twenty-year study (Table 30). Reproduction remained high in 2007 with mean brood size peaking at 1.59 (Table 31).

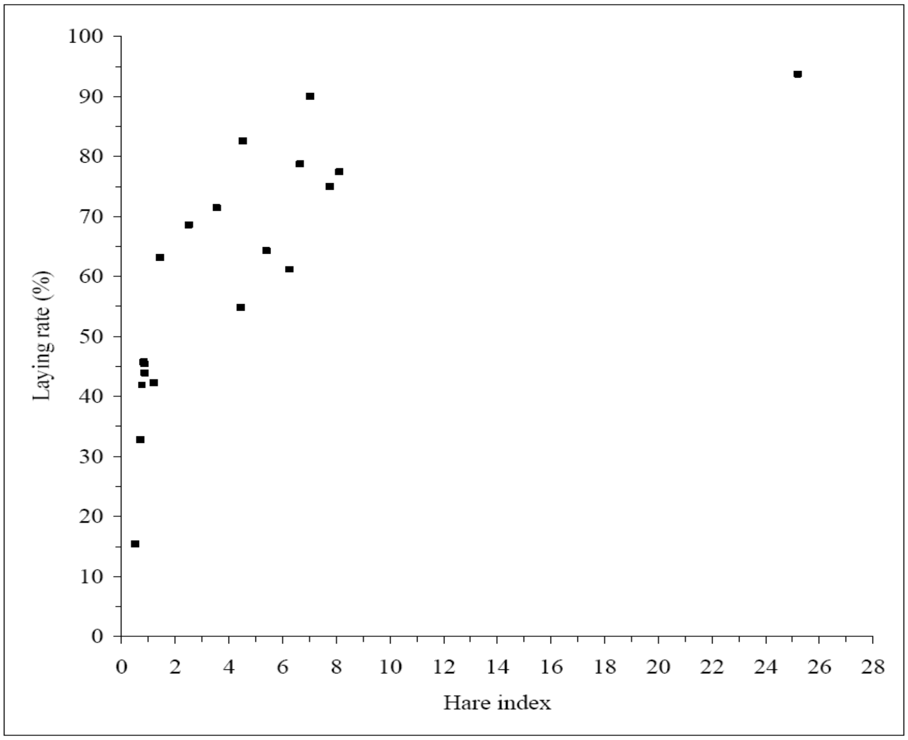


Figure 36. Annual Golden Eagle laying rate (percentage of territorial pairs with eggs) in relation to the number of snowshoe hares detected each field day, Denali National Park and Preserve, Alaska, 1988-2006. The point in the upper right corner of the graph represents 2006 (McIntyre 2006).

Table 31. Summary of nesting territory occupancy rates, laying rates, success rates, mean brood size and overall population productivity for golden eagles in Denali National Park and Preserve, Alaska, 1988-2008 (McIntyre 2009).

Year	Occupancy rate (%)	Laying rate (%)	Success rate (%)	Mean brood size	Overall population productivity
1988	88.24	71.67	81.40	1.40	0.82
1989	85.29	87.93	84.31	1.63	1.21
1990	80.56	82.76	70.83	1.56	0.91
1991	82.67	70.97	84.09	1.49	0.89
1992	84.15	56.52	46.15	1.39	0.36
1993	82.76	45.83	69.70	1.70	0.54
1994	84.85	35.71	50.00	1.10	0.20
1995	83.58	48.21	70.37	1.26	0.43
1996	89.71	42.62	88.46	1.22	0.46
1997	83.13	69.57	72.92	1.66	0.84
1998	80.49	51.52	64.71	1.50	0.50
1999	88.89	72.22	80.77	1.64	0.96
2000	85.37	75.71	64.15	1.50	0.73
2001	83.95	64.71	52.27	1.35	0.46
2002	89.02	13.70	40.00	1.00	0.05
2003	85.54	35.21	52.00	1.46	0.27
2004	89.02	43.84	50.00	1.25	0.27
2005	88.37	53.95	68.29	1.36	0.50
2006	90.91	78.75	80.95	1.49	0.95
2007	91.01	74.07	76.67	1.59	0.90
2008	87.21	68.00	66.67	1.53	0.69

In 2008, all measures of fledgling production declined from the previous two years, despite the continued abundance of snowshoe hare (McIntyre 2009). Fledgling production was higher than the long-term study average of 40.9, but still lower than 2006 and 2007 by nearly 25%. There currently is no indication that this decline is linked to an increase in the Denali golden eagle population. In other words there is no evidence of a density dependent response in Denali's golden eagles, meaning that increased density has not lead to a decrease in brood size (McIntyre 2008)

Threats and Stressor Factors

Stressors for golden eagles that nest or are raised in Denali vary over time and by location. Local stressors in Denali include repeated low-level over-flights during critical nesting periods, increased disturbance from hikers, and changes in food supply and habitat. Across their large and diverse non-breeding ranges and migration corridors, stressors include loss of habitat, decreased prey availability, lead poisoning, electrocution from power lines, and shooting. A newer and perhaps substantial stressor is the rapid construction of large wind-farms across the western United States, often in areas used by Denali's golden eagles in migration and during winter (DENA, McIntyre, pers. comm. 2011).

A study of juvenile golden eagles from Denali found that most mortality was the result of starvation, electrocution, and poaching (McIntyre et al. 2006b). The risk of mortality was greatest during their first autumn migration and early winter with most deaths from starvation and dehydration. This is most likely due to their lack of hunting experience. Juvenile golden eagles from Denali spend less than 2 months at the nest after fledging, learning how to hunt while still receiving food from their parents. This is a significantly shorter postfledging dependence period than in resident golden eagle populations (McIntyre and Collopy 2006).

Although lead was not considered to be a cause of juvenile mortality in the McIntyre et al. (2006b) study, three juveniles were found to have lead within their systems. Lead tends to impair survival by inhibiting the ability to hunt, obtain, and digest food (McIntyre et al. 2006b). The chance of a golden eagle ingesting lead is highest during or shortly after hunting season, when eagles may feed on carcasses containing lead shot. Although the use of lead shot for waterfowl hunting has been banned in the U.S. and Canada, ammunition containing lead is still used for hunting upland birds, small game, and larger mammals (McIntyre et al. 2006b).

According to Martin et al. (2009), there is some evidence that human disturbance has an impact on Denali's golden eagle population. Their analysis showed that the potential presence of hikers negatively affected the colonization of nesting territories, although it did not appear to affect overall reproductive performance. In the past, very small areas around occupied golden eagle nests that are accessible to tourists have been temporarily closed to protect the nesting eagles (McIntyre 2006).

Data Needs/Gaps

More research is needed on the habitat use, feeding habits, and movements of Denali's golden eagles when they are not nesting to better understand factors that affect the population. Data are also needed regarding the survival and turnover rates of the territorial eagle population for a complete understanding of their population dynamics (McIntyre 2005).

Golden eagles usually do not enter a breeding population until they obtain adult plumage during their fifth summer (Kochert et al. 2002). Little is known about their time between leaving the nest and entering the breeding population. This includes information about migration routes and behaviors, wintering locations, summer ranges, and habitat use (McIntyre et al. 2008).

Given the importance of prey abundance to golden eagle productivity, a long-term monitoring program for snowshoe hare and other prey species would be useful for golden eagle management. Efforts are underway to develop a snowshoe hare monitoring program (McIntyre 2009).

Overall Condition

Results from the long-term monitoring program at Denali indicate that the nesting population of golden eagles is stable and well adapted to local conditions. While there are periodic fluctuations in reproductive rates related to prey abundance, these fluctuations appear to be within the range of natural variability.

Level of Confidence

The consistent monitoring of Denali's nesting golden eagle population since 1988 provides sufficient data for comparison with current survey results.

Sources of Expertise

The primary sources of expertise for this condition assessment were McIntyre (2005, 2006, and 2009) and McIntyre et al. (2006b).

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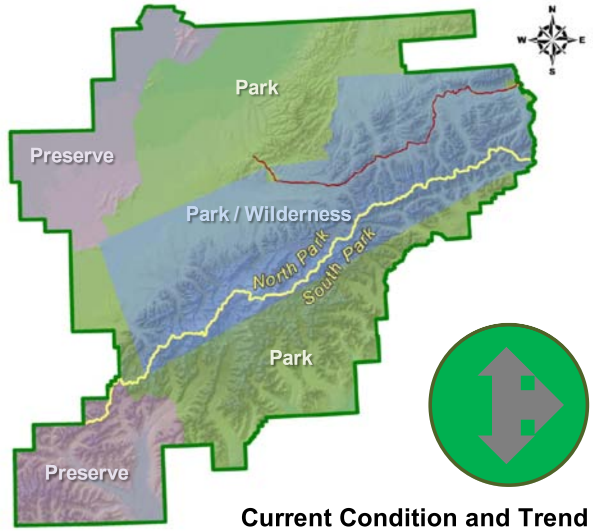
4.10 Native Plant Community



Current Condition and Trend

Description

As primary producers, plants form the foundation of every terrestrial and aquatic ecosystem (Roland et al. 2003). The flow of energy through an ecosystem, as well as the structure and habitat diversity of the ecosystem, are strongly influenced by its plant communities. Consequently, understanding the factors that influence the type and distribution of vegetation is critical to understanding the ecosystem itself (Roland et al. 2003). Vegetation patterns within Denali are known to be controlled by various environmental factors, which in turn are strongly influenced by topographic variables such as slope, aspect, and elevation (Roland 2004). Changes in Denali's vegetation have been shown to impact other species and processes within the park and preserve (Roland 2006c). Vegetation serves as browse and cover for ungulates and small mammals as well as nesting and foraging habitat for birds. Any change in vegetation will affect these species as well as their predators. Nutrient cycling, snow distribution, and wildfires are also influenced by the type and abundance of vegetation (Roland 2006c).

The ecological history and therefore the plant communities of Denali National Park and Preserve have been significantly influenced by several periods of glacial advance and retreat over the past two million years. Regions of the park and preserve north of the Alaska Range were part of the Beringian flora and fauna refugium that was connected to northeastern Asia and isolated from the rest of North America during the Pleistocene ice ages. As a result, many plants in Denali have their evolutionary origins in Eurasia (Roland 2004). During periods of glacial retreat, regions in and around Denali were also subject to plant colonization and migration from both interior North America and the Pacific Northwest. This has led to a high level of plant diversity throughout this region of Alaska. In fact, Denali National Park and Preserve contains about 90% of the vascular plant species that can be found in Wrangell-St. Elias National Park and Preserve, a park that is more than twice as large as Denali (Roland 2004).

There are 753 plant species known to exist in Denali, including 53 taxa classified as rare in Alaska and 14 considered globally imperiled (Roland 2004). Species found in the park and preserve that are considered critically imperiled within the state of Alaska include *Agrostis clavata, Arnica diversifolia, Carex echinata* ssp. *echinata*, *Carex interior*, and *Najas flexilis* (Roland 2004). Most of the plant species documented in Denali are herbaceous forbs, nearly all of them perennial. Fully 60% of the vascular plants in Denali fall into this class (Roland 2004). Approximately 24% of the park and preserve's plant species consist of graminoids, 11% are woody vascular plants, and the remaining 5% is made up of ferns and lower vascular plants (Figure 37; Roland 2004).

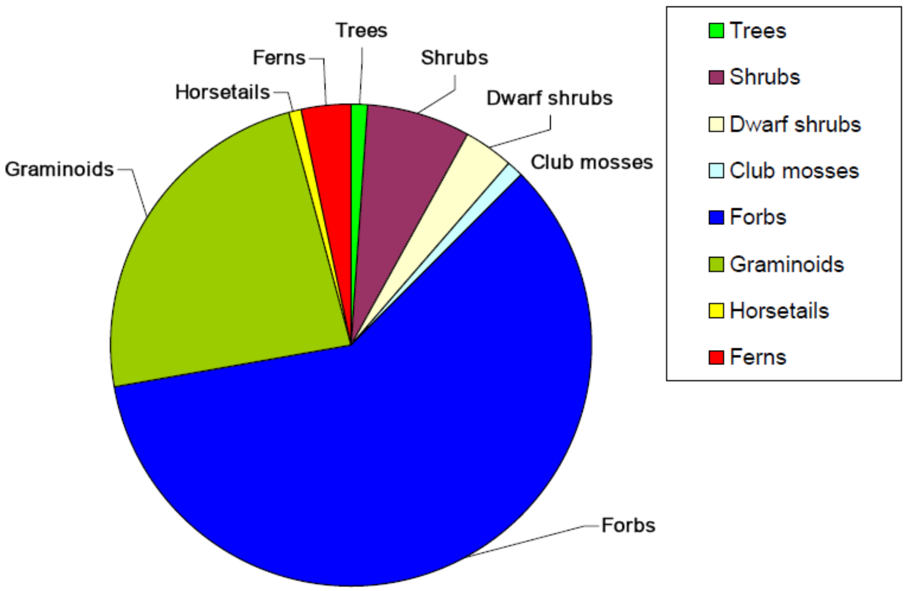


Figure 37. Percentage of Denali's vascular flora occurring in eight different growth forms (Roland 2004).

Denali's native plants can also be categorized into six floristic elements based on biogeography: 1) Circumpolar (31% of species) - plants that occur on all polar land masses including Europe, Asia, Greenland, and North America, 2) Incompletely circumpolar (16%) - species found in boreal areas of Asia and North America but not in Europe and Greenland, 3) North American (25%) - plants generally restricted to North America, 4) Amphiberingian (23%) – species known only from parts of North America and northern Asia that were part of Beringia, 5) Amphiatlantic (1%) - species that occur in North America, Greenland, and Europe, but have not been found in Asia, 6) Alaska-Yukon endemics (4%) – plants found only in Alaska and northwestern Canada (Figure 38; Roland 2004).

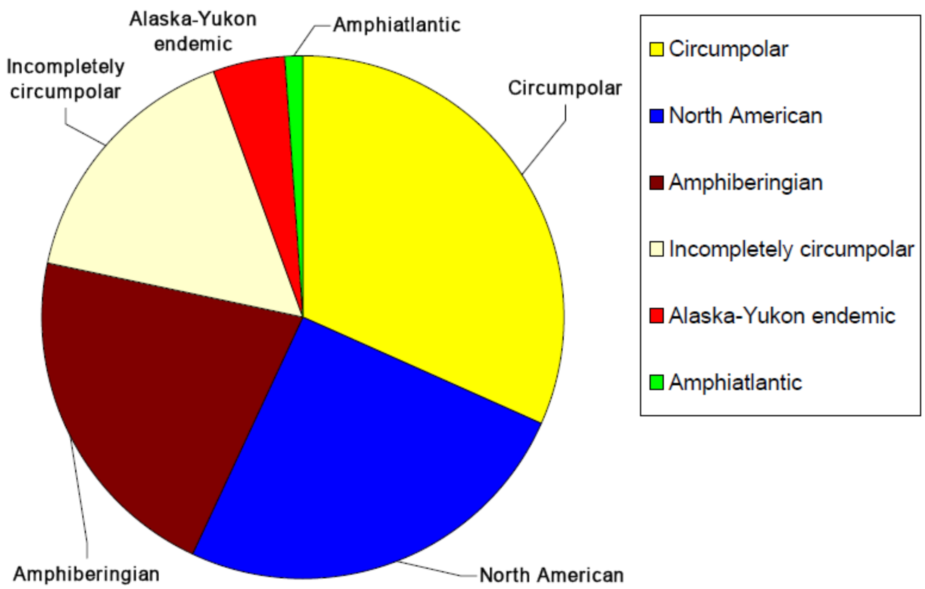


Figure 38. Percentage of Denali's vascular flora in each of six floristic elements (Roland 2004).

Measures

Plant species composition as measured in the vegetation monitoring program
Number of native plant species lost
Presence of exotic plant species
Anthropogenic change in native plant community distribution
Species expected vs. found

Reference Conditions/Values

In 1902, L. M. Prindle conducted the first scientifically documented plant collections in Denali National Park and Preserve (Roland 2004). Historically, plant collection has been limited to areas within and adjacent to the park road corridor due to ease of access. As a result of Denali's vast size, limited accessibility, sporadic documentation and collection, and a lack of data on plant distribution, the park had little scientifically documented historical information on vascular plants beyond the park road corridor (Roland 2004 and Swanson 2000). As of 1998, there were 490 vascular plant species documented within the park and preserve (Roland 2004).

A park-wide floristic inventory completed in 2001 and subsequent monitoring have provided baseline data on the plant communities of Denali and the relationships between landscape and vegetation. As monitoring data continues to be collected from year to year, this record will provide the information necessary to detect major vegetation and ecosystem changes that occur over time.

Data and Methods

Inventory and Monitoring

In 1992, a formal vegetation monitoring protocol for Denali was established based on five watersheds in the park and preserve as organizing landscape features. Plots were arranged along an elevation transect to study changes in forest and treeline dynamics in relation to a changing climate. This design relied on judgment-based sample allocation without randomization of samples (Roland et al. 2003). Thus this approach was spatially limited and did not support the development of inferences across the broader park and preserve landscape. In addition, staff realized that this approach was not financially feasible and was not meeting management needs (Roland et al. 2003). Based on these shortcomings, research into the development of a systematic grid system for floristic monitoring began in 1998.

Between 1998 and 2001, a floristic inventory of Denali was undertaken to collect and document vascular plants throughout the entire park and preserve (Roland 2004). The study inventoried vascular plants at 197 sites throughout Denali (Figure 39; Roland 2004). The floristic inventory included a wide range of habitats across the landscape. It also focused on areas away from the park road, where the majority of past botanical research was conducted, so as to fill gaps in geographic and taxonomic knowledge of vascular plants (Roland 2004). The inventory was specifically focused on selecting a set of survey sites across the entire spectrum of vegetation types, landscape positions, site moisture characteristics, and soil conditions that occur in Denali National Park and Preserve (Roland 2004).

The primary goal of this inventory was to develop a voucher-based record of all plant species known to occur in the park and preserve and to assemble all floristic data into a single database

(Roland 2004). As part of this goal, a GIS layer of the floristic regions in Denali was developed, and previous research was synthesized with new information into a report documenting all the existing floristic knowledge for the park and preserve (Roland 2004). After completion of the inventory, Roland (2004) believes that 95-98% of vascular plants occurring in Denali are now documented with a voucher specimen.

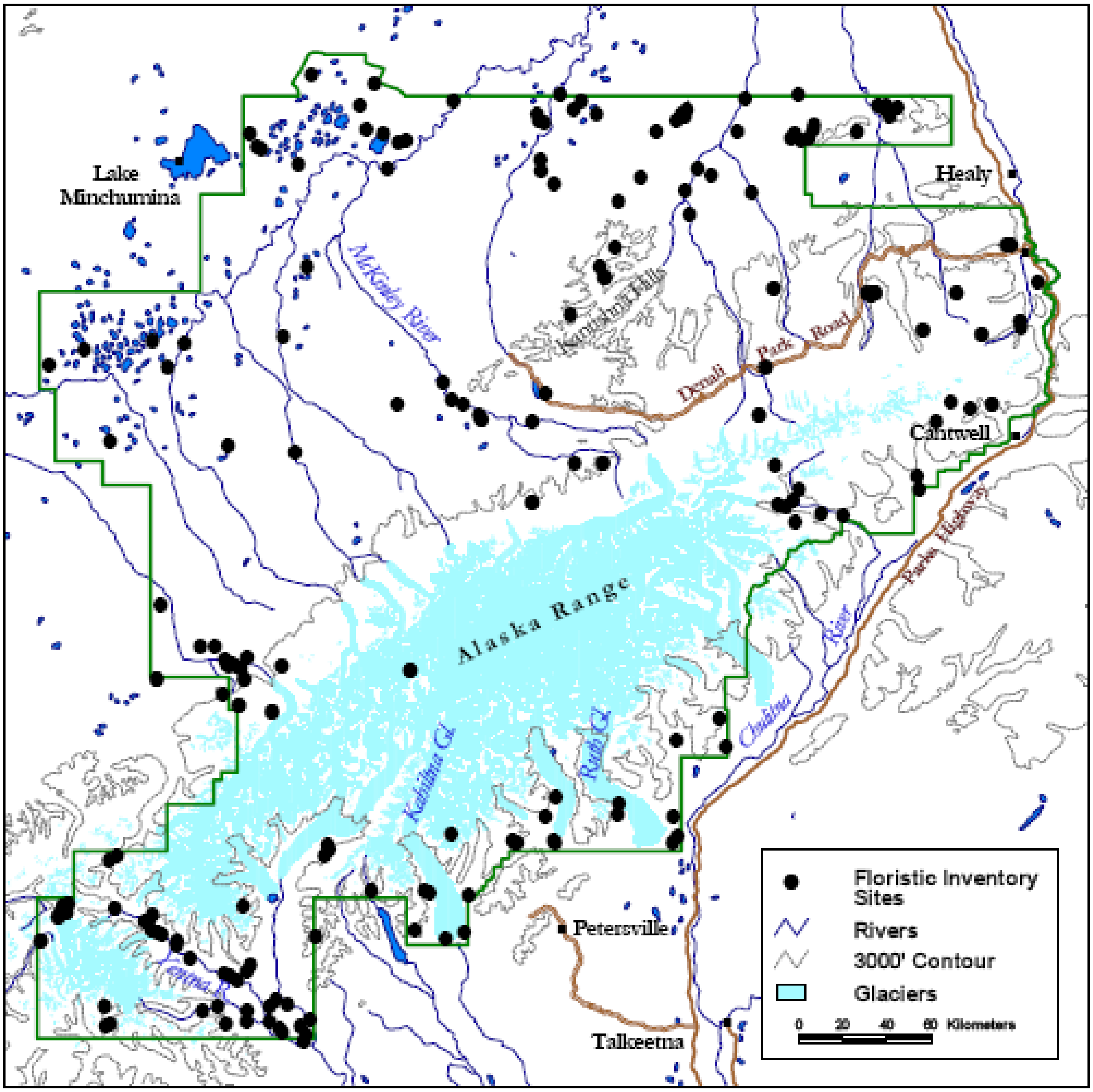


Figure 39. Locations of the 197 sites surveyed in the Denali Floristic Inventory Project, 1998-2001 (Roland 2004).

The vascular plant inventory separated the park and preserve into nine different floristic regions grouped by similar ecological and floristic characteristics: Interior Boreal Upland, Interior Boreal Lowland, Interior Boreal Floodplain, Interior Alpine Outer Range, Interior Alpine Alaska Range, Southcentral Boreal Subalpine, Southcentral Boreal Lowland, Southcentral Boreal Floodplain, and Southcentral Alpine Mountain (Roland 2004). These floristic regions and the ecological subsections that they contain are found in Table 32.

Table 32. The nine floristic regions [Bold] of Denali National Park and Preserve, and the ecological subsections that were merged to form these regions (Roland 2004).

Interior Boreal Floristic Regions:
Interior Boreal Floodplain and Alluvial Fan Region
Yukon-Kuskokwim Bottomlands-Lowland Floodplains & Terraces
Alaska Range-Interior Lowland Floodplains & Terraces & Fans
Interior Boreal Lowland Floristic Region
Yukon-Kuskokwim Bottomlands-Eolian Lowlands
Yukon-Kuskokwim Bottomlands-Minchumina Basin Lowlands
Alaska Range-Interior Glaciated Lowlands
Alaska Range-Toklat Basin Lowlands
Interior Boreal Upland Floristic Region
Kuskokwim Mountains-Boreal Low Mountains
Alaska Range-Interior Glaciated Uplands
Alaska Range-Boreal Outer Range & Kantishna Hills
Alaska Range-Interior Boreal Mountains
Alaska Range-Teklanika Boreal Mountains & Plateaus
Interior Alpine Floristic Regions:
Interior Alpine Outer Range Region
Kuskokwim Mountains-Alpine Low Mountains
Alaska Range-Alpine Outer Range & Kantishna Hills
Alaska Range-Teklanika Alpine Mountains & Plateaus
Alaska Range-Interior Alpine Flood Plains & Terraces & Fans (in part)
Interior Alpine Alaska Range Region
Alaska Range-Interior Nonvegetated Alpine Mountains
Alaska Range-Interior Alpine Mountains
Alaska Range-Interior Alpine Flood Plains & Terraces & Fans (in part)
Southcentral Boreal Floristic Regions:
Southcentral Boreal Floodplain and Alluvial Fan Region
Cook Inlet Lowlands-Lowland Floodplains & Terraces & Fans
Southcentral Boreal Lowland Region
Cook Inlet Lowlands-Glaciated Lowlands
Southcentral Boreal Subalpine Region
Alaska Range-Southcentral Boreal & Subalpine Mountains
Southcentral Alpine Floristic Regions:
Southcentral Alpine Mountain Region
Alaska Range-Southcentral Nonvegetated Alpine Mountains
Alaska Range-Southcentral Alpine Mountains

In 2001, a new long-term monitoring protocol was developed for Denali after reviews of the original watershed-focused program raised questions about its statistical validity and spatial scale

(Roland et al. 2003). Vegetation is one of the key resources in this new protocol and is one of the primary components in the NPS Inventory and Monitoring Program. The new monitoring program is designed to observe ecological changes in the park and preserve over time (decades to centuries) at different spatial scales up to the landscape level, and to support the management and preservation of the Denali's resources (Roland et al. 2003).

Roland et al. (2003) explains the vegetation monitoring protocol in great depth and discusses results from the first two years of sampling. The new protocol is classified as a systematic two-stage design, which is a probability-based approach. The first stage involved establishing a grid of 66 sites at 20 km intervals within the park and preserve. The first point in the grid was selected randomly, so that all points in the park and preserve had an equal probability of selection. This process allows inferences to be made from sample sites to the rest of the park and preserve, which was not possible under the old monitoring protocol. The second stage involves the establishment of "mini-grids" (Figure 40) placed at each of the established sites, which consist of five rows each with five plots, for a total of 25 plots at a spacing of 500 meters. At each point within the mini-grid, a circular 16m diameter plot with an area of 200 m2 is established for plant and data collection. Data collected during sampling is stored in a Microsoft Access database for further analysis. Roland et al. (2003) proposes revisiting and sampling each mini-grid once every ten years.

The mini-grid vegetation survey also collects data on physical variables within the plots including elevation, slope, permafrost status, and soil characteristics (Roland 2006b). This allows researchers to analyze the relationship between physical variables and vegetation patterns such as species richness and biogeographic affinities of plant communities, vertical community structure (plant stature), tree density and species distribution, and distribution of the dominant vegetation types (Roland 2006b). The effects of physical gradients on Denali's vegetation, based on five years of data collection, are discussed in Roland (2006b). This report also includes preliminary results for the first 20 mini-grids studied in Denali. More than 500 permanent vegetation plots have been established and sampled for physical and floristic data as of the 2006 field season. (Roland et al. 2003).

Baseline data collected during the first round of sampling will be used as a reference for comparison with future sampling results. After the second round of data is collected it will be possible to detect changes from the baseline condition (Roland 2006b). One sampling iteration of the entire park and preserve is projected to take an average of six years to complete, so it may be study year 13 or 14 before the study area has been sampled twice and changes can be assessed at the regional scale (Roland et al. 2003). As of the publication of Roland (2006b), NPS staff were approximately halfway through establishing all permanent plots for the vegetation monitoring program in Denali.

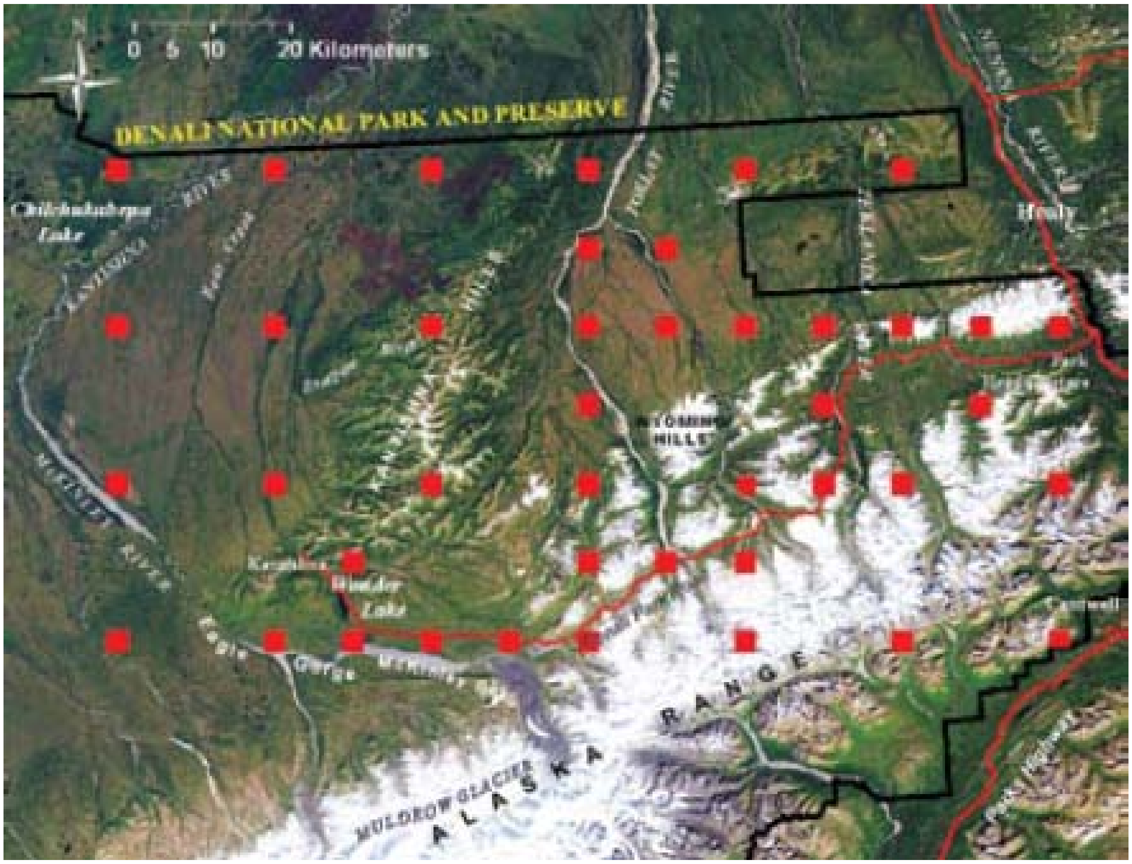


Figure 40. An illustration of CAKN's vegetation monitoring protocol design, with mini-grids (red squares), located on a macro-grid of points spaced 10 or 20 km across the park landscape (Roland 2006a).

<u>Other research</u>

Additional research on Denali's plant communities was obtained during the NRCS soil survey completed in 2004 (Clark and Duffy 2006) and through an exotic plant survey of the park road corridor in 2000 (Densmore et al. 2001). Denali's Exotic Plant Management Team has reported on the status of exotic plant species in developed areas of the park and eradication efforts every year since 2004 (Weidman and Mahovlic 2008).

Since 1992, park staff have also monitored white spruce reproductive output in six plots near park headquarters to detect inter-annual variation and long-term trends in spruce cone and seed production, particularly with regard to climate (Roland 2008). Researchers have gathered data annually on spruce cone production, seed production, and seed viability in both forest and treeline areas. Results show that spruce reproduction is highly variable over time, with a few highly productive years distributed among longer periods of generally low reproduction (Roland 2008). Seed viability also varied among years, but was not synchronized with cone and seed production. On average, spruce reproduction (cone and seed production and seed viability) has been higher in forest plots than in treeline plots (Table 33; Roland 2008). This is likely due to the higher number of large, mature trees in forested areas and possible sampling error in treeline plots where seeds are more likely to be distributed by wind and not caught in seed traps (Roland 2008). Seed viability appears to decrease with elevation, suggesting that growing season length and warmth influences crop viability at northern latitudes (Roland 2008). Results also suggest that warmer temperatures lead to increased seed viability. During short, cool summers, virtually no viable seeds were produced in treeline plots (Roland 2008).

Table 33. Mean spruce reproduction measures for three forested and three treeline plots at Denali, 1992-2007 (Roland 2008).

	Forest plots	Treeline plots
Cone production (per tree)	71.2 ± 27.2	41.9 ± 11.2
Seed production (per trap)	71.5 ± 31.4	4.4 ± 1.4
Seed viability	9%	4%

Since 2000, seed crops appear to be increasing in treeline sites and decreasing in forest sites. In 2004 and 2005, cone production was above average in treeline sites but below average in forest sites, perhaps due to abnormally warm or dry seasons (Roland 2008). This may indicate that forest sites, where spruce trees are much denser, are more vulnerable to drought stress than sparse treeline sites (Roland 2008). Higher productivity in treeline spruce will likely lead to increased dispersal into new areas and potential colonization of open tundra areas (Roland 2008).

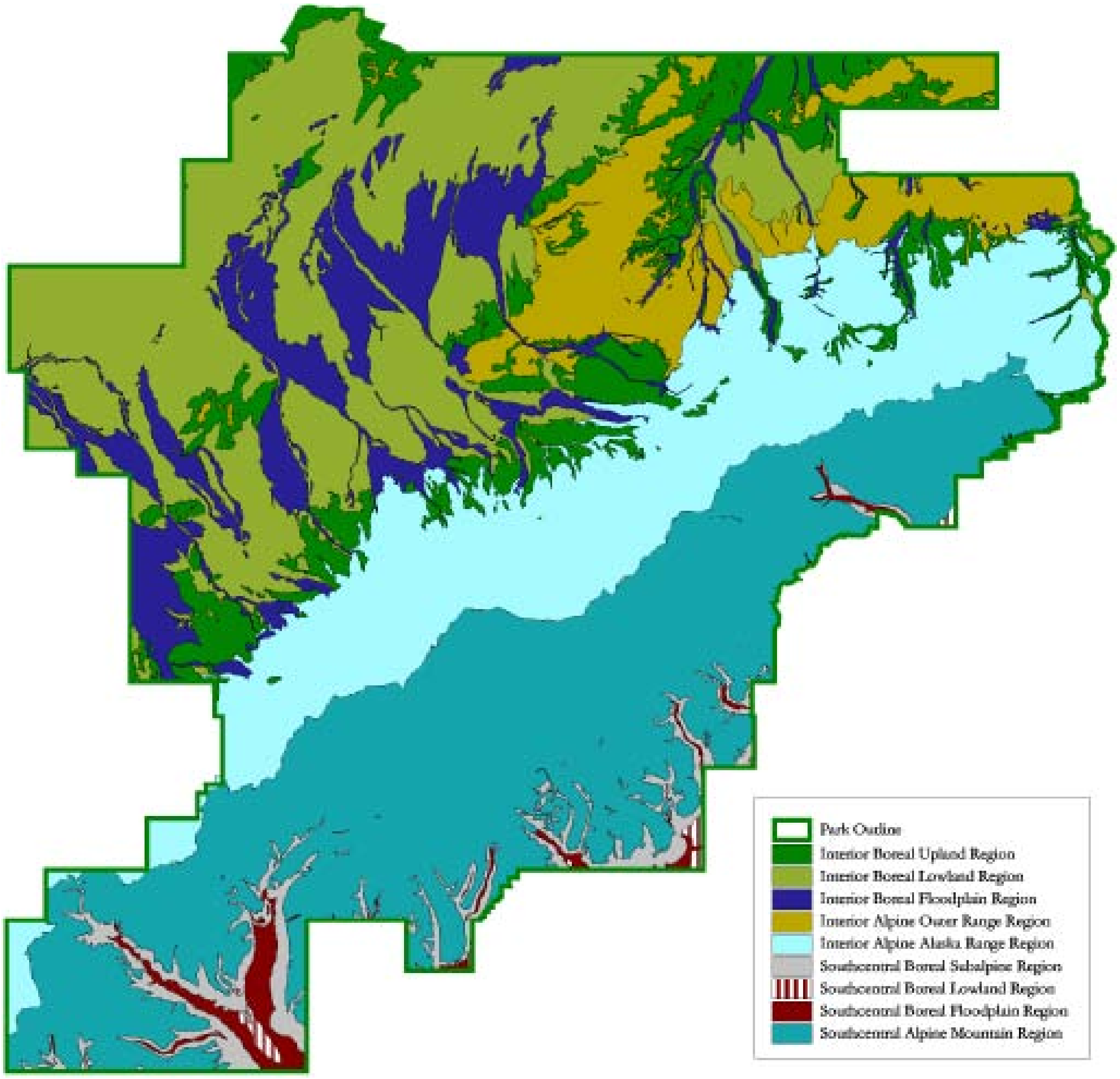


Figure 41. The nine floristic regions that were identified for Denali National Park and Preserve (Mercator Projection, NAD 1927) (Roland 2004).

Current Condition and Trend

Plant species composition as measured in the vegetation monitoring program

The vascular plant inventory of 1998-2001 established nine floristic regions for Denali National Park and Preserve based upon shared ecological characteristics (Figure 41). The smallest of the nine floristic regions is the Southcentral Boreal Lowland Florisitc Region, encompassing a mere 73 km^2 of the park and preserve (Roland 2004). The majority of this region is spruce-broadleaf forest, with low shrub birch-ericaceous and peatlands also present (Photo 15; Roland 2004). Sixty-one species new to Denali were found here, 38 of them in wetlands. These wetland areas produced "the most new species and range extensions, *per unit area surveyed*, of any single habitat in the Park" (Roland 2004).

Photo 15. The forests and peatlands of the Southcentral Boreal Lowland Floristic Region (left), and the East Fork of the Yentna River in the Southcentral Boreal Floodplain and Alluvial Floristic Region (right) (Roland 2004).

The Southcentral Boreal Floodplain and Alluvial Fan Floristic Region is located south of the Alaska Range, covering only 298 km^2 of Denali (Roland 2004). Nearly a quarter of the region is covered by barren silt and gravel, freshly deposited by rivers. Vegetational succession in this region starts with scrub thickets, which are replaced by broadleaf forests, which over time become mixed spruce-broadleaf forests (Photo 15; Roland 2004). A total of 52 species new to the park and preserve were found in this relatively small area: 13 in forests, 22 in wetlands, 11 in aquatic habitats, and six in active floodplains (Roland 2004).

The Southcentral Boreal Subalpine Floristic Region occupies 872 km^2 of Denali (Roland 2004). The landcover consists primarily of dense, closed tall alder scrubs and forb-herbaceous meadows (Photo 16; Roland 2004). This region contained 62 species new to the park, including 29 in forb-herbaceous meadow and 19 in open wetland habitats (Roland 2004).

Photo 16. A mosaic of closed alder scrub and forb-herbaceous meadows in the Southcentral Boreal Subalpine Floristic Region (left), a view of the Interior Alpine Outer Range Floristic Region in the Kantishna Hills (right) (Roland 2004).

The Interior Alpine Outer Range Floristic Region covers 1,907 km^2 north of the Alaska Range in Denali (Photo 16; Roland 2004). This region is dominated by low shrub vegetation, primarily dwarf birch and ericaceous shrubs and, to a lesser degree, alpine dwarf scrub tundra (Roland

2004). Willow scrub and several woodland types were also observed (Roland 2004). This floristic region contains two mountain ranges, the Teklanika Mountains and the Kantishna Hills, which support distinctive floral communities (Roland 2004). The Kantishna Hills support coastal floristic elements unique in Interior Alaska, while the Teklanika Mountains produced new localities for many endemic species (Roland 2004).

The Interior Boreal Floodplain and Alluvial Fan Floristic Region makes up 2,283 km^2 of Denali (Roland 2004). Seventy-three percent of these areas are occupied by three open boreal forest types: stunted spruce, open woodland spruce, and forested areas that have recently burned (Roland 2004). Plant communities in the remaining area include spruce-broadleaf forest and low birch-ericaceous shrub (Roland 2004). Little plant diversity exists in the parts of this region that are dominated by boreal forest vegetation (Roland 2004). Diversity was highest when there were shifts in glacial rivers to other channels, causing flooding that altered the soil conditions of these sites (Roland 2004). Flooding prevents the establishment of typically dominant plant species, allowing for a range of successional vegetation types in these areas (Photo 17; Roland 2004). Thirty-five plant species new to the park and preserve were found in this region, including 17 in wetlands along the river terraces (Roland 2004).

Photo 17. The complex mosiac of communities of an abandoned river channel in the Interior Boreal Floodplain and Alluvial Fan Floristic Region (left), and an open, subalpine wetland in the Interior Boreal Upland Floristic Region (right) (Roland 2004).

The Interior Boreal Upland Floristic Region comprises 2,420 km^2 of Denali (Roland 2004). More than half of this region is covered with scrub vegetation, including low shrub birch-ericaceous-willow and low shrub-sedge (Roland 2004). Open woodland and forest landcover types make up most of the remaining area, with tundra vegetation covering a very small percentage of the region (Roland 2004). The highest species diversity in this region was found in two communities where woody vegetation was less prevalent: open subalpine communities on dry bluffs and steep slopes, and open wet meadows and aquatic sites (Photo 17; Roland 2004). The dry open bluff sites were rich in endemic species, while the wetlands and aquatic sites contained many species new to the park and preserve (Roland 2004).

The Interior Alpine Alaska Range Floristic Region occupies approximately 4,800 km^2 of the Denali land-base (Roland 2004). Approximately half of this region is unvegetated, covered by either snow and ice or bare rocky ground. Where vegetation does occur, landcover types include dwarf shrub, low shrub birch-ericaceous-willow, and “sparse vegetation” (Roland 2004). This region contained the highest number of rare plant species in the park and preserve (31) and produced 18 species new to Denali (Roland 2004). The majority of rare and endemic species in the region were found on xeric alpine slopes, including tundra, fellfield, and rocky outcrops (Photo 18; Roland 2004). Species new to the park and preserve were primarily found in meadows in low Alaska Range passes with transitional climates on the southern edge of the floristic region (Roland 2004).


Photo 18. Dwarf-scrub tundra and mountains in the Interior Alpine Alaska Range Floristic Region (left), and the mosaic of spruce forest, wet meadows, and ponds in the Interior Boreal Lowland Floristic Region (right) (Roland 2004).

The second largest floristic region is the Interior Boreal Lowland Floristic Region, which occupies 5,900 km^2 of Denali (Roland 2004). Seventy-five percent of these areas are covered by stunted spruce, open woodland spruce, and forested areas that have recently burned. Wet herbaceous meadows, low boggy shrub-sedge, and mixed white spruce forest are also present in the region (Photo 18; Roland 2004). Boreal forest vegetation dominates most areas due to the widespread presence of permafrost. Other plant communities are found primarily along rivers and ponds where there has been a disruption in the ice-rich permafrost (Roland 2004). Like the Interior Boreal Floodplain, forested areas in this region are notably species-poor (Roland 2004). Of the 70 species new to Denali found in this region, only three were found in forested areas (Roland 2004). A significant portion of the Interior Boreal Lowland region consists of wetlands, which have been historically underrepresented in vegetation surveys and were therefore a primary target of this inventory. A majority of the species new to the park and preserve from this region were found in wetlands and other aquatic habitats (Roland 2004).

The final floristic region is the Southcentral Alpine Floristic Region which encompasses the largest area of Denali at 6,930 km^2 (Roland 2004). Sixty percent of the land is covered with snow, ice, and bare ground (Roland 2004). Areas that are vegetated contained alpine fellfields, very sparse tundra, and open riparian areas with large amounts of bare ground (Roland 2004). The dry tundra and rubble slope habitats in this region supported the greatest number of rare and endemic plants of any area in the park (Photo 19; Roland 2004).

Photo 19. A rubble slope in the Southcentral Alpine Floristic Region (Roland 2004).

Number of native plant species lost

No native plant species are known to have been lost from Denali (DENA 2009). This tends to indicate a fairly healthy and stable native plant community in the park and preserve.

Presence of exotic plant species

Traditionally Alaska has been protected from exotic species by its location, climate, and inaccessibility (Weidman and Mahovlic 2008). As a result, exotic plants are a relatively recent threat to Alaskan ecosystems. These species tend to displace native plants and can sometimes contaminate gene pools by interbreeding (Schrader and Hennon 2005). Exotic plants may originate from escaped ornamentals, seeding after road construction projects, or as hitchhikers on equipment or gear (Schrader and Hennon 2005). Given their hardiness and tolerance, many exotic plant species establish themselves in heavily disturbed areas such as road corridors, landing strips and gravel bars (Schrader and Hennon 2005). The large number of visitors to Denali and frequent construction projects in recent years make the park and preserve particularly vulnerable to exotic species invasion (Weidman and Mahovlic 2008).

Since 2000, 31 species of exotic plants have been recorded in Denali National Park and Preserve (Table 34). Fifteen of these were found by the NPS exotic plant management team (EPMT) during the 2008 field season (Weidman and Mahovlic 2008). Species found to be most significant and therefore the focus of eradication efforts in 2008 were common dandelion (*Taraxacum officinale* ssp. *officinale*), bird vetch (*Vicia cracca*), narrowleaf hawksbeard (*Crepis tectorum*), and white sweet clover (*Melilotus alba*) (Photo 20; Weidman and Mahovlic 2008). All documented exotic plant occurrences are in developed or disturbed areas, such as the park entrance (Plate 29; Roland 2004, Weidman and Mahovlic 2008). Densmore et al. (2001) recommended seeding low-growing native species along the park road shoulders to prevent exotics from establishing and spreading through these vulnerable areas. There is no evidence of exotic species invading undisturbed native plant communities.

Photo 20. Narrowleaf hawksbeard (left) and white sweet clover (right) along the park road in Denali National Park and Preserve (Densmore et al. 2001).

Table 34. List of exotic plant species found in Denali National Park and their locations. Species in bold were found in 2008 (adapted from Weidman and Mahovlic 2008).

Scientific Name	Common Name	Location in Park
Brassica rapa	field mustard	Kantishna
Bromus inermis ssp. inermis	smooth brome grass	Front country
Capsella bursa-pastoris	shepherd's purse	Headquarters
Chenopodium album	**common lambsquarters**	**Front country/HQ**
Crepis tectorum	**narrowleaf hawksbeard**	**Front country**
Descurainia sophia	flixweed	Front country/HQ
Erysimum cheiranthoides	wormseed mustard	Front country/Kantishna
Hordeum jubatum	**foxtail barley**	**Front country**
Lappula squarrosa	European stickseed	Park road
Lepidium densiflorum	common pepperweed	Front country/HQ/Road
Leucanthemum vulgare	oxeye daisy	Park road
Linaria vulgaris	**yellow toadflax**	**Railroad**
Lupinus polyphyllus	**bigleaf lupine**	**Park road**
Matricaria discoidea	**pineapple weed**	**Front country**
Melilotus alba	**white sweetclover**	**Front country/Park road**
Melilotus officinalis	**yellow sweetclover**	**Park road**
Phleum pratense	common timothy	Front country/Kantishna
Plantago major	**common plantain**	**Front country**
Polygonum aviculare	prostrate knotweed	Front country/Kantishna

Table 34. List of exotic plant species found in Denali National Park and their locations. Species in bold were found in 2008 (adapted from Weidman and Mahovlic 2008) (continued).

Scientific Name	Common Name	Location in Park
Polygonum convolvolus	black bindweed	Kantishna
Ranunculus repens	creeping buttercup	Front country
Silene noctiflora	night-blooming cockle	Kantishna
Sonchus oleraceus	annual sowthistle	Headquarters
Spergula arvensis	corn spurry	Kantishna
Stellaria media	common chickweed	Park road/Kantishna
Taraxacum officinale ssp. officinale	**common dandelion**	**Front country**
Trifolium hybridum	**alsike clover**	**Front country**
Trifolium pratense	**red clover**	**Front country**
Trifolium repens	**white clover**	**Front country**
Tripleurospermum perforata	**scentless false mayweed**	**Railroad**
Vicia cracca	**bird vetch**	**Front country**

Anthropogenic change in native plant community distribution

Although no anthropogenic change in plant distribution has been documented in Denali, the Central Alaska Network has identified human disturbance as an issue of high management priority (Swanson 2000). More research is needed to identify the impacts that anthropogenic factors have on plant communities within Denali National Park and Preserve.

Species expected vs. found

Prior to the 1998-2001 floristic inventory, researchers compiled a list of 409 vascular plant taxa that were expected to be found in the park and preserve (Roland 2004). The inventory documented 622 vascular plant species, including 224 species previously unknown in Denali and one species (*Bidens tripartita*) new to the state of Alaska (Roland 2004). During the NRCS soil survey, botanist Mike Duffy collected an additional 30 species new to Denali (Roland 2004). Researchers believe that at least 95% of all the vascular plant species that occur in Denali National Park and Preserve have now been documented with voucher specimens (Roland 2004).

Threats and Stressor Factors

Potential threats to native plant communities listed in DENA (2009) are contamination, climate change, and the manipulation of plant populations. Invasive species are a source of contamination that is easily spread by human activities (Schrader and Hennon 2005). The extension of roads or trails from the main park road may lead to the spread of exotics into the native plant communities (Roland 2004). Any increase in flight-seeing and other recreational activities has a high potential to negatively impact native plant communities. While insects and diseases have not significantly impacted Denali's vegetation in recent years, they are a constant threat. Roland (2006b) found some evidence suggesting that tamarack (*Larix laricina*) trees in the park were affected by a larch sawfly (*Pristiphora erichsonii*) outbreak in the mid- to late-1990s.

Climate warming is clearly inducing change in the northern latitudes worldwide, including Alaska (Roland 2006a). Melting of glaciers and frozen soils, degradation of ancient permafrost, and the expansion of woody vegetation into open areas are all dramatic changes seen at Denali that may be attributed to climate change (Roland 2006a). The increasing invasion of alpine tundra and other open areas by woody plants is a significant threat to the high plant diversity in Denali (Roland 2006a).

Evidence suggests that permafrost degradation and the resulting increase in active layer depth will lead to major changes in vegetation patterns, which in turn impact wildlife habitat (Roland and McIntyre 2006). The distribution of permafrost varies between the nine floristic regions of the park and preserve (Figure 42). Regions with larger areas of permafrost will be more vulnerable to changes in vegetation. According to Swanson (2000), CAKN parks lack sufficient data to understand the current condition of permafrost and potential threats, because existing data is incomplete, unanalyzed, or poorly obtained. While information on permafrost in Denali has increased somewhat with the publishing of the NRCS Soil Survey (Clark and Duffy 2006), more research and analysis is needed.

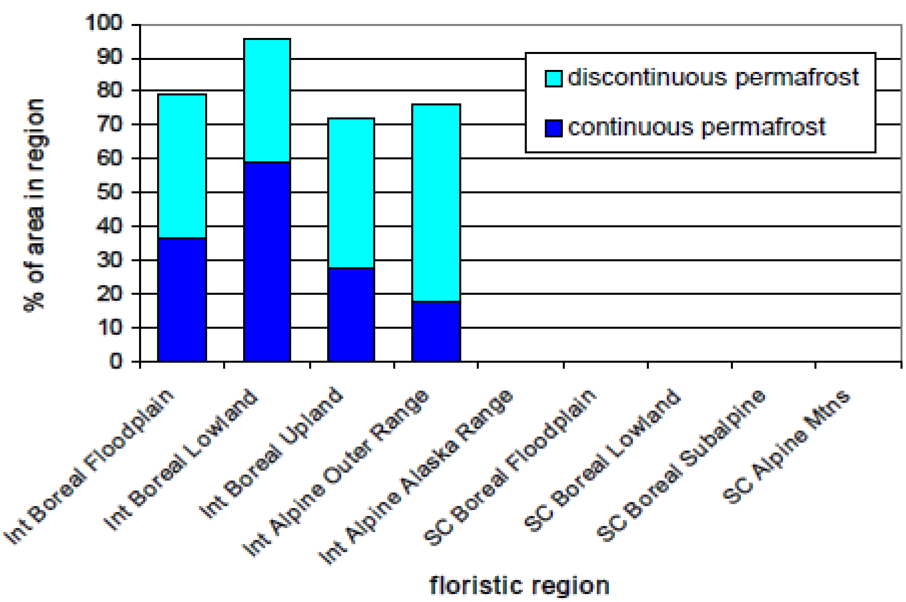


Figure 42. The percentage of area within each floristic region of Denali National Park and Preserve underlain by soil units with discontinuous and continuous permafrost. These quantities were derived from a GIS analysis of the Soils Inventory coverages (Roland 2004).

Fire reduces the amount of tall woody vegetation, which affects habitat for mammals and therefore impacts human subsistence (Roland 2006b). The occurrence and impact of fire varies between the nine floristic regions (Figure 43). Some regions have an extensive history of forest fires while others, primarily south of the Alaska Range, show no evidence of wildfires. The floristic region most affected by fire in Denali is the Interior Boreal Floodplain where an estimated 17.4% of vegetation has burned over the past 50 years (Roland 2004).

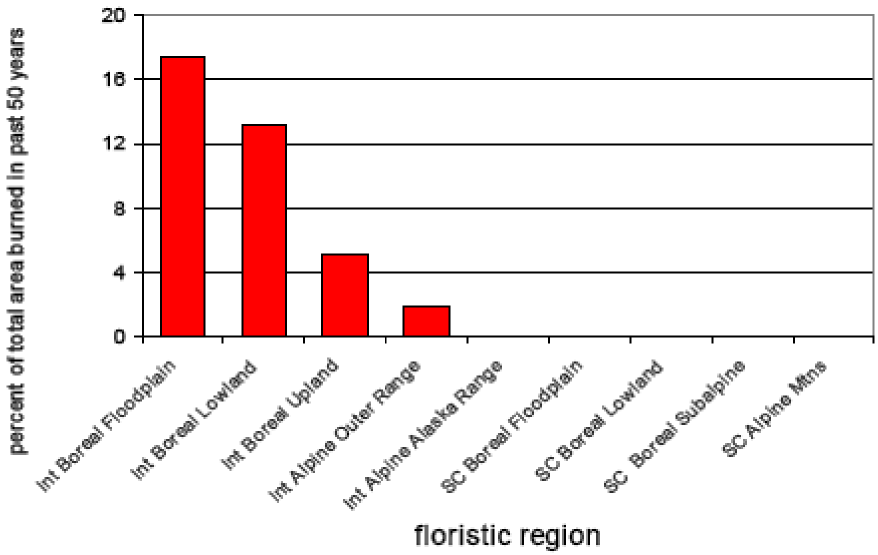


Figure 43. The percentage of area within each floristic region of Denali National Park and Preserve burned by fire in the last 50 years. These quantities were derived from a GIS analysis of the fire perimeters mapped in the park and preserve during that period of time (Roland 2004).

<u>Data Needs/Gaps</u>
Both Roland (2004) and DENA (2009) noted the need for a complete, park-wide nonvascular plant inventory (including mosses, lichens and liverworts). This is a major missing data set for understanding and managing the biological diversity of the park and preserve. Further research is also needed into the effects of human disturbance on Denali's plant communities and possible impacts of contaminants on mosses and lichens (DENA 2009).

<u>Overall Condition</u>
Recent inventory and monitoring of Denali's native plant community composition have not produced any evidence of significant change or damage. No losses of native plant species are known and no native plant communities are presently at risk due to anthropogenic change (DENA 2009). Exotic plant species are present, but only in developed areas (DENA 2009). For these reasons, the current condition of native plant communities is considered to be good. No trend can be assigned at this time, because repeat sampling has not yet occurred at the mini-grid monitoring sites.

Level of Confidence
The history of plant collections and the floristic inventory at Denali provide an excellent base of information about the composition of the native plant communities in the park and preserve. The new monitoring program has started to provide valuable data gathered in a rigorous and consistent method. Future data gathered under this protocol will be very useful in determining changes to the plant communities over time.

Sources of Expertise
The primary source of information regarding the native plant community is Roland (2004, 2006b) and Roland et al. (2003).

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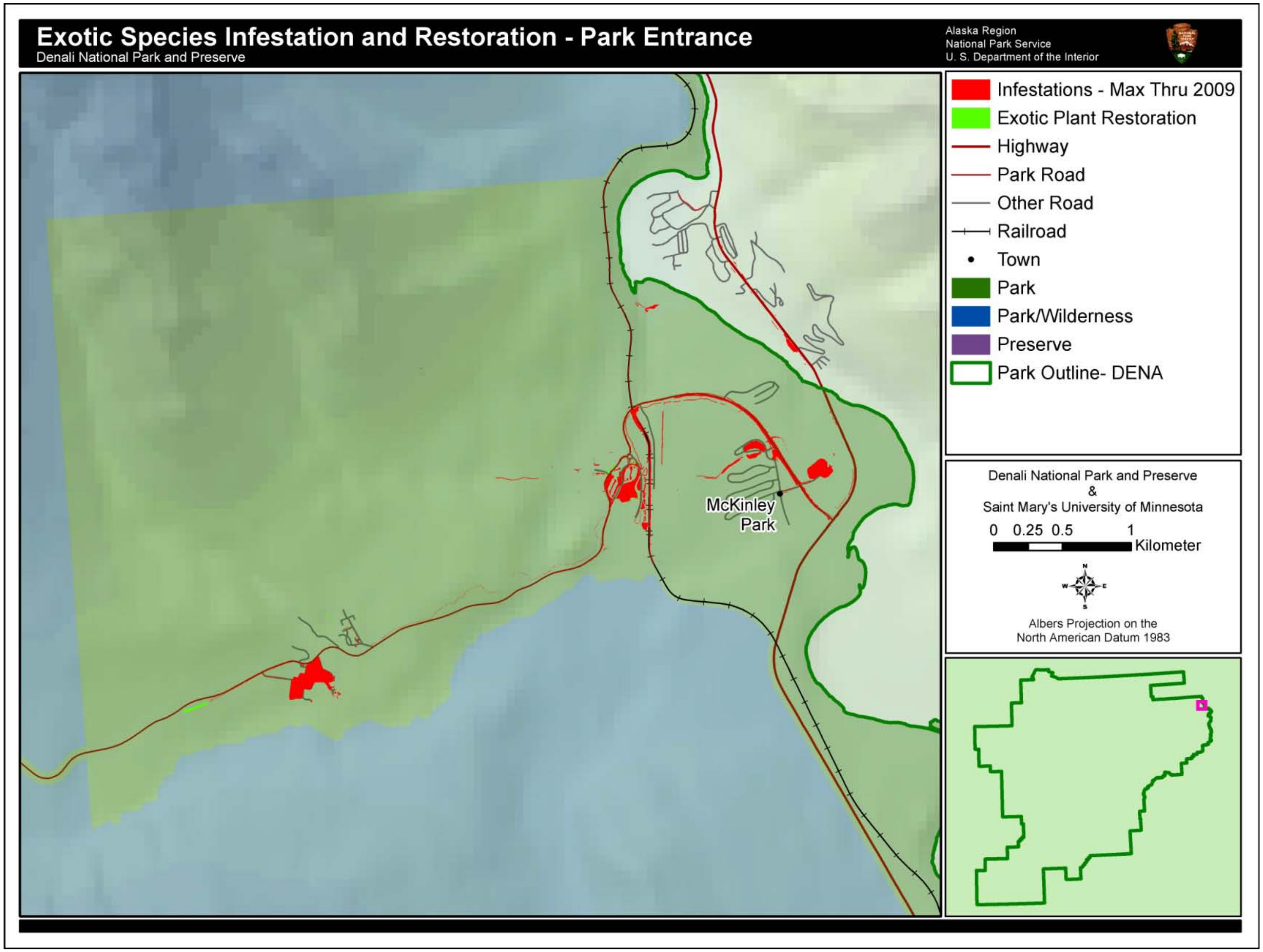
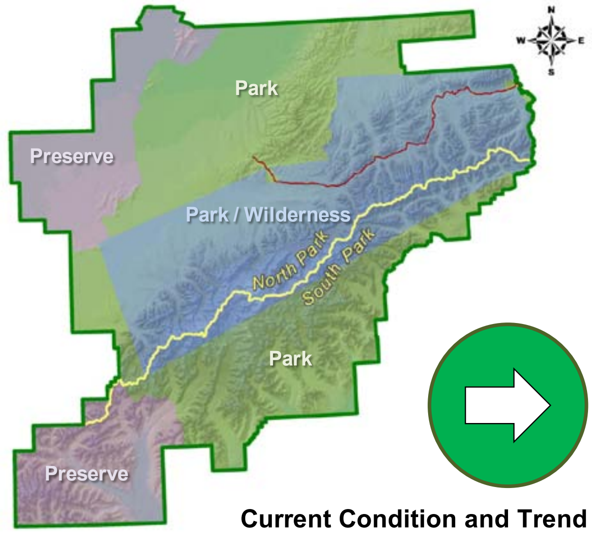


Plate 29. Exotic species infestation and restoration sites at the DENA entrance (Exotic Plant Management Team 2010, NPS 2010). There are additional exotic species infestation sites and restoration along the park road, which are not within the extent of this map.

4.11 Fire

Description



Current Condition and Trend

Fire has been identified as the dominant ecological process in the northwestern region of Denali National Park and Preserve (Allen 2005). Fires can have a landscape-level influence on vegetation structure and composition, permafrost dynamics, water quality, air quality, nutrient cycling, primary productivity for herbivores, and biodiversity (Allen 2005). In the absence of fire, organic matter accumulates and insulates the ground, causing the permafrost table to rise (DENA 2007). As a result, ecosystem productivity declines, contributing to a decrease in vegetation and habitat diversity over time (DENA 2007). Nutrients are returned to the soil through fire, both during the initial combustion and through increases in decomposition following a burn (DENA 2007). Some species are dependent on the disturbance caused by fire, such as black spruce (*Picea mariana*) with cones that open and release seed in response to the heat of canopy fires (DENA 2010a).

In Alaska's boreal forest and tundra ecosystems, burn severity strongly impacts post-fire vegetation patterns and succession (Sorbel and Allen 2005). If burn severity is low or moderate, the aboveground plant materials will be damaged but much of the vegetation will be able to regenerate quickly from roots and stems. Severe fires, however, also kill off much of the underground root structure of shrubs and herbaceous plants, forcing reproduction to occur by seed, a much slower process (Sorbel and Allen 2005).

Changes in vegetation due to fire, in turn affect wildlife distribution and habitat use. Patchy fires create a mosaic of habitat types frequently used by snowshoe hares and martens, while moose often browse on sprouting willow and other shrubs (Sorbel and Allen 2005). Small mammals such as voles often thrive in recently burned areas, creating large colonies in the remaining duff and feeding on new vegetation. Caribou, on the other hand, appear to avoid recently burned areas due to the absence of lichen, their primary winter food source (Sorbel and Allen 2005).

The occurrence, extent, and severity of fires in Alaska are strongly influenced by climate, terrain, and vegetation (Allen 2005). The fire regime is also likely affected by local and global climate change (Allen 2005). Due to record high temperatures and low precipitation, the summer of 2004 had the most extensive fire season in Alaska's recorded history with over six million acres burned (Sorbel and Allen 2005). The 2005 fire season was the second largest on record for Denali National Park and Preserve with seven fires burning 117,500 acres (Allen 2005).

Wildfires in Denali can range from "creeping subterranean fire in tundra to fast moving ground or canopy fire in surface fuels or spruce stands" (DENA 2007). Fire is the dominant ecological process in the taiga and tundra north of the Alaska Range where black spruce is abundant and precipitation is limited (DENA 2010b). South of the Alaska Range where the climate is wetter, fires are infrequent and usually limited to small patches of aspen, cottonwood, and birch (DENA 2010b). The highest concentration of ignitions occurs north and west of Kantishna, beyond the west end of the park road, and in the Stampede corridor in the northeast part of the park (DENA 2007). Fire behavior generally depends on fuel type, fuel loading, fuel moisture content, topography, and local weather conditions. There are four fire behavior systems, based on fuel type, in Denali: grass/tundra, deciduous forest/shrublands, mixed forests, and conifers (DENA 2007).

The most common ignition source for fires in Denali is lightning, with 90% of all fire incidents annually triggered by this source (Figure 44; DENA 2007). Most fires in Denali, 84% on average, start in June and July when lightning occurrence is high (DENA 2007). Human-caused ignitions have decreased drastically from 43% of fire incidents prior to 1980 to just 13% in the last 30 years (DENA 2007). Most human-caused fires occur along the park road or near the railroad/Parks highway corridor.

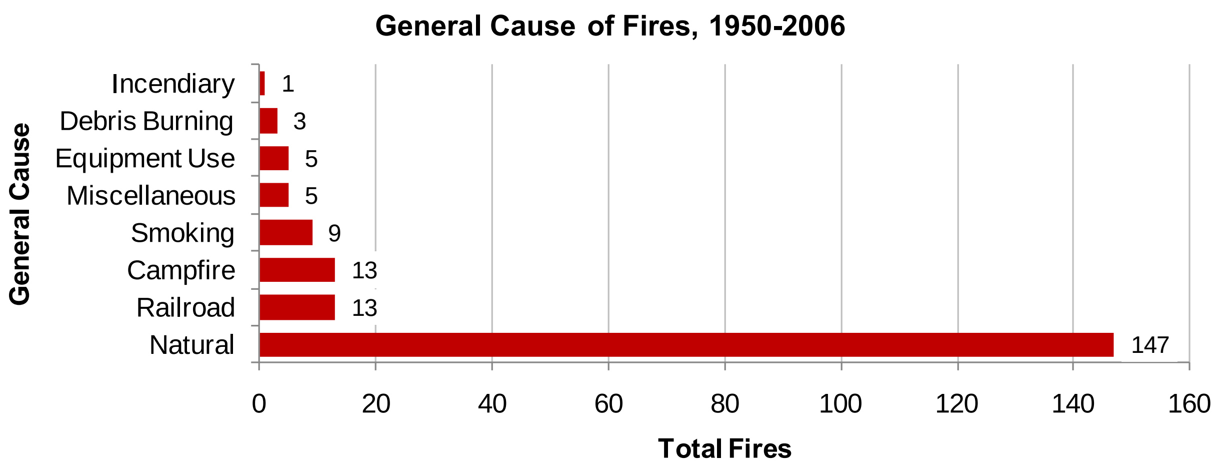


Figure 44. General cause of the 196 wildland fires in Denali National Park and Preserve, 1950-2006 (adapted from DENA 2007).

The primary objective of Denali's fire management program, in accordance with NPS policy, is to allow natural forest and tundra fires to fulfill their ecological role in vegetation succession (DENA 2007). Prior to the early 1980s, suppression actions were taken on the majority of fires (DENA, Weddle, pers. comm. 2010). Following the 1982 implementation of the Alaska Interagency Fire Management Plan - Tanana/Minchumina Planning Area, significant areas of the park and preserve were designated to allow fires to burn to the greatest extent possible while minimizing risk to sensitive resources, recognizing that fire is an important ecological process within a naturally regulated ecosystem. Natural fires within the park and preserve will be allowed to burn unless they threaten private in-holdings, certain identified historic sites, or neighboring lands that are zoned for protection.

Denali is divided into four fire management units (FMUs), each receiving a different level of management as summarized in Table 35 (DENA 2007). Nearly 93% of the park and preserve fall under the limited management option and less than 1% receives critical protection (Plate 30;

DENA 2007). Most areas not under limited management are around administrative facilities, private in-holdings, or along boundaries with private land (DENA 2007).

Table 35. Summary of the preplanned management response for the four FMUs within Denali (DENA 2007). Note: Though these are the preplanned management response for each FMU, in any of the designated areas the full range of management responses are available for implementation.

Protection/Management Level	Policy/Response
Critical	Aggressive suppression of fires within or threatening designated areas; Highest priority for available resources.
Full	Aggressive suppression of fires within or threatening designated areas, depending upon availability of resources.
Modified	Prior to the designated conversion date, typically 10 July, fires in this area receive the same response as the "Full" level. Following the conversion date fires in this area receive the same response as the "Limited" level.
Limited	Wildland fires allowed to burn within predetermined areas but are monitored to ensure the protection of human life and site-specific values.

Though broadcast burning implementation of prescribed fire has not been used as a tool in Denali, it may be utilized in the future to meet specific resource management goals (DENA 2007). Prescribed burns could be used to restore historical conditions at selected sites or to reduce hazardous fuel loads in areas requiring protection (DENA 2007). If global climate change or other stressors lead to changes in the fire regime, prescribed fire may be used to maintain ecosystem integrity (DENA 2007).

Measures
Number of acres burned per year
Number of natural fire starts per year
Total duration (days) of fire incidents annually from first start date to final declared out date
Fire season duration (days) and timing (dates)
Percentage of burns by severity class annually

Reference Conditions/Values
The reference condition for number of acres burned per year, number of natural fire starts per year, and total duration of fire incidents is to remain within the range of natural variability from 1952 to the present (DENA 2009). For the duration and timing of fire season, the reference condition is to remain within the range of natural variability from 1993 to the present time (DENA 2009). The reference condition for percent of burns by severity class is to remain within the range of natural variability from 1983 to the present (DENA 2009). Currently burn severity data is only available for 2000-2005. Historical records and images are being analyzed and more burn severity data is expected to be available in the future.

Data and Methods
The state of Alaska began keeping systematic fire records in 1940, resulting in "fairly complete and reliable" information on moderate to large fires since that time (Buskirk 1976). Efforts to compile historical data on fires within Denali began in the 1970s (Buskirk 1976). Regular monitoring during the fire season produces data on the location, extent, and severity of burns within the park to determine annual fire frequency, average fire size and variability in burn

severity (Allen 2005). Information is also collected on the cause of the fire, physical characteristics at the point of origin, and vegetation types burned (Allen 2005). All data is stored in the DOI Wildland Fire Management Information System. Between 1950 and 2005, a total of 586,729 acres burned within Denali National Park and Preserve with an average of 10,477 acres burning each year (Plate 31; Allen 2005). The average wildfire size is 3,025 acres with an average of 3.4 fires occurring per year (Allen 2005). As an example year, data for the seven wildfires that occurred in Denali during 2005, all caused by lightning, are presented in Table 36.

Table 36. The seven wildfires in Denali during 2005, with the number of acres burned and start and end dates (adapted from Allen 2005).

Fire name	Acres burned in Denali	Start date	End date
Highpower Creek	113,655	6/14	9/30
Herron River	3,653	6/14	7/12
McKinley River	91	6/15	7/12
Bear Creek	25	6/17	7/9
Wigand Creek	0.3	6/21	6/21
Muddy River	12	6/28	7/4
Birch Creek	73	7/26	8/27

Burn severity is measured by comparing pre- and post-fire satellite imagery to determine a Differenced Normalized Burn Ratio (dNBR). This method is described in detail in Sorbel and Allen (2005). The accuracy of the dNBR method was tested by sampling Composite Burn Index (CBI) plots established on the ground in recently burned areas (Photo 21). CBI methods involve scoring burn severity based on 22 variables including soil cover/color change, duff and litter consumption, percent of colonizers, percent of altered foliage, and percent of canopy mortality (Sorbel and Allen 2005). A comparison of CBI scores and dNBRs for the same areas shows that dNBR is "a suitable measure and predictor of burn severity in Alaska national parks" (Sorbel and Allen 2005).

Photo 21. Monitoring a high severity burn in Denali National Park and Preserve in 2000. Note the 100% tree mortality and fire moss growing on exposed soils (NPS photo, in Sorbel and Allen 2005).

Some research has been conducted on the effects of fire and burn severity on species composition and structure of vegetation, active layer depth, and wildlife habitat (Allen 2005). A 2005 pilot project on Denali's fire ecology tested the use of videography as a method for classifying fuels and landcover, validating succession patterns relative to burn severity, and identifying fire effects on moose browse at different post-burn intervals (Allen 2005). Forty-three plots were established along two transects in areas that had burned five and fifteen years ago. Preliminary results showed that the post-fire dominant vegetation types in both age classes were low mixed shrub-sedge tussock tundra (26% of plots), low mesic birch-ericaceous shrub types (17%) and deciduous-spruce mixes on upland landforms (17%) (Allen 2005). The study also suggested that moose browse availability was higher in 15-year plots than in more recently burned areas, although results were variable and not significant (Allen 2005). In the 15-year plots, 44% of shrub species preferred by moose were browsed while only 25% of these species were browsed in 5-year plots (Allen 2005).

As part of the NRCA, SMUMN GSS was asked to analyze available fire data related to the condition measures. Both an ESRI polygon shapefile of fire perimeters and tabular fire history data with latitude and longitude coordinates were provided to SMUMN GSS. The tabular dataset is more complete and was used for calculating acres burned per year, number of natural fire starts per year, and fire season duration and timing. In addition to calculating annual statistics, the time periods before and after the management change in 1982 were compared using a Student's t-test and SPSS 16. Minor adjustments were made to the data to address incomplete records. The spatial polygon dataset was used to determine the number of acres that have re-burned. Burn severity and potential vegetation spatial data were obtained through NPS (2010) and used with ESRI ArcGIS to analyze burn severity distribution and the relationship between burn severity and vegetation.

Current Condition and Trend

Number of acres burned per year

Figure 45 shows the number of acres burned per year in Denali from 1946 to 2009. The significant increase ($p < 0.05$) in acres burned per year in the last 30 years can be at least partially explained by a change in management policies in the early 1980s. The average number of acres burned per year prior to 1983 was 2,920 acres (SD = 7,439), and the average number of acres burned since 1982 has been 19,215 (SD = 36,770). When this change is taken into consideration, the number of acres burned in recent years appears to be within the range of natural variability. Figure 46 is included with a logarithmic scale for better visualization of smaller fires.

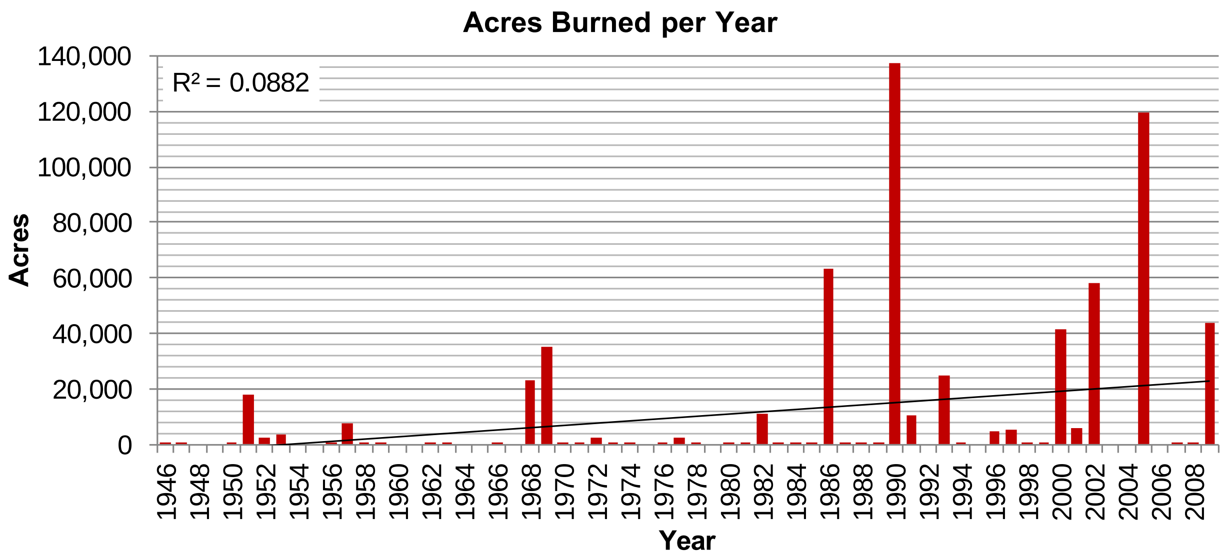


Figure 45. Total number of acres burned per year, 1946-2009, with trend line (DENA 2010c).

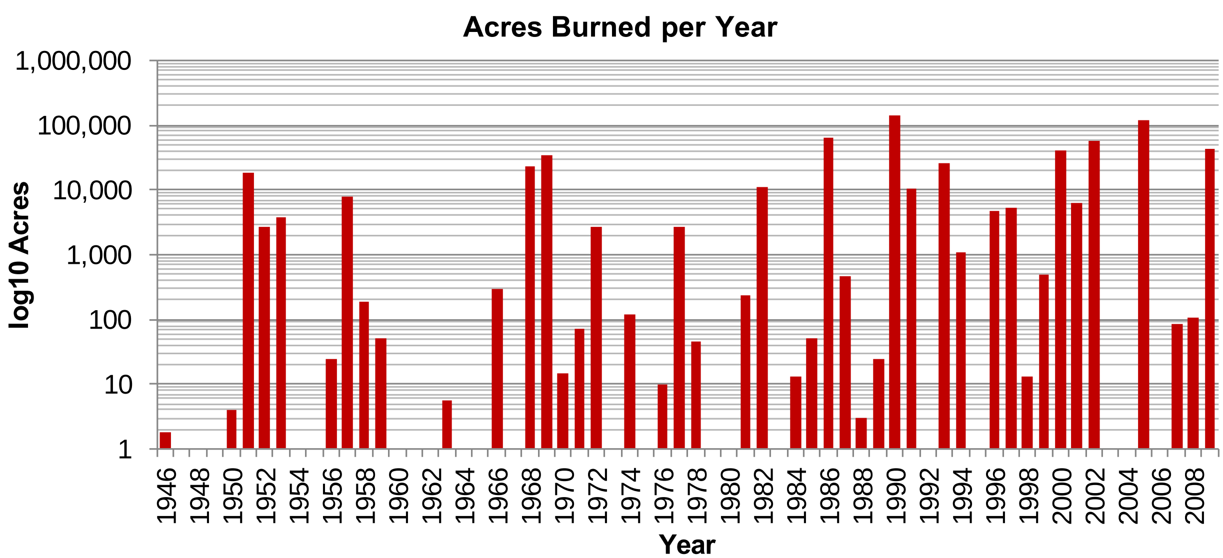


Figure 46. Total number of acres burned per year, 1946-2009 (DENA 2010c). Note the $\log^{10}$ scale.

Areas Re-burned

Between 1952 and 2009, the total amount of area re-burned, as calculated from the available polygon data, was 41,272 acres. It should be noted that the available fire perimeters for re-burn analysis is not complete prior to the 1980s. Therefore, the total number of acres re-burned could be greater. On average there were approximately 13 years between re-burn events, although there was much variability (S.D. = 9 years; Figure 47, Figure 48). More re-burn events were recorded in the last decade (2001 – 2010) compared to the previous decade (Figure 47, Figure 48), but this statistic could be greatly impacted by the lack of complete fire perimeters prior to the 1980s.

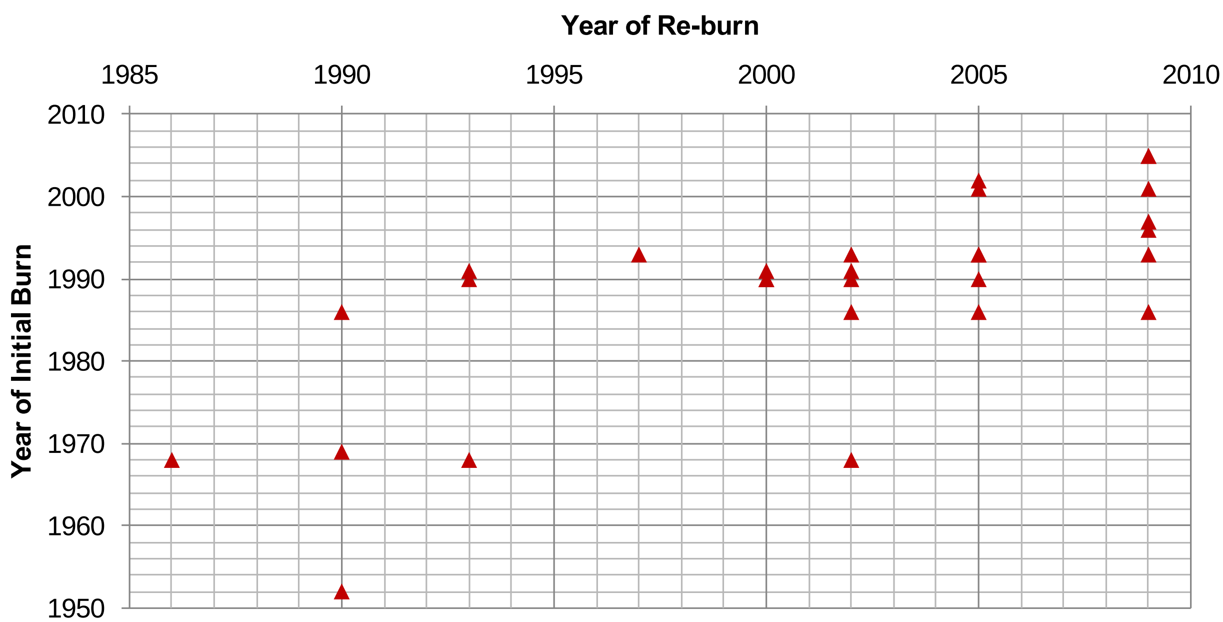


Figure 47. Re-burns: Red triangles represent re-burn events with the year of the intial burn on the vertical axis and the year of the re-burn on the horizontal axis (DENA 2010d).

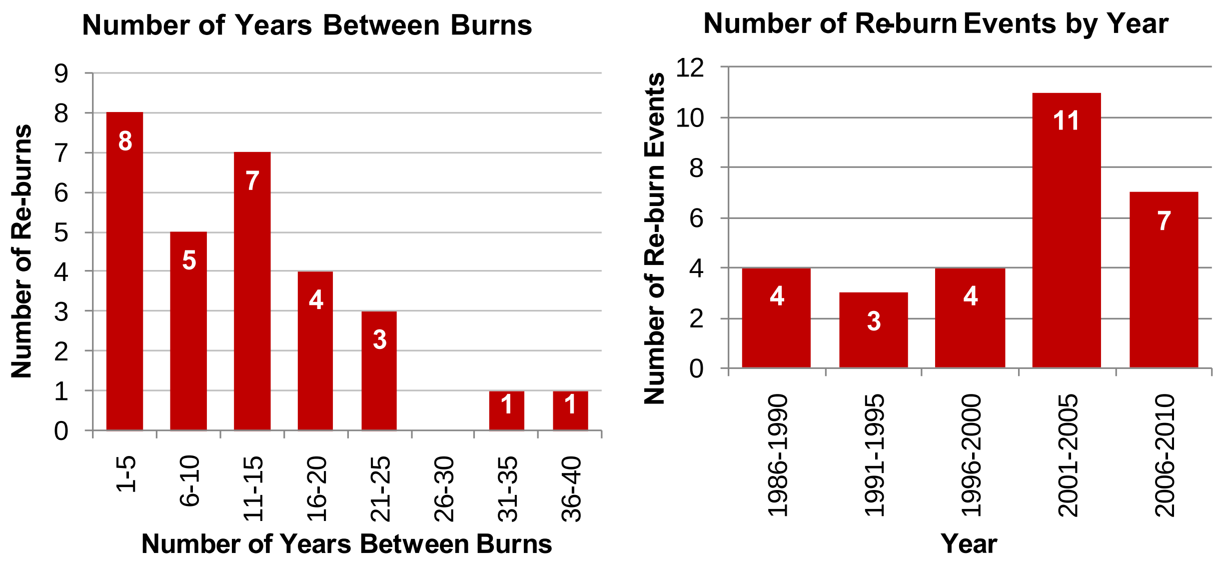


Figure 48. Re-burns: Frequency of duration in years between burns (left) and number of re-burn events by year (right) (DENA 2010d).

For each re-burn event, Figure 49 depicts the year of the initial burn, the year of the re-burn, and the number of acres re-burned (y-axis). Although a relatively large number of locations re-burned in 2009 (Figure 49), most of these locations were smaller areas (Figure 49, Figure 50). The majority of re-burn events have been less than 3,000 acres, but occasionally there are larger areas of re-burn (Figure 49, Figure 50). The locations where re-burns have occurred are depicted on Plate 32.

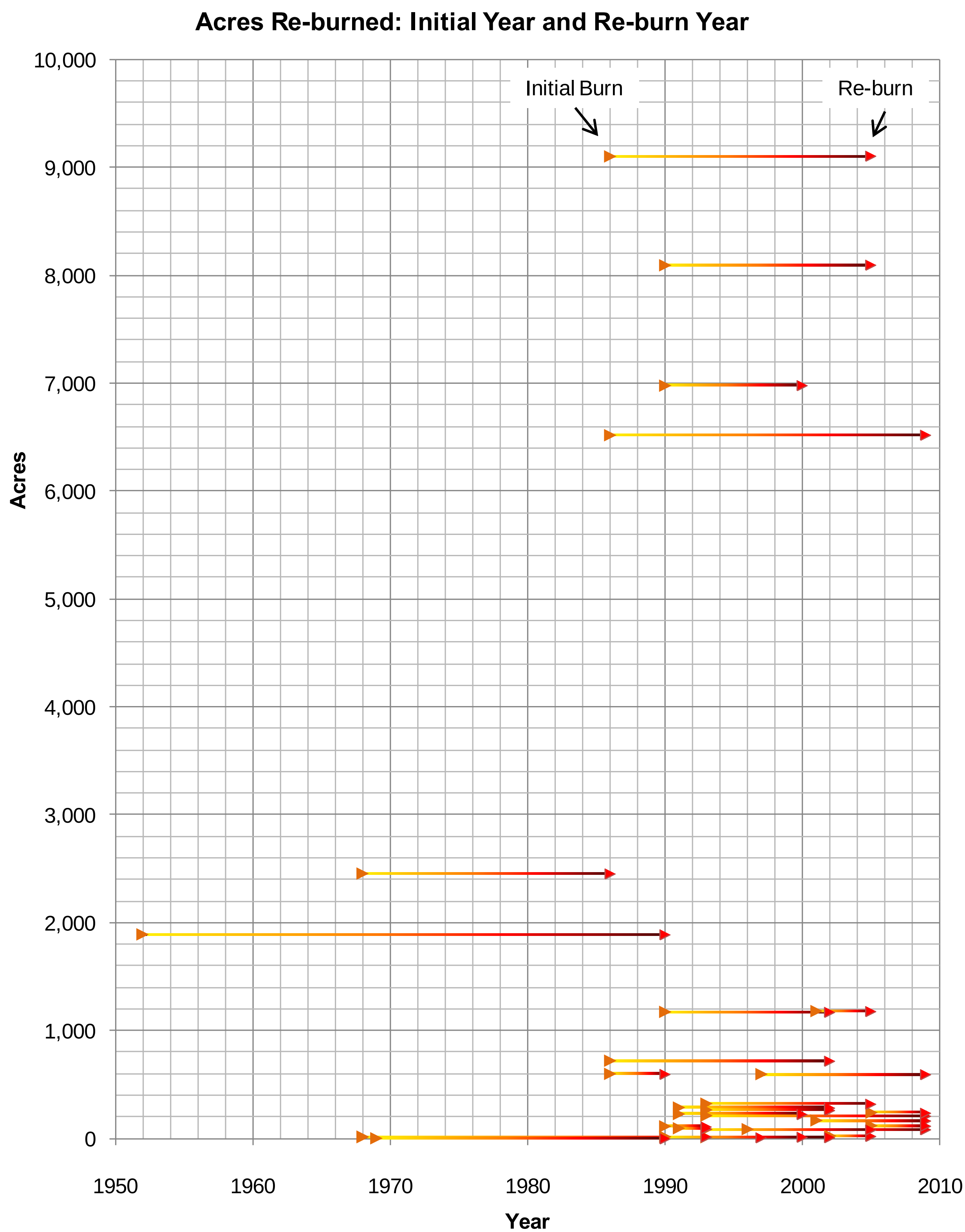


Figure 49. Re-burns: Year of intial burn represented by orange triangle; Year of re-burn represented as red triangle; Vertical axis represents hectares of area re-burned; Horizontal lines represent time between re-burn (DENA 2010d).

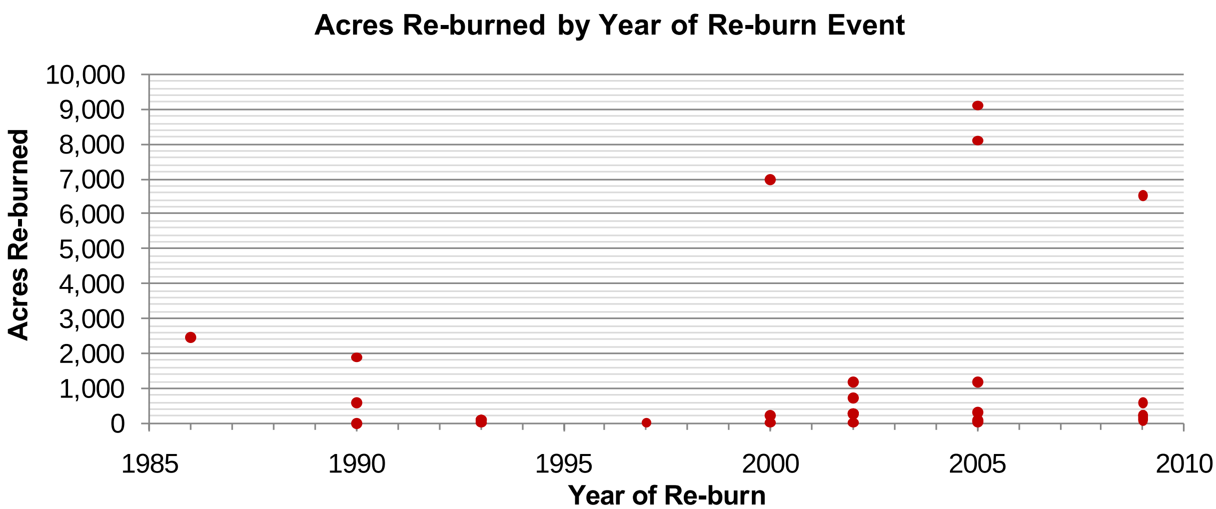


Figure 50. Acres re-burned by year of re-burn event (DENA 2010d).

Number of natural fire starts per year

The number of natural fire starts per year from 1952 to 2009 is shown in Figure 51. This graph shows that recent findings are well within the range of natural variability for this time period. The average number of natural fire starts per year from 1983 to 2009 (3.7, SD = 4.2) is not significantly different from the 1952 to 1982 time period (2.1, SD = 2.9).

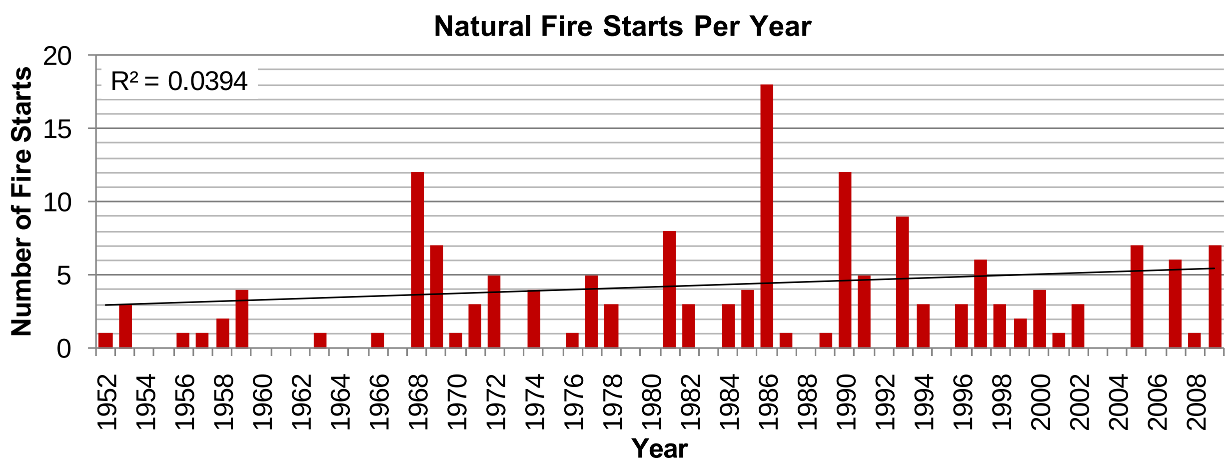


Figure 51. Natural fire starts per year, 1952-2009 (DENA 2010c).

Total duration (days) of fire incidents annually from first start date to final declared out date

The data available for this measure is presented in Table 37. As with number of acres burned per year, much of the variation in this data can be explained by the change in management policies in the early 1980s. Once suppression efforts declined, the duration of fire incidents naturally increased. While there is some evidence that the annual duration of fire incidents has increased over time, analysis of this data is problematic due to incomplete or inaccurate data. End dates are often difficult to determine in remote areas of Denali and may not be recorded accurately.

Table 37. Total number of fires per year and total number of fire incident days annually. Total number of fire incident days represents the sum of each fire's duration in days from first start date to final declared out date. Data was incomplete for some years due to inaccurate or unrecorded end dates. For these years, duration is reported as "at least xx days" (DENA 2010c).

Year	Number of fires per year	Total number of fire incident days	Year	Number of fires per year	Total number of fire incident days
1946	2	2	1981	8	at least 10
1947	1	1	1982	3	17
1950	2	2	1983	1	1
1951	4	26	1984	3	5
1952	1	12	1985	4	14
1953	3	18	1986	20	234
1956	1	at least 1	1987	5	49
1957	3	6	1988	1	55
1958	4	35	1989	1	10
1959	4	5	1990	12	508
1962	1	1	1991	5	179
1963	1	1	1993	9	287
1966	1	2	1994	4	53
1968	16	at least 42	1996	4	92
1969	9	at least 51	1997	8	171
1970	1	1	1998	4	at least 10
1971	12	13	1999	2	at least 14
1972	7	24	2000	4	182
1973	1	at least 1	2001	1	51
1974	4	8	2002	5	at least 6
1976	2	5	2005	7	230
1977	6	19	2007	6	93
1978	5	at least 5	2008	1	at least 1
1980	1	1	2009	8	290

Fire season duration (days) and timing (dates)

The duration of Denali's fire season since 1946 is shown in Figure 52. The duration was calculated as the number of days from the first fire discovery of the year to the last "fire controlled" date. The fire season fluctuates over time but is generally increasing. The average fire season duration from 1983 through 2009 was 44 days (SD = 39). This is significantly greater ($p<0.05$) than the 1946 to 1982 time period (20 days, SD =27). Two of the longest fire seasons in Denali's recorded history have occurred in the past decade.

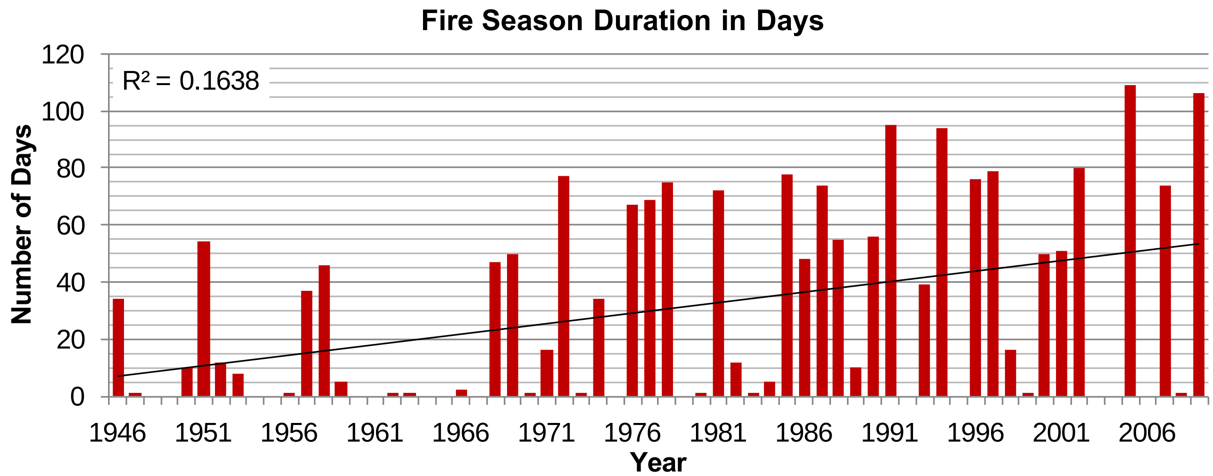


Figure 52. Fire season duration: Number of days from first fire discovery to final fire controlled date (DENA 2010c).

Figure 53 shows the date that fires were discovered by year and whether they were natural or human caused. Most fires that occur outside the traditional fire season are attributed to human causes.

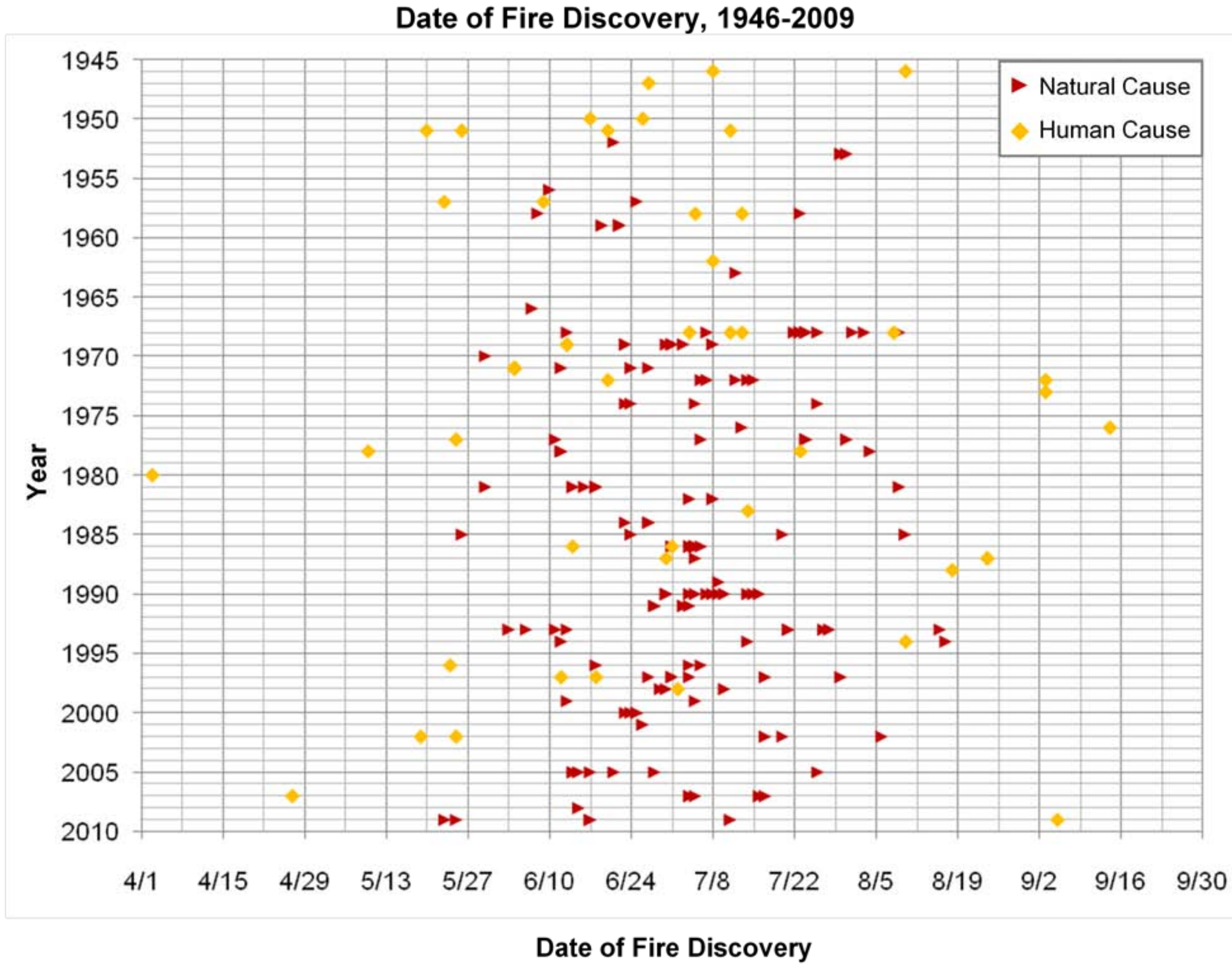


Figure 53. Date of all documented fire discoveries, 1946-2009, by year (DENA 2010c).

Figure 54 shows the timing of wildfires as number of starts per month by decade. Prior to 1980 there were no fire starts in April, yet there were April starts in the 1980s and 2000s. There were also no fire starts during September prior to 1970 yet there were several in the 1970s and 2000s. This past decade is the first time in recorded history that fires have started during six different months (April-September), suggesting that the fire season may be getting longer.

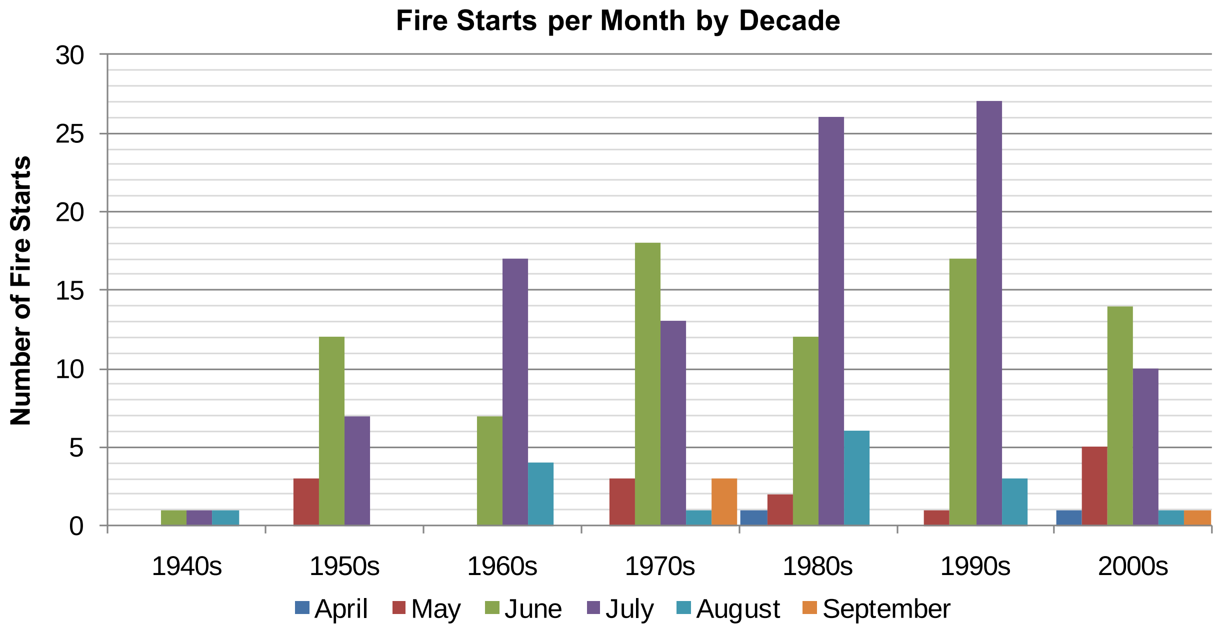


Figure 54. Number of fires starts per month, grouped by decade (DENA 2010c).

Percentage of burns by severity class annually

Burn severity is a measure of the ecological impact of fire, in terms of plant mortality, depth of the burn in organic layers, or amount of biomass consumed (Sorbel and Allen 2005). In 2005, there was a lower percentage of severely burned areas and a higher percentage of moderately burned areas than in 2000 (Figure 55). However since data is limited at this time, it is difficult to say if this apparent decrease in burn severity is a significant trend.

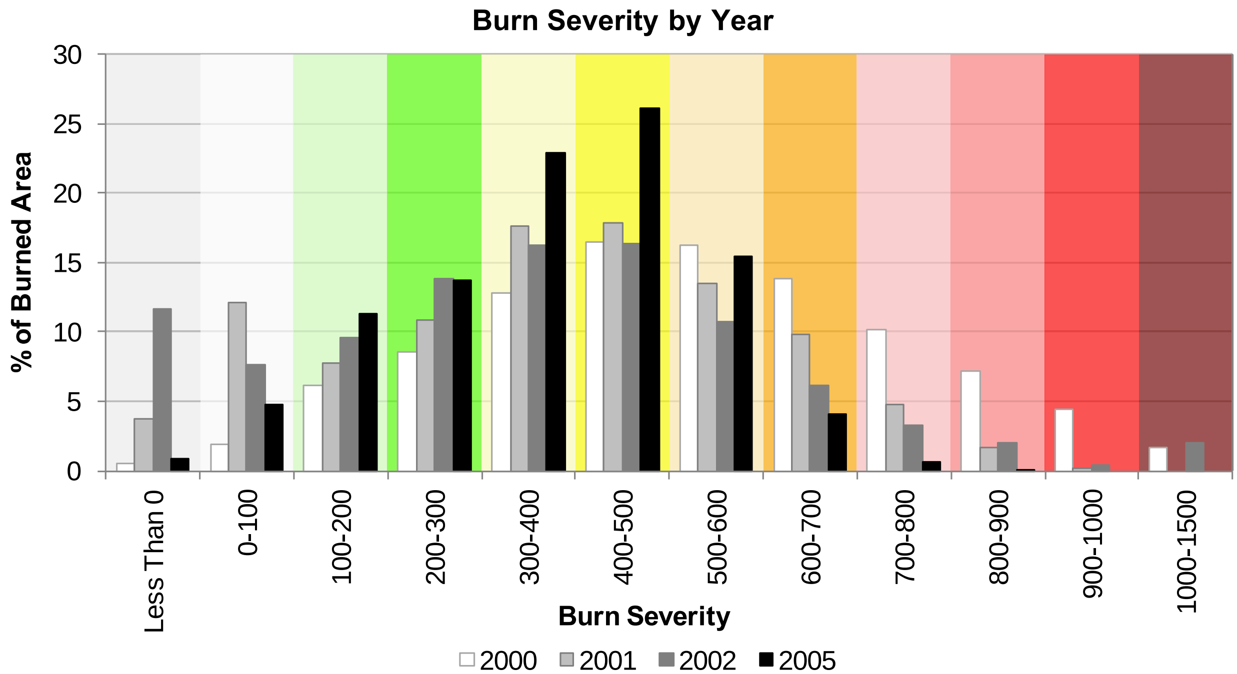


Figure 55. Percent of burns by severity class (NPS 2010). Note: 2002 data has errors.

An analysis of burn severity by vegetation class suggests that severity is influenced by vegetation type. Shrub or scrub areas appear to experience a higher percentage of severe fires while woodlands have more moderately severe fires (Figure 56; Plate 33). Low severity burns were most common in riparian white spruce/mixed hardwoods/mixed scrub vegetation. As additional years of burn severity analysis become available and there is a desire to analyze trends over time, values could be averaged within a specified period of time (e.g, five years) or a moving average statistic could be developed.

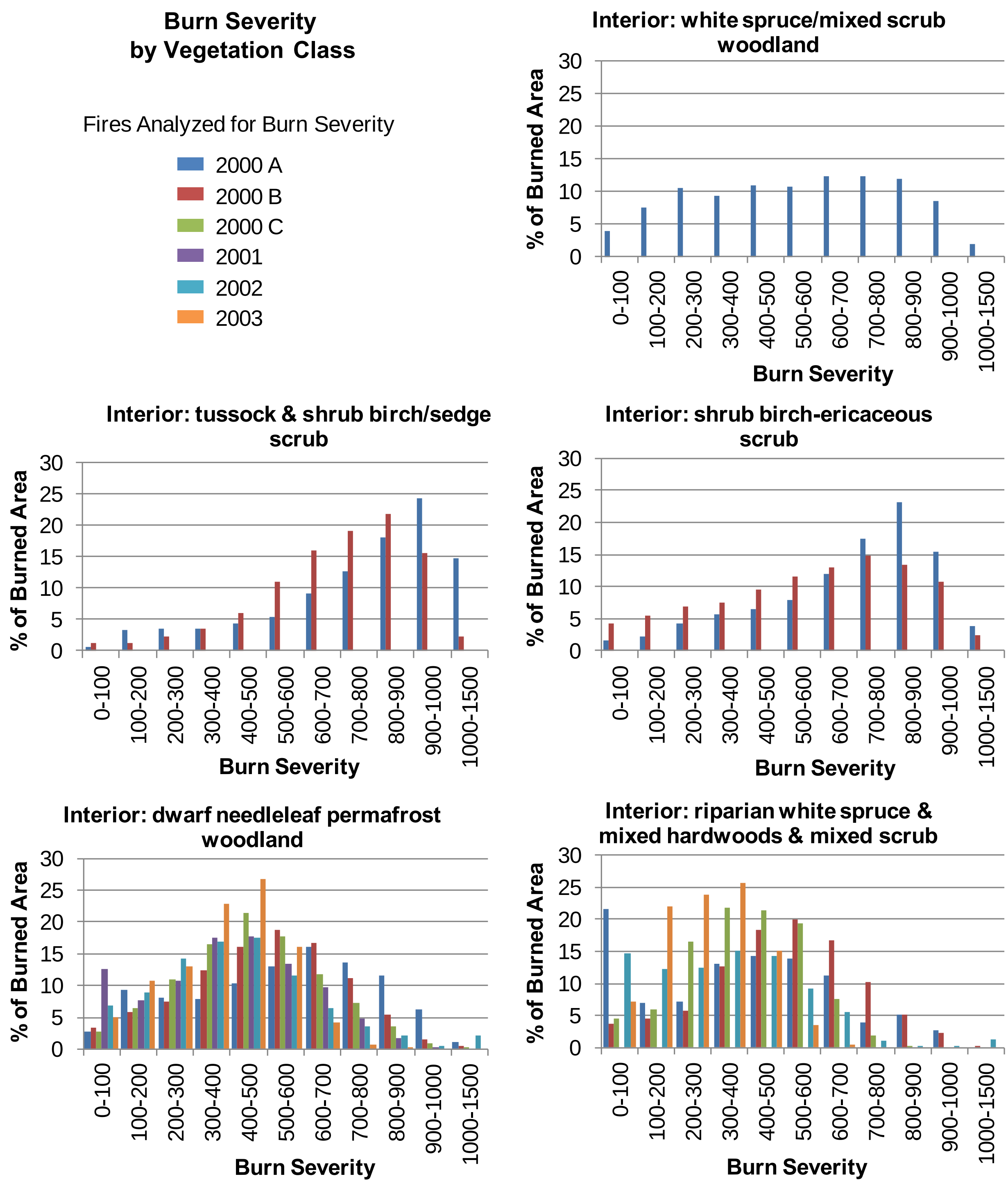


Figure 56. Burn severity by vegetation type (NPS 2010). Vegetation type represents the potential vegetation class derived from the soil survey and ecological classification of Denali National Park and Preserve conducted between 1997 and 2004 (Clark and Duffy 2006). The percentage represents the percent of vegetation type burned in each severity class.

Threats and Stressor Factors

DENA (2009) lists potential threats to current fire conditions as climate change, habitat fragmentation, and the occurrence of fires outside the historic range of variability. The increased temperatures and changes in hydrological cycles that are expected with climate change will have a significant impact on weather patterns, fire occurrence and extent of wildland fires, as well as flora and fauna distribution (DENA 2007). Fire frequency will likely increase at high latitudes and some research suggests this may further contribute to climate warming by releasing more carbon into the atmosphere (Goetz et al. 2007). Park managers recognize that, "fire management programs may require significant restructuring to respond to the changes resulting from global climate change" (DENA 2007).

Insect and plant disease outbreaks could also affect Denali's fire regime. Feeding by bark beetles, defoliators, and other insects can alter the accumulation and distribution of fuels (McCullough et al. 1998). The amount of sun and wind reaching the surface fuels could also increase as a result, affecting the moisture levels of moss and other live woody material. These two factors – fuel availability and moisture levels – "play a large role in determining the risk of fire ignition, behavior, and intensity" (McCullough et al. 1998). Fire, in turn, may make forests more vulnerable to insect and disease attacks (McCullough et al. 1998).

Data Needs/Gaps

DENA (2009) highlights several data needs in order to better understand the park and preserve's fire regime and management options. Fire and fuel management goals are currently limited by a lack of understanding of fire history and fire regime controls, particularly prior to 1950. Very few studies have been conducted to determine fire return intervals in Alaska (DENA 2009).

Most fire management agencies in the state currently use the Canadian Forest Fire Danger Rating System (CFFDRS) to predict fire danger, behavior, and severity. However, this system was developed for pine dominated forests and there is some concern that it may not accurately predict conditions in Alaska's spruce forest and tundra ecosystem (DENA 2009). This system needs to be evaluated, particularly the fuel moisture drying indices, to determine if it is accurately measuring conditions on the ground and the resulting fire behavior.

The effect of fire on hydrology in boreal forests is poorly understood. Research into the relationships between fire severity, size, season and hydrology characteristics such as permafrost changes, lake drying patterns, water budgets, sediments, temperature, debris, nutrients and aquatic organisms in streams and wetlands would be particularly helpful for management purposes (DENA 2009).

More information is needed on the relationship between fire and the distribution of wildlife throughout the park and preserve. This will in turn help managers understand any effects fire may have on subsistence. Subsistence users often request increased fire suppression and additional research would help to address their concerns (DENA 2009). While some studies have been conducted on the response of caribou and moose to fire, little is known about its impact on fish, furbearers, and berry production. Scientific information on the attitude and response of the public in general to fire management and the agencies involved is also lacking (DENA 2009).

Previous studies detected some differences in burn severity trends between the four fuel/vegetation types in the park and preserve (Allen and Sorbel 2008). More research is needed into burn severity and fire behavior, particularly in white spruce, deciduous forests, and tundra vegetation types, before any patterns can be fully understood (Allen and Sorbel 2008). In addition, little is known about the impact of repeated fires in the same landscape, for example the changes in upland and other habitats as a result of frequent fires over time (DENA 2009).

Overall Condition

According to Denali's Fire Management Plan (DENA 2007), Alaska fire management personnel believe that the fire ecology of Denali "is relatively unchanged from the condition prior to the development of organized suppression efforts." The number of acres burned and natural starts per year remains within the range of natural variability, but the duration of fire incidents and fire season appear to be increasing.

Level of Confidence

Extensive data is available on fire extent, ignition sources, and fire season duration. Although some inaccuracies and errors exist, this data provides sufficient information for assessing current condition and trends for these measures. Burn severity is a more recently developed measure and, as a result, it is more difficult to identify any changes over time.

Sources of Expertise

The primary sources of expertise for this assessment were the Denali Fire Management Plan (DENA 2007), Sorbel and Allen (2005), and Allen (2005).

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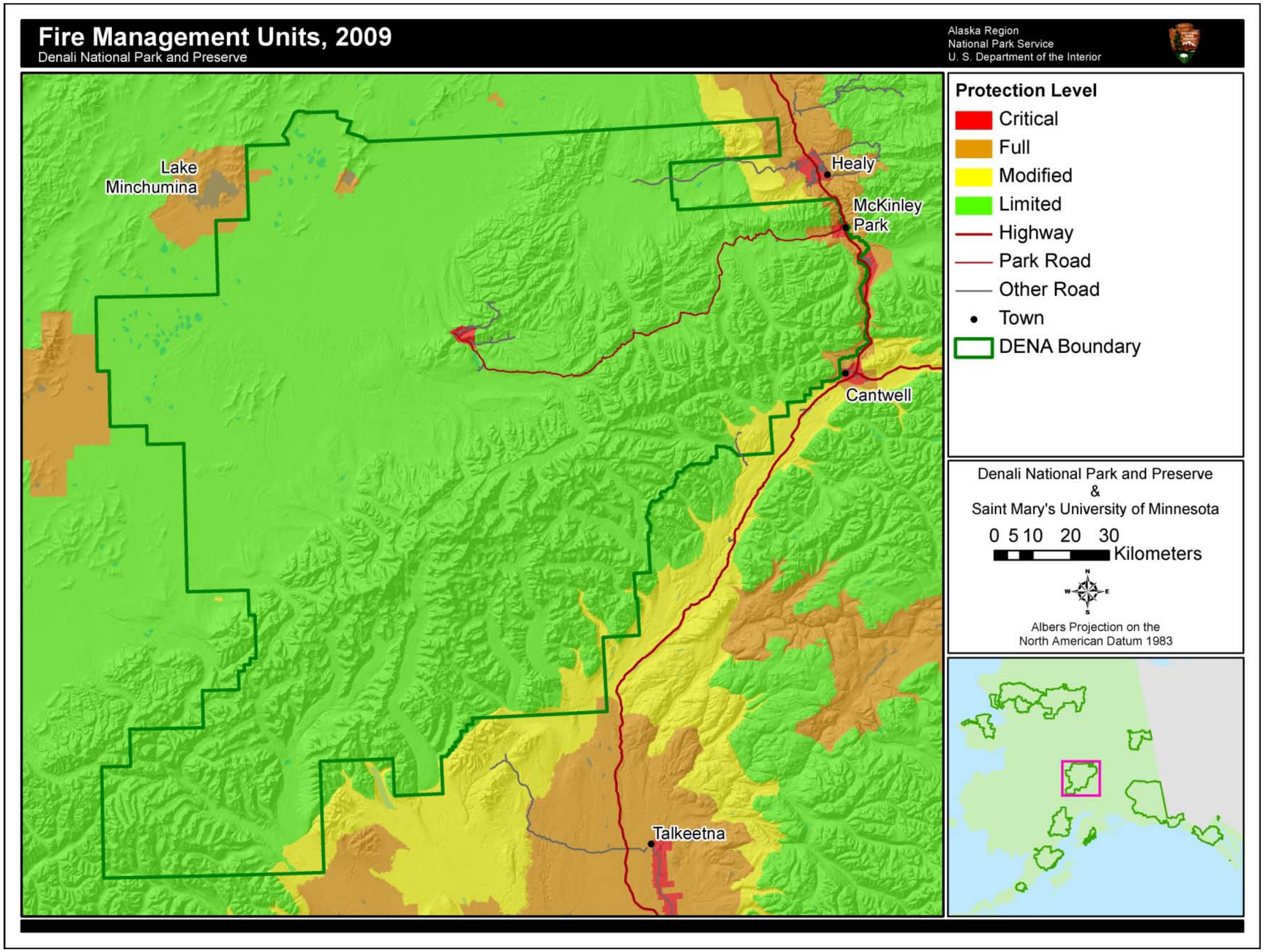


Plate 30. Fire management units, 2009 (NPS 2010).

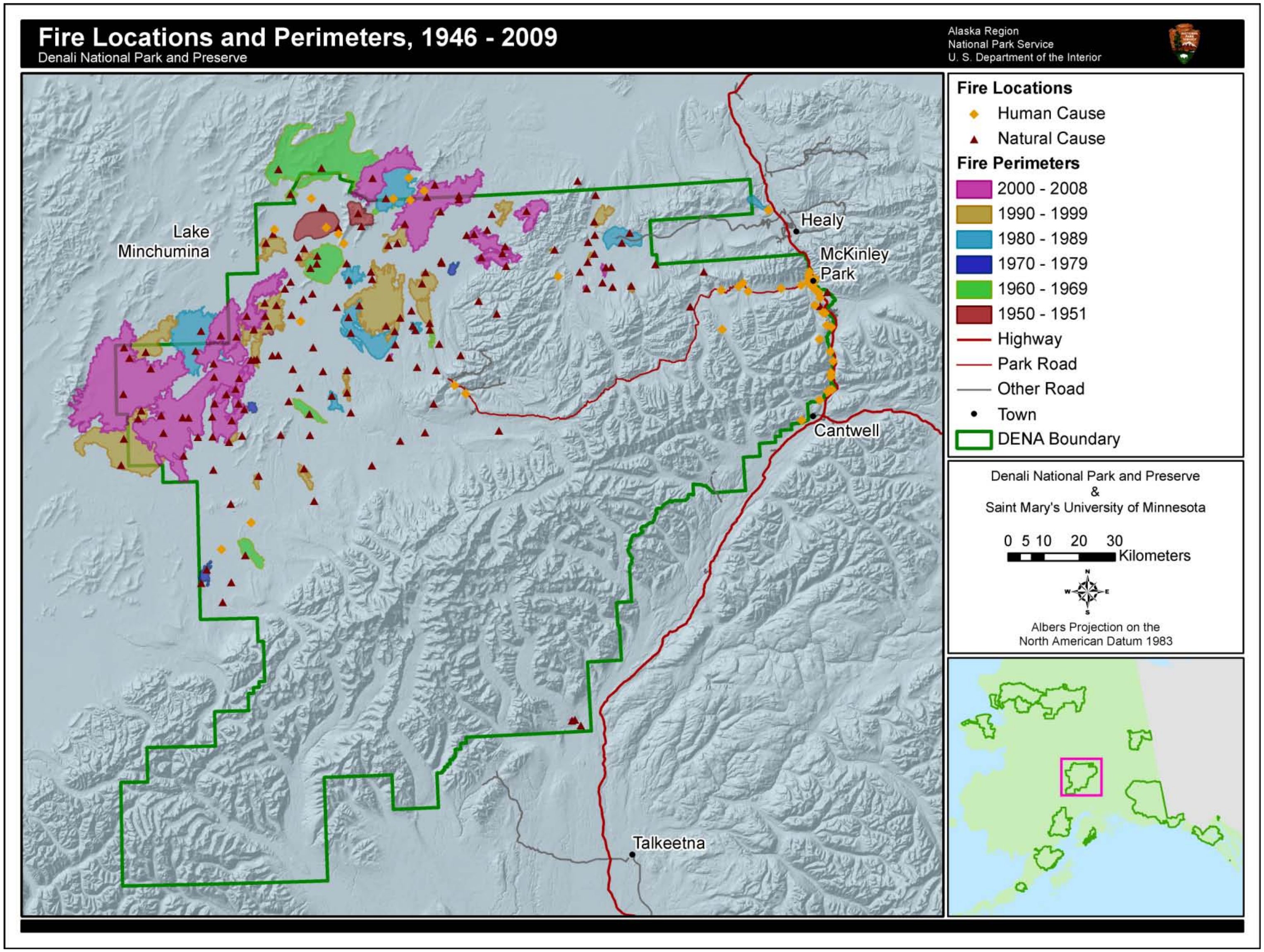


Plate 31. Fire locations and perimeters, 1946-2009 (NPS 2010, DENA 2010b, c).

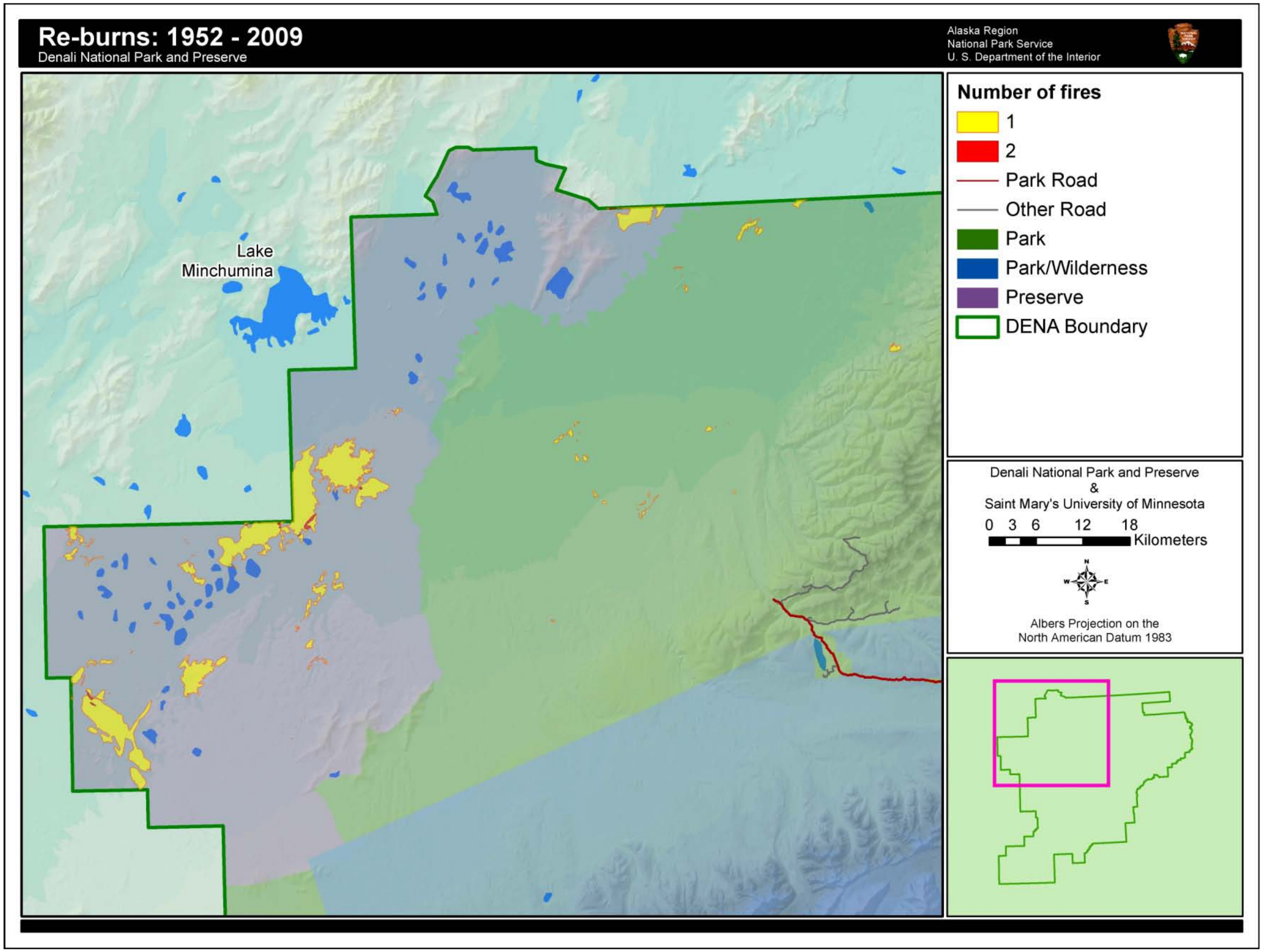


Plate 32. Re-burns: Areas burned more than once, 1952-2009 (NPS 2010, DENA 2010c).

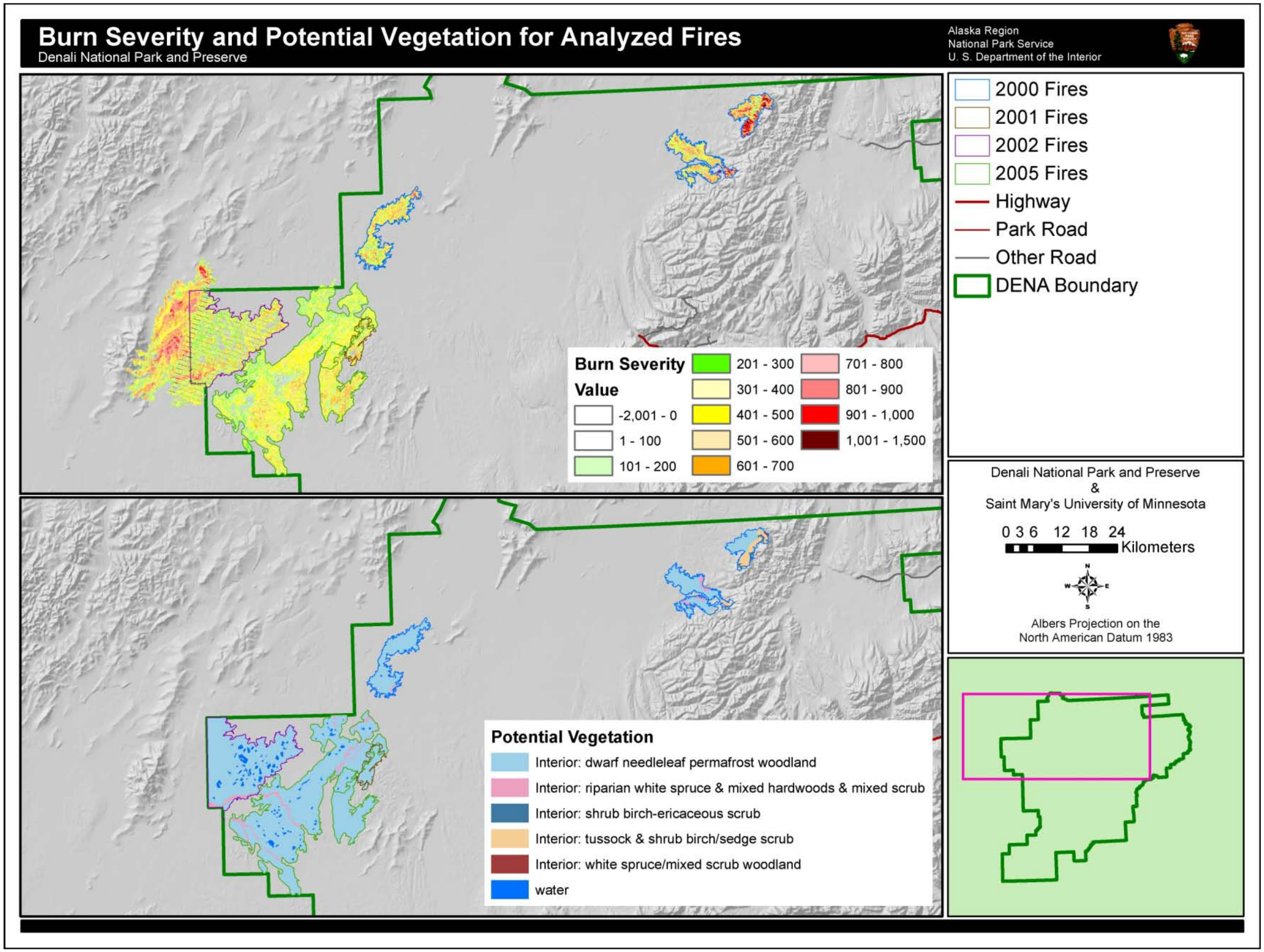
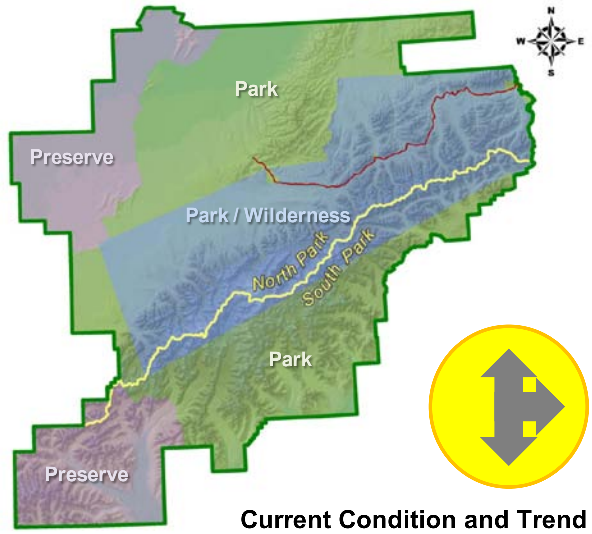


Plate 33. Burn severity for analyzed fires in DENA (NPS 2010).

4.12 Lake Ecosystem Function

Description



Current Condition and Trend

Denali National Park and Preserve is home to over 12,000 lakes (DENA 2009b). Shallow lakes and wetlands support large populations of mammals and waterfowl, which some people still rely upon for survival (Larsen et al. 2004). Shallow lakes and other wetlands are among the world's most productive environments and provide a wide variety of ecological benefits (Mitsch and Gosselink 1986). They are important for water storage, flood mitigation, erosion control, groundwater recharge, water filtration, and climate stabilization (Mitsch and Gosselink 1986). Shallow lakes were chosen as a vital sign by the CAKN inventory and monitoring program due to their abundance, small size, importance in the ecosystem, and vulnerability to climate change (Larsen 2006). Lakes and wetlands in Alaska are affected not only by precipitation and evaporation, which is influenced by temperature, but also by variation in snowpack, melting glaciers, and thawing permafrost (Larsen et al. 2004, DENA 2009a). Concern has been growing in recent years over shrinking lakes in Denali and across the state of Alaska (CAKN 2008).

Photo 22. Wonder Lake and Mount McKinley (NPS photo, in Thornberry-Ehrlich 2010).

Most of Denali's lakes are nutrient poor and classified as oligotrophic (Larsen 2006). Oligotrophic lakes are characterized by low productivity, which means they are relatively free of weeds and algal blooms but also cannot support large fish populations (Shaw et al. 2004). Measurements commonly used to assess lake ecosystem condition include total nitrogen and phosphorus levels as well as chlorophyll A levels. Nitrogen enters lakes through the decay of plant matter, nitrogen fixation by leguminous plants, and directly from the atmosphere. It is second only to phosphorus as an important nutrient for plant and algae growth (Shaw et al. 2004). Elevated phosphorus levels in lakes, often due to human activities, contribute to excessive aquatic plant growth (Shaw et al. 2004). Chlorophyll A is commonly used to estimate phytoplankton biomass and therefore primary productivity (Lillie and Mason 1983). The abundance and type of aquatic macroinvertebrates are also regularly used to assess lake ecosystem health because they are generally easy to collect and differ in their tolerance of water quality conditions (EPA 2010a).

Measures

Total acres of lake surface area of lakes over 1 acre
Number of lakes over 1 acre of surface
Selected standard measurements of limnological ecosystem function (i.e. primary productivity)

Reference Conditions/Values

According to DENA (2009b), the reference condition for lake surface area is total acreage within the range of natural variation. The reference condition for number of lakes is also no change from range of natural variation. The reference condition for limnological ecosystem function measurements are yet to be determined (DENA 2009b).

Data and Methods

<u>CAKN</u>

The CAKN vital signs monitoring program focuses on detecting long-term trends in water quantity (number, area, and distribution of lakes), water quality, aquatic vegetation composition and structure, and macroinvertebrate taxa richness and relative abundance (Larsen et al. 2011). A detailed monitoring protocol can be found in Larsen et al. 2011.

From 2006 to 2008 the lake monitoring project sampled 128 lakes in the northwestern corner of Denali, obtaining detailed observations of water quality and physiography (DENA, Larsen, pers. comm. 2010). The lakes sampled are represented on Plate 34. Thirty of the lakes sampled during the first year were chosen as index sites and were re-sampled in 2007 to measure inter-annual variation. The initial results for these 30 sites are available in Larsen (2006) and summarized in Table 38. Data from 2007 and 2008 has not been published at this point.

Table 38. Summary of chemical characteristics for the 30 shallow lakes sampled in 2006; all measures are mg/L unless otherwise specified (Larsen 2006).

Parameter	Minimum	Maximum	Mean	SE
Alkalinity	5	139	35	3.3
Total N	0.43	1.29	0.74	0.01
Total P	0.007	0.041	0.021	0.009
Orthophosphate	0.002	0.005	0.003	0.0008
Nitrate	0.002	0.015	0.004	0.0007
Ammonia	0.003	0.080	0.014	0.001
Silica	0.16	3.93	0.96	0.13
Sodium	0.85	4.65	2.18	0.10
Potassium	0.21	2.80	0.86	0.06
Calcium	0.81	34.58	6.79	0.65
Magnesium	0.42	14.77	3.14	0.30
Sulfate	0.02	1.04	0.16	0.02
ChlA (mg/m^3)	0.64	6052	2.15	0.14
Chloride	0.17	1.30	0.56	0.24
Dissolved organic carbon	9.91	27.97	17.14	0.46
pH	5.11	9.37	7.22	0.10
Specific conductance (μS/cm)	13	870	95	17

In another study by the CAKN monitoring program, 2007 Landsat satellite images of the Minchumina basin lowlands (MBL) and the Eolian lowlands (EL) in the northwestern corner of Denali were compared to aerial photos of these areas from 1980 (CAKN 2008). These images were analyzed to track changes in lake size, abundance, and distribution over time. While little change was observed in the MBL, analysis showed that 26 % of lakes in the EL had shrunk in size (Figure 57; CAKN 2008). Another 19% had become wet meadows and could no longer be classified as lakes (CAKN 2008).

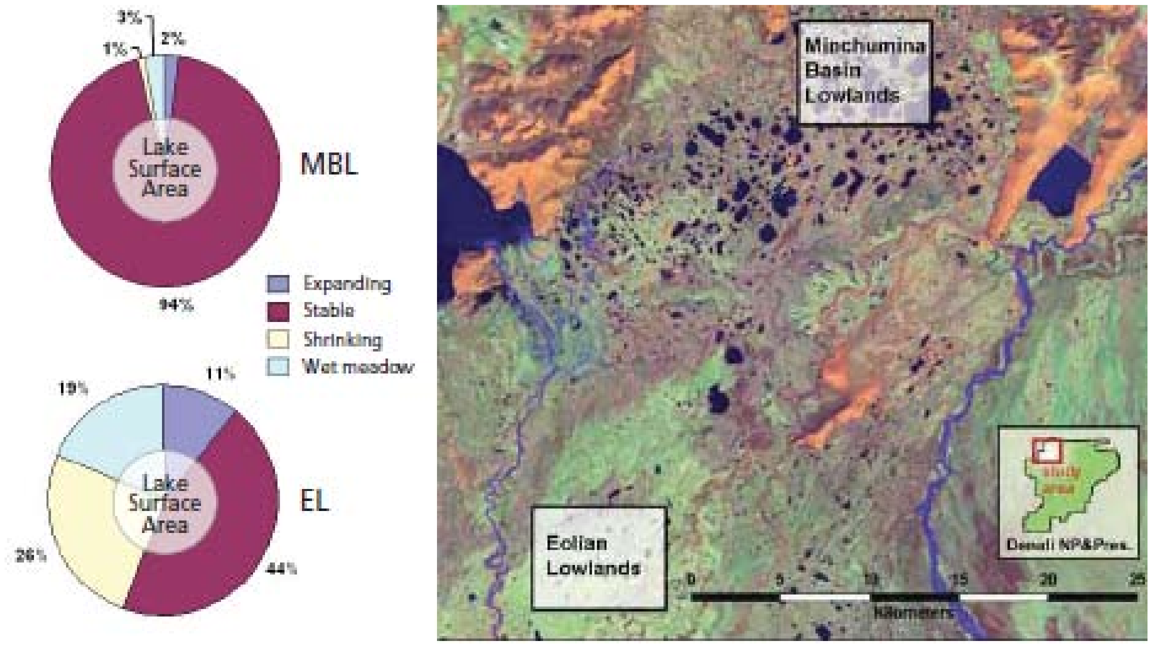


Figure 57. Changes in lake surface area between 1980 and 2007 in the Minchumina Basin Lowlands (left) and the Eolian Lowlands (right) (from CAKN 2008).

<u>Additional Studies</u>

Riordan (2005) explored the loss of closed- basin surface water (lakes) across Alaska, including a portion of Denali National Park and Preserve (Riordan 2005). The approximate location of his study area within Denali is shown in Figure 58. A comparison of historical aerial photos with Landsat imagery from 2000 showed an estimated 4% decrease in surface water area in the Denali study area between 1950 and 2000 (Riordan 2005). Forty-two water bodies disappeared completely during this time, most likely after the warming trend that began in 1977 (Riordan 2005). This loss of surface water is primarily attributed to warming air temperatures and the related increase in evapotranspiration, since precipitation levels remained relatively stable during this time (Figure 59; Riordan 2005).

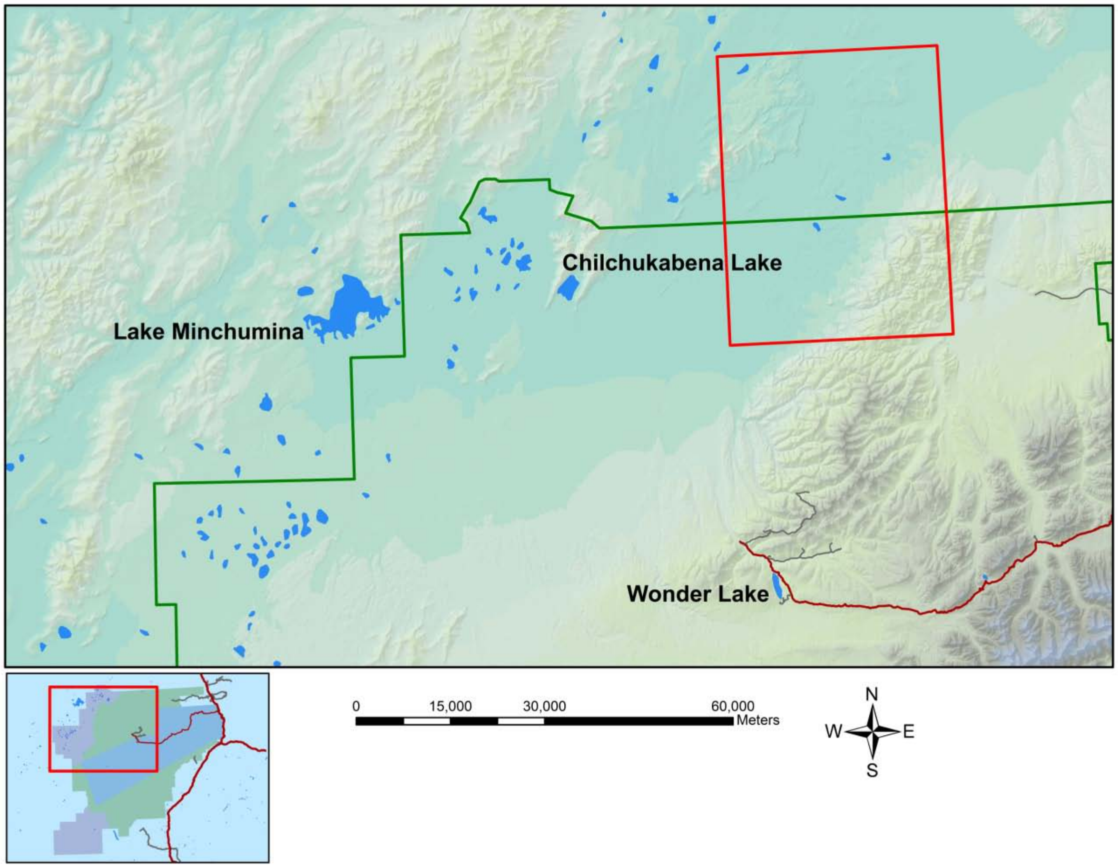
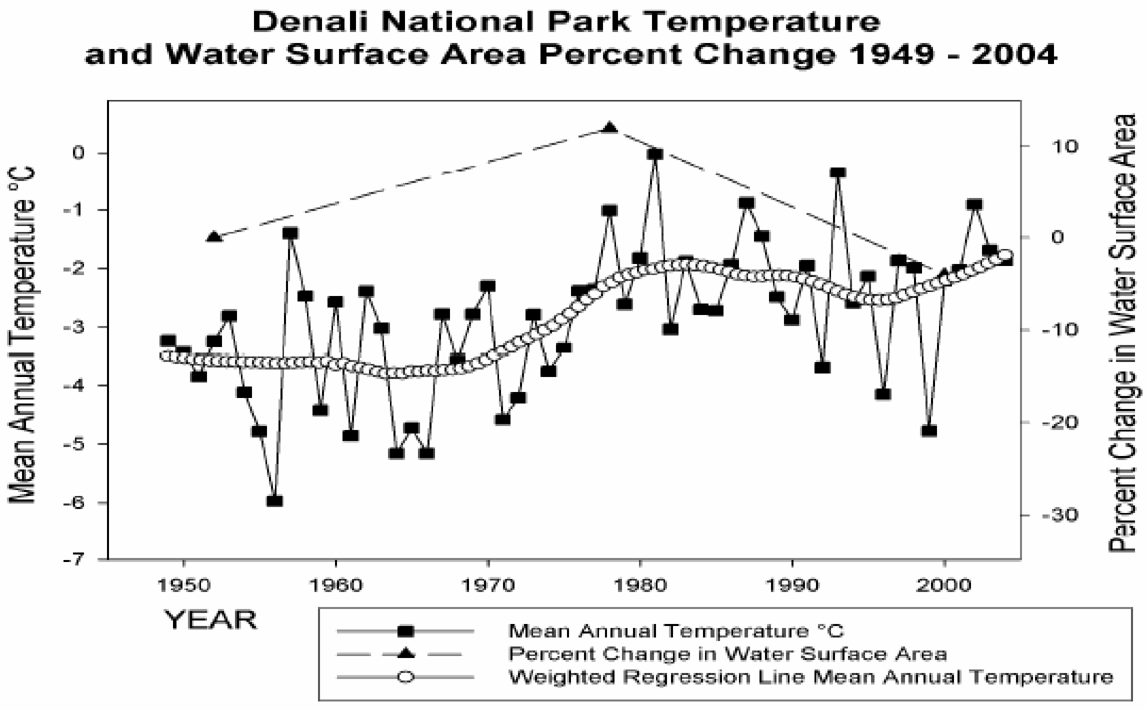


Figure 58. The approximate location of Riordan's (2005) study area (outlined in red). The three large lakes in or near Denali National Park and Preserve being cooperatively studied by the USGS and NPS (DENA 2009a) are also shown.



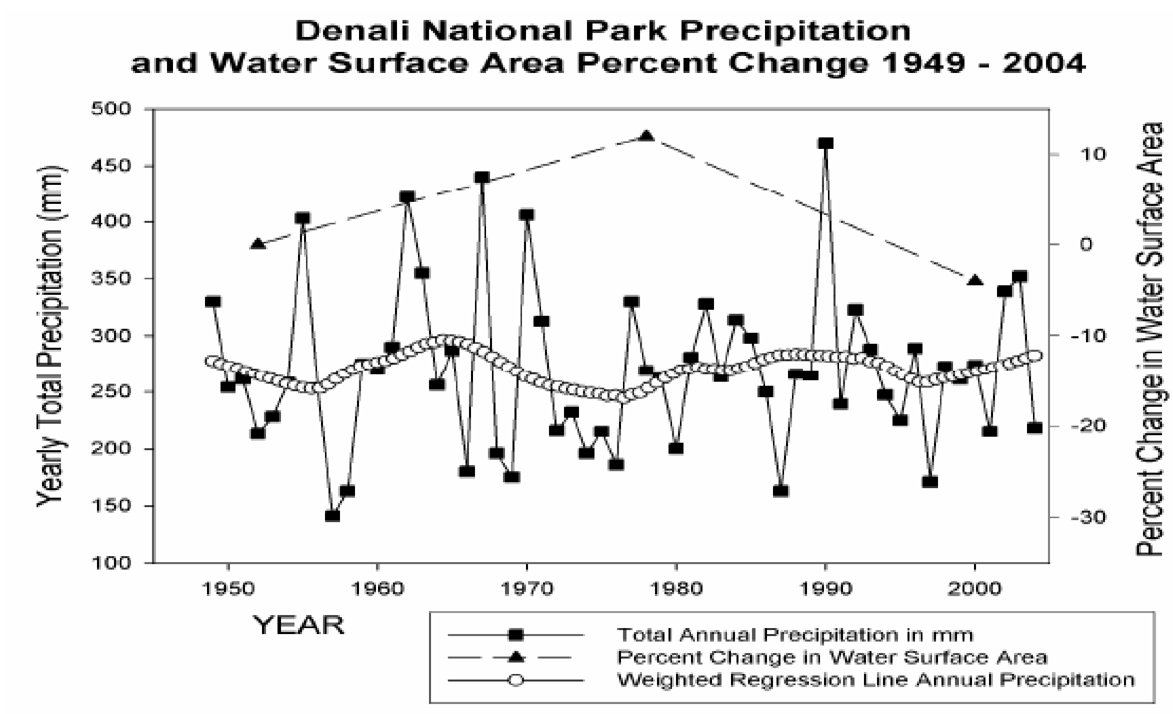


Figure 59. Percent change in water surface area compared to mean annual temperature (top) and yearly total precipitation (bottom) (Riordan 2005).

The U.S. Geological Survey (USGS), Alaska Science Center, and Denali staff are conducting a cooperative study of three large lakes in or near the park and preserve: Wonder Lake, Lake Chilchukabena, and Lake Minchumina (Figure 58; DENA 2009a). Data collection began in 2007 with the objectives of developing a baseline water quality dataset and determining how physical properties relate to watershed processes and climate (DENA 2009a). The ultimate goal is to better understand the physical behavior of large lakes in response to climate changes. USGS researchers installed temperature sensors at multiple depths in the three lakes to help them determine the timing of ice-out and ice-on as well as the temperature and mixing of lake waters throughout the year (DENA 2009a, Arp et al. 2010). Researchers also compared satellite images of the three lakes from 1986 and 2002. Images showed that Lake Minchumina's surface area had increased by 28% while the area of the other two lakes remained stable (DENA 2009a).

The Western Airborne Contaminants Project (WACAP), an interagency study of national parks in western states and Alaska, included two lakes in Denali: Wonder and McLeod. They collected water, sediment, and fish samples to determine if contaminants were present, where they were accumulating, and if they posed an ecological threat (Landers et al. 2008). While the focus of this study was on anthropogenic contaminants, it also reported several physical and chemical characteristics of the lakes including surface area, depth, pH, total nitrogen and phosphorous, and chlorophyll A levels (Figure 60).

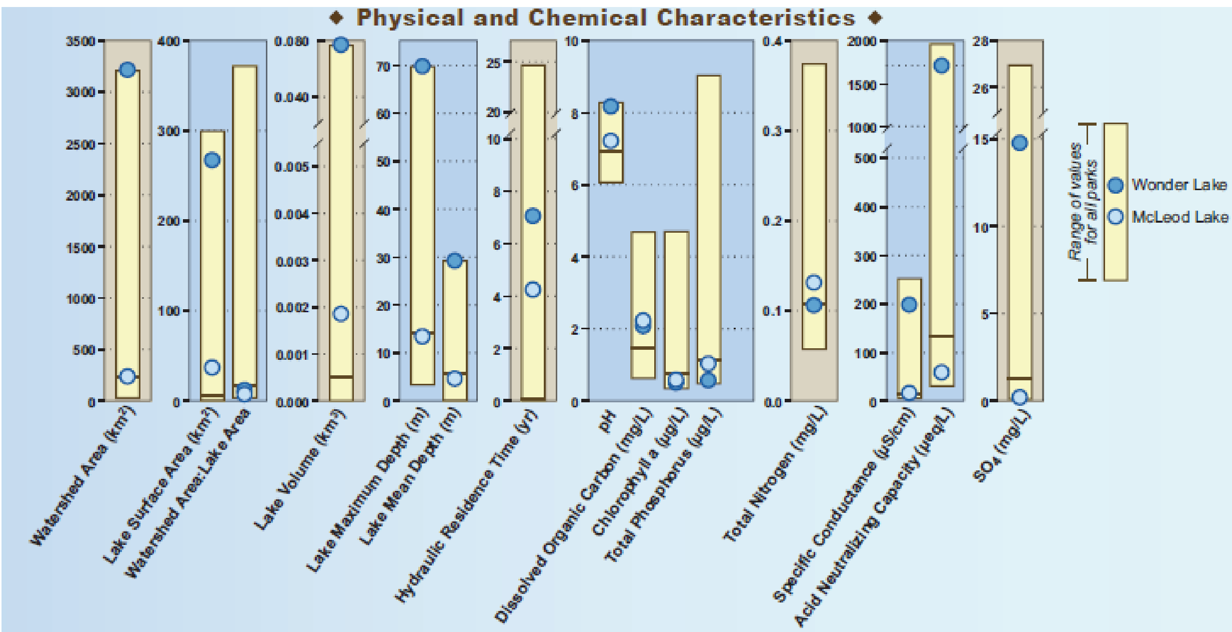


Figure 60. Physical and chemical characteristics of Denali's Wonder and McLeod Lakes, in comparison to other parks in the WACAP study (Landers et al. 2008).

Current Condition and Trend

<u>Total acres of lake surface area of lakes over one acre</u>

Although several studies have addressed changes in lake surface area in certain regions of Denali, little analysis has been conducted park-wide. An analysis of National Hydrography Dataset (NHD) maps updated in 1985 estimated the total surface area of lakes over one acre within Denali at 66,945 acres (Figure 61). This represents 1.1% of the total area of the park and preserve.

Riordan's study (2005) in a northern region of Denali found an estimated 4% decrease in lake surface area between 1950 and 2000 (Table 39). Evidence from the CAKN monitoring program indicates that some lakes in the northwestern part of the park and preserve are also decreasing. Between 1980 and 2007, 26% of lakes in the Eolian lowlands shrunk in size (CAKN 2008). In contrast, Lake Minchumina has recently increased in surface area by 28% (DENA 2009a).

Table 39. Estimated changes in lake surface area and number of lakes in a portion of Denali Park and Preserve, 1950-2000 (Riordan 2005).

	1951-54	1979-81	2000
Lake surface area (ha)	1758	1964	1681
Number of lakes	876	964	834

<u>Number of lakes over one acre of surface</u>

Little analysis has been done of the number of lakes park-wide. An analysis of NHD maps updated in 1985 found an estimated 7,366 lakes over one acre in the park and preserve (Figure 61). The majority of lakes (85%) were under 10 acres while only 88 lakes were over 100 acres in size. In Riordan's northern study area, an estimated 42 water bodies were lost between 1950 and 2000 (Table 39; Riordan 2005). However, he notes that assessing the number of lakes alone can be deceiving, as a single water body often divides into multiple water bodies as it shrinks (Riordan 2005). The CAKN monitoring program has not yet produced any statistical results regarding number of lakes, although reports from the field indicate that several lakes have filled in with vegetation or have dried so extensively that only small remnants remain (Larsen 2006).

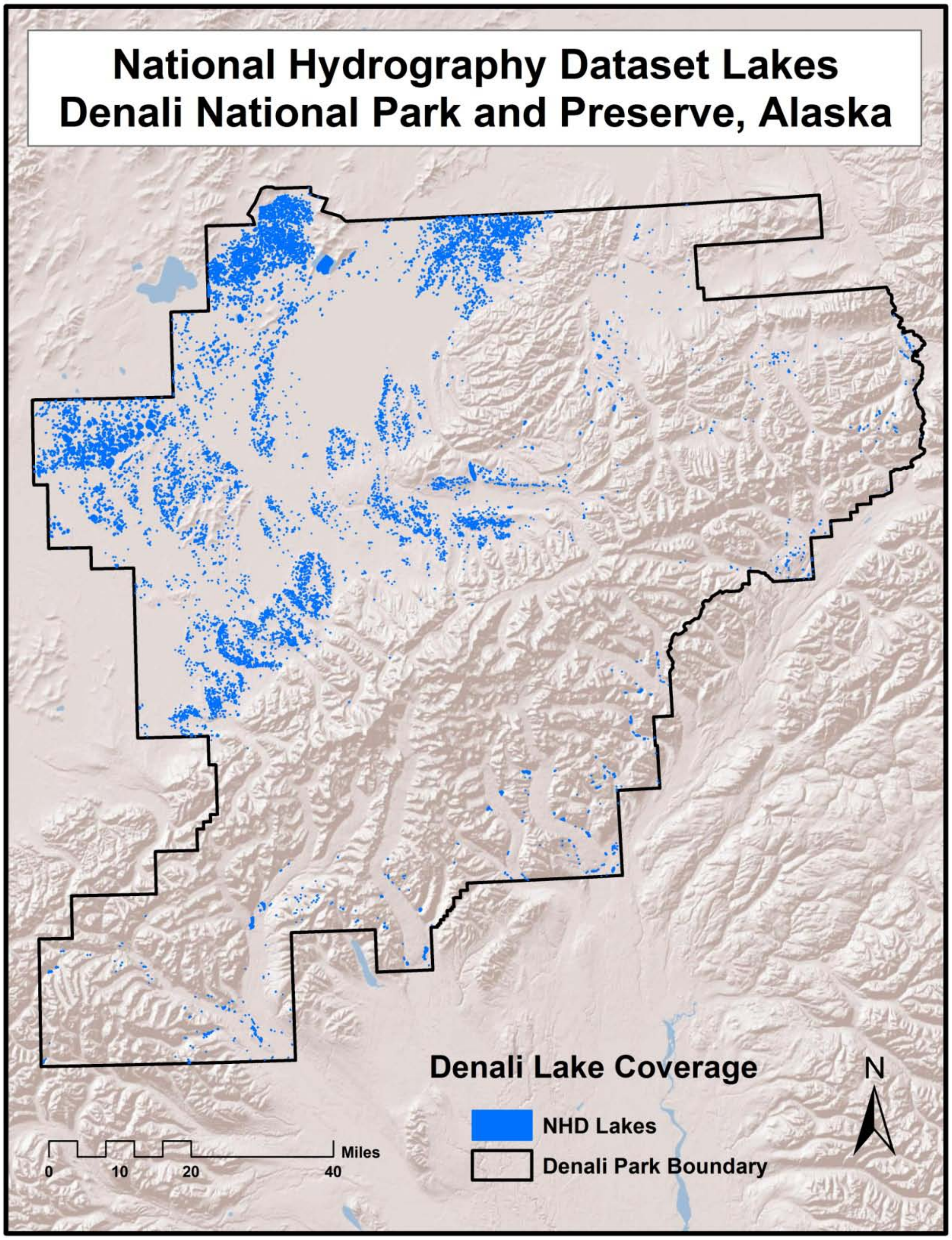


Figure 61. Distribution of lakes over 1 acre within Denali, based on NHD maps.

Selected standard measurements of limnological ecosystem function (i.e. primary productivity)

Total Nitrogen
Total nitrogen levels in all the shallow lakes sampled from 2006 to 2008 ranged from 140 to 2310 µg/L with a mean of 655 µg/L (Figure 62; Larsen 2010). Lakes with multiple samples were averaged before calculating overall mean.

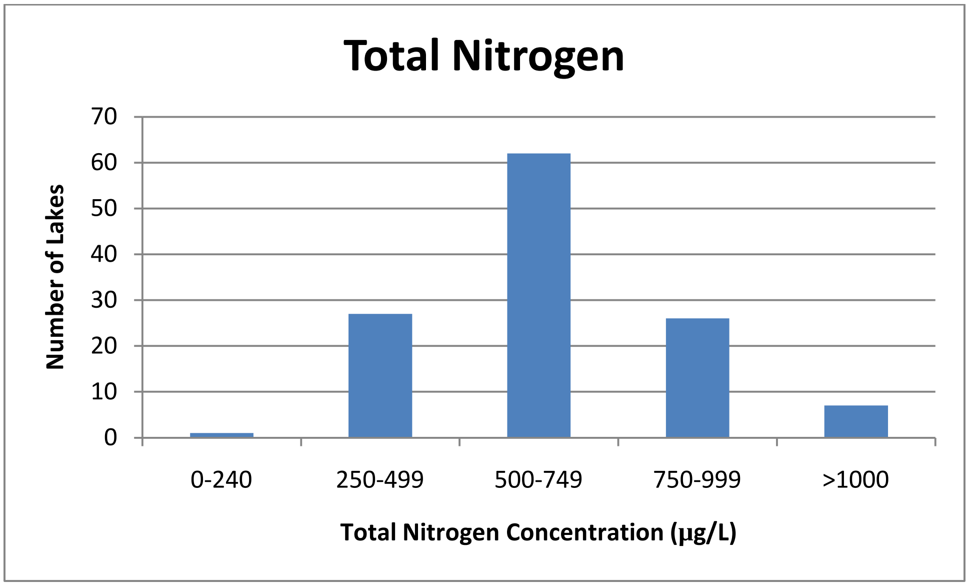


Figure 62. Total nitrogen (µg/L) for lakes sampled in Denali, 2006-2008 (data from Larsen 2010).

Total Phosphorus
Total phosphorus levels in all shallow lakes sampled ranged from 4 to 143 µg/L with a mean of 21.4 µg/L (Figure 63; Larsen 2010). Lakes with multiple samples were averaged before calculating overall mean.

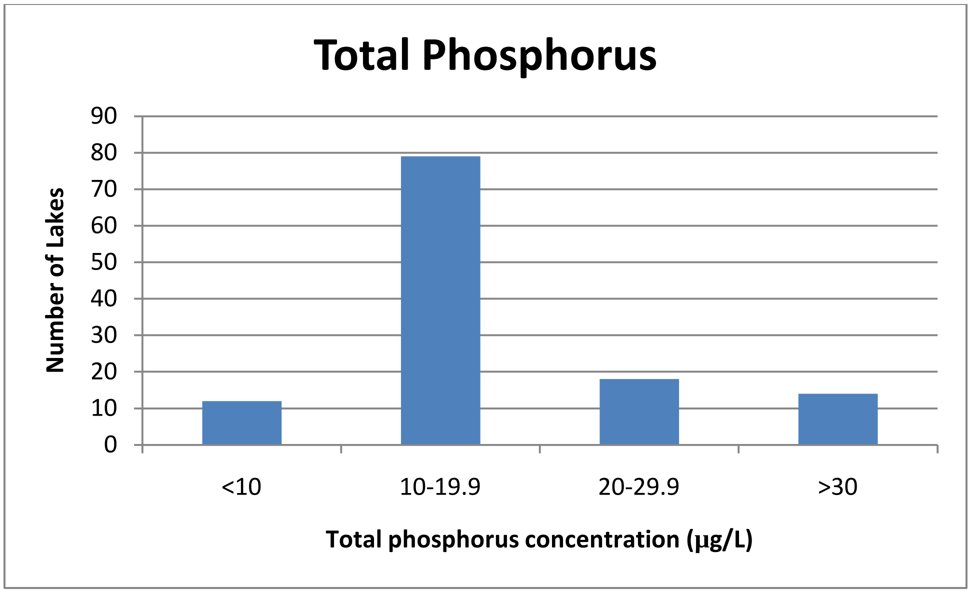


Figure 63. Total phosphorus (µg/L) for lakes sampled in Denali, 2006-2008 (data from Larsen 2010).

A comparison of total phosphorus and total nitrogen concentrations within the thirty index lakes at Denali suggests a positive relationship between the two nutrients (Figure 64). The point in the top right of the graph represents a lake where a massive thaw slump occurred, resulting in unusually high nutrient levels (DENA, Larsen, pers. comm. 2011). This point is shown on the graph to maintain the integrity of the sample dataset, however, the value of the point has been removed from the regression line calculation.

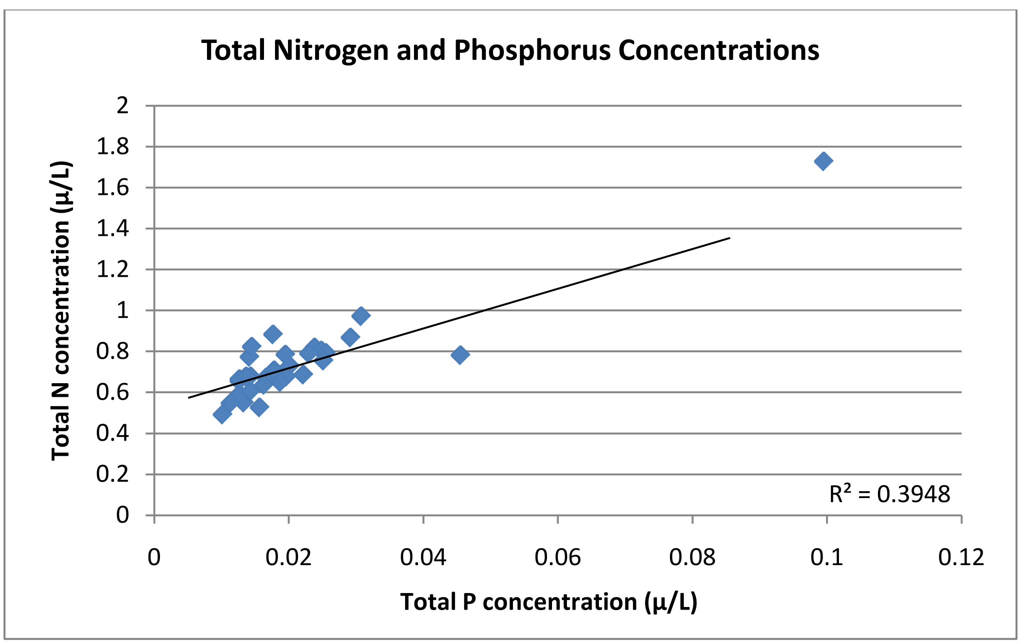


Figure 64. A comparison of total nitrogen and total phosphorus concentrations in the 30 index lakes within Denali National Park and Preserve, 2006-2007 (data from Larsen 2010). The outlier in the top right is not included in the regression line calculation.

Chlorophyll A

Chlorophyll A levels in shallow lakes sampled from 2006-2008 ranged from 0.29 to 23.04 µg/L with a mean of 3.21 µg/L (Figure 65; Larsen 2010). Lakes with multiple samples were again averaged before calculating overall mean. According to Lillie and Mason (1983), concentrations below 10 µg/L indicate good water quality while values below 5 µg/L and 1 µg/L indicate very good and excellent water quality respectively.

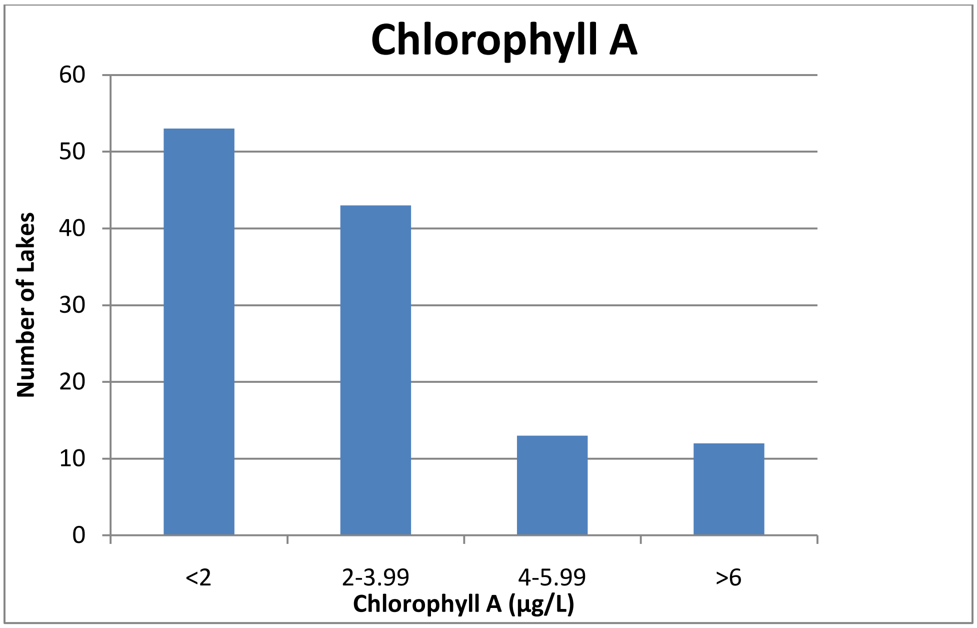


Figure 65. Chlorophyll A levels (µg/L) for lakes sampled in Denali, 2006-2008 (data from Larsen 2010).

Comparisons between chlorphyll A levels and total nitrogen and phosphorus concentrations within the thirty index lakes at Denali suggests that these variables are related. As nitrogen and phosphorus levels increase, so do chlorophyll A levels (Figure 66 and Figure 67). The point on the top right in each graph represents the lake with the massive thaw slump and has again been removed from the regression line calculation.

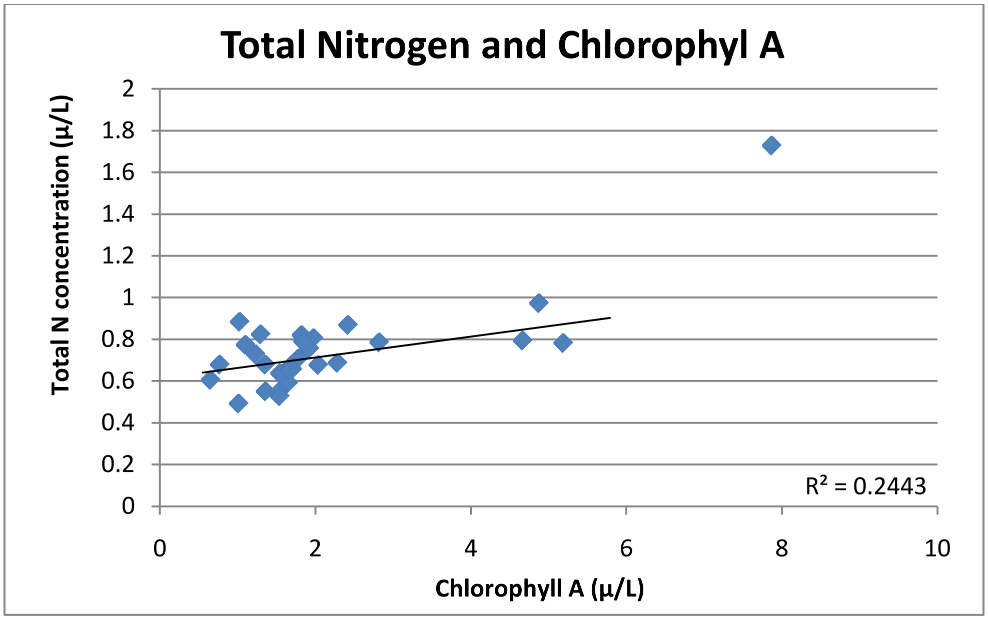


Figure 66. A comparison of total nitrogen concentration and chlorophyll A levels in the 30 index lakes within Denali National Park and Preserve, 2006-2007 (data from Larsen 2010). The outlier in the top right is not included in the regression line calculation.

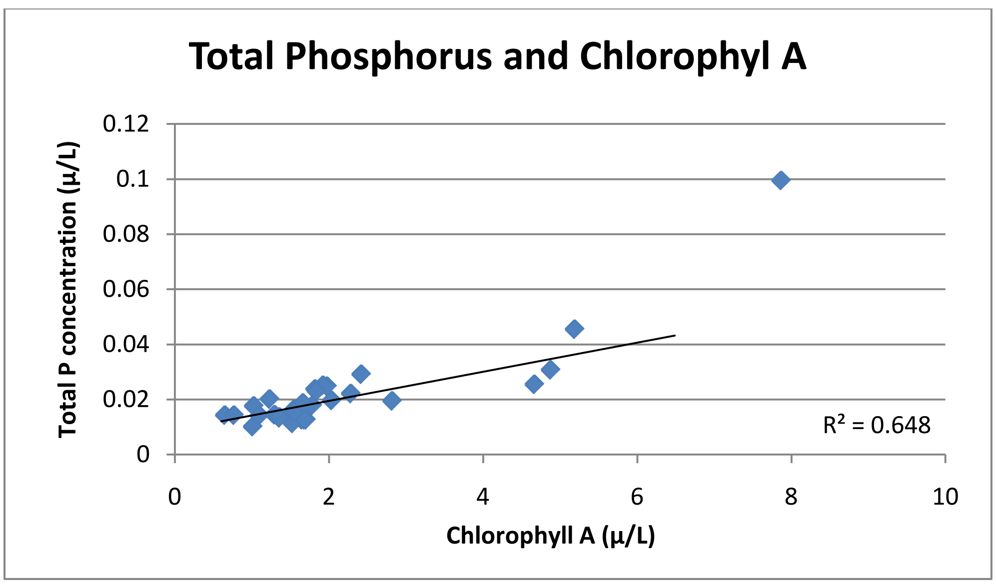


Figure 67. A comparison of total phosphorus concentration and chlorophyll A levels in the 30 index lakes within Denali National Park and Preserve, 2006-2007 (data from Larsen 2010). The outlier in the top right is not included in the regression line calculation.

Macroinvertebrates

Taxa richness was determined for the 30 lakes sampled in June and July of 2006 and 2007. The number of taxa per lake ranged from 15 to 73 with a mean of 53.5 (Figure 68; Larsen 2010). Taxa from the insect order Ephemeroptera, often considered indicators of good water quality (EPA 2010b), were found in 23 of the 30 lakes (Larsen 2010).

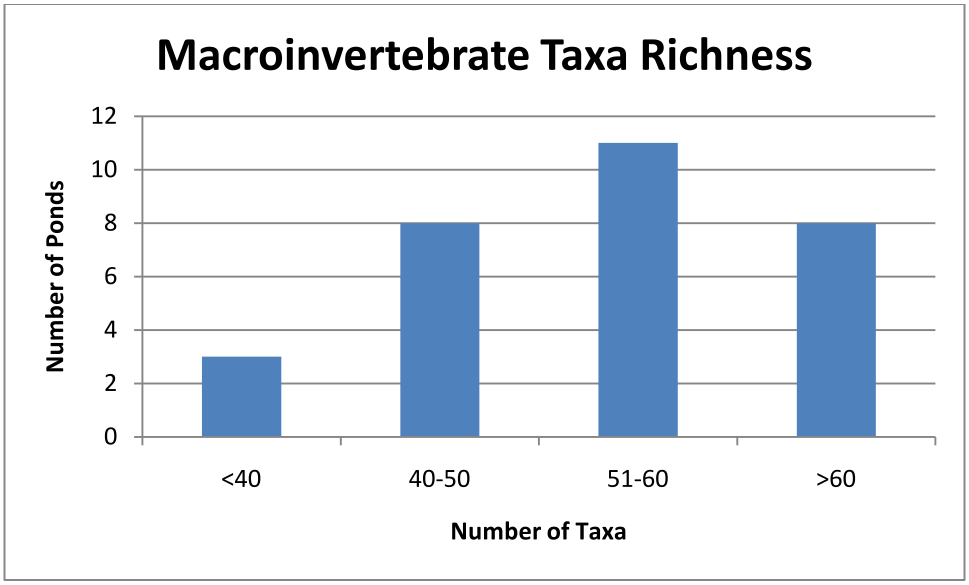


Figure 68. Number of macroinvertebrate taxa for lakes sampled in Denali, 2006-2007 (data from Larsen 2010).

Threats and Stressor Factors

According to DENA (2009b), threats and stressors to lake ecosystem function include exotic aquatics and lake drying. Other stressors include subsurface drainage, changing plant communities, and drying soils (Riordan 2005). Airborne contaminants have also been found in sediments and fish from Wonder and McLeod Lakes within the park and preserve (Landers et al. 2008) and will be discussed in detail in section 4.14 of this assessment.

Many of the stressors to Denali's lake ecosystems can be attributed to the larger threat of climate change. Denali is expected to become warmer and drier during the next century (SNAP et al. 2009). Although precipitation is expected to increase, warmer temperatures and increased evapotranspiration due to a longer growing season will likely cause a decrease in water levels (SNAP et al. 2009). While shrinking lakes have already been observed in Denali, researchers noticed that not all lakes were affected equally, suggesting that increasing temperatures and evapotranspiration were not the only factors contributing to lake drying (Naranjo 2009).

Subsurface drainage appears to be playing a key role in lake drying in Denali. Both surrounding soil composition and permafrost conditions are factors in lake stability. Between 2006 and 2007, water levels in lakes that were underlain by sand dropped about six inches while lakes underlain by fine silt or clay remained relatively unchanged (Naranjo 2009). Differences in soil composition could explain the changes observed in the Eolian lowlands, where lakes are underlain by sand and discontinuous permafrost, but not in the Minchumina basin lowlands, where soils are made up of thick peat layers and frozen silt (Figure 57; CAKN 2008).

Subsurface drainage can also increase greatly as permafrost thaws with increasing temperatures. When permafrost is present under a lake, the frozen soils provide a "protective ring", preventing water from draining out through the soil (Naranjo 2009). Permafrost is sometimes protected from thawing by surface layers of peat moss and organic matter that insulate it from solar radiation. As the climate warms, conditions may become less favorable for peat moss and the permafrost could lose its protective insulation as well (Naranjo 2009). Other threats to permafrost include wildfires and talik expansion. Taliks are areas of unfrozen soil under lakes where the deepest waters do not freeze. As climate warms and water temperatures rise, these taliks will likely grow and further increase subsurface drainage of lakes (Riordan 2005).

Data Needs/Gaps

Very little is known about the physical, chemical or biological structure of lake ecosystems in Denali, despite their ecological importance (Larsen et al. 2004). While the CAKN monitoring program is addressing many of these needs, more information is needed on water chemistry (particularly related to possible pollution issues), sedimentation, and the impacts of invasive and exotic aquatic species.

Overall Condition

According to DENA (2009b) the number of lakes and total lake surface area within the park and preserve is unknown. However, research suggests that many of the shallow lakes are shrinking or disappearing. Measures of lake ecosystem function collected up to this point show that Denali's lakes are generally nutrient poor (Larsen 2006) but suggest that water quality is good.

Level of Confidence

Since lake ecosystem research at Denali has been minimal until recent surveys began, it is difficult to assess the current condition and any trend in lake ecosystem function.

Sources of Expertise

The primary sources of expertise for this assessment were Larsen et al. (2004), Larsen (2006), Riordan (2005), and data provided by Larsen (2010).

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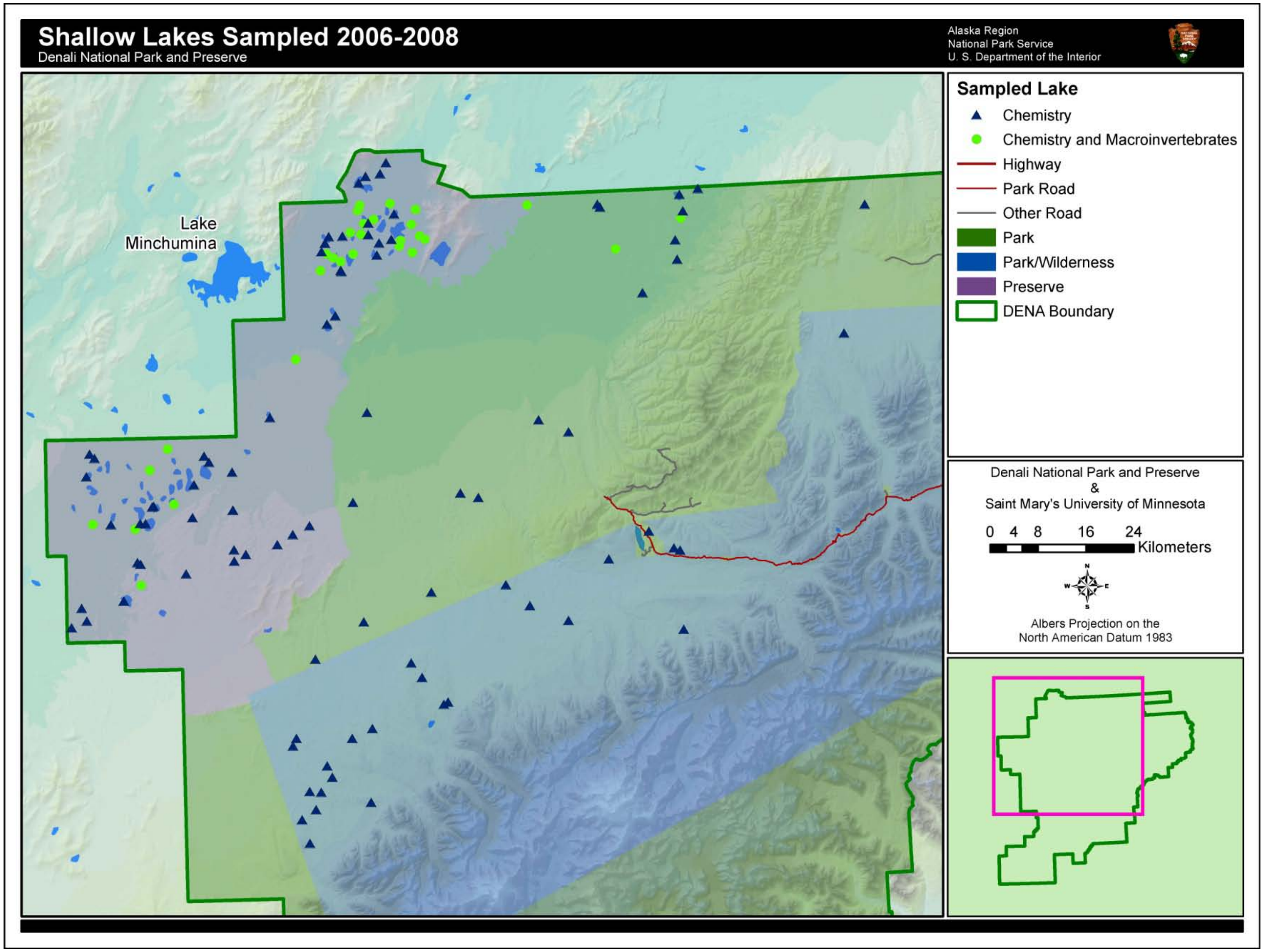
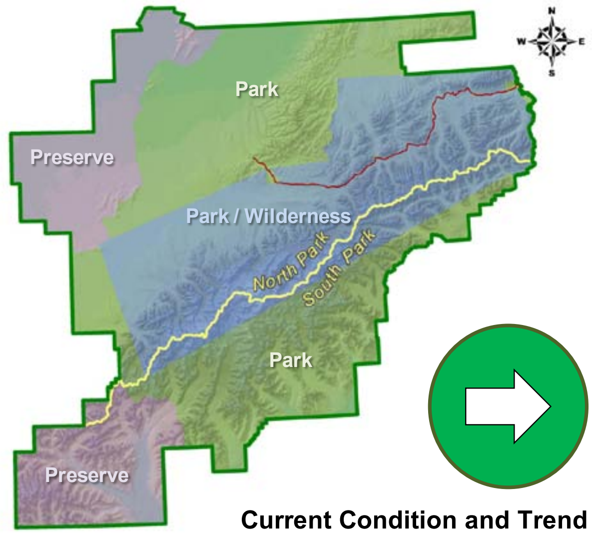


Plate 34. Shallow lakes sampled for the CAKN vital signs monitoring program, 2006-2008 (Larsen 2010)

4.13 Air Quality

Description



Current Condition and Trend

Air quality in Denali is considered nearly pristine, due primarily to Alaska's low population density and relatively low levels of industrial activity (MacCluskie and Oakley 2005, NPS Air Resources Division 2008). However, air pollution from both regional and international sources is recognized as an increasing threat, not just to air quality but also to water quality, soils, vegetation, and wildlife (MacCluskie and Oakley 2005, NPS Air Resources Division 2008). Some airborne pollutants, such as pesticides and mercury, can pose serious threats to the health of wildlife and humans, particularly when they accumulate in the ecosystem (NPS 2010a, DENA 2009a). The National Park Service has identified visibility, atmospheric deposition, and ozone as key air quality indicators and has monitored trends in national parks throughout the United States (NPS 2010a). Impaired visibility hinders visitors' ability to see and appreciate their surroundings (NPS 2010a). Atmospheric deposition causes acidification and fertilization of soil and surface water which affects ecological health, while ozone impacts both human health and native plant communities (NPS 2010a).

Denali has been designated as a Class I airshed (areas over 5,000 acres designated as Wilderness and national parks over 6,000 acres in August 1977) and therefore receives the strongest protection available under the Clean Air Act (DENA 2010). Unfortunately some of the air pollution reaching Denali every year is coming from international sources beyond the reach of the Clean Air Act. Small amounts of pollutants from power plants, smelters, agriculture, and other sources are transported to the park from other continents via two primary transport pathways. "Arctic Haze," which occurs throughout the arctic, brings pollutants over the North Pole into Alaska (DENA 2010). The contaminants carried in this haze include sulfur and nitrogen compounds, and heavy metals, which could eventually be deposited in the snow, water, vegetation, and soils of Denali (NPS Air Resources Division 2008). Dust from Asia and contaminants from global sources can also travel across the Pacific Ocean and settle in Alaska. While the transport of dust appears to be a long-running natural event, dust storms are expected to increase in frequency because of desert expansion in Asia, largely due to human activities (AK DEC 2002). Anthropogenic contaminants transported into the park from international sources are also expected to increase as global development increases (AK DEC 2002).

Several seasonal patterns have been detected in Denali's air quality. Airborne contaminant levels are low in the summer but peak in late winter and early spring (DENA 2009a, AK DEC 2002). Visibility typically declines twice during the year; once in late winter due to Arctic haze and trans-Pacific transport, and also during the summer when wildfires are common (AK DEC 2002). Smoke from wildland fires is the largest annual contributor to hazy conditions in the park and preserve (DENA 2009a).

Measures
Concentration of ground-level ozone
Atmospheric deposition of sulfur in precipitation
Atmospheric deposition of nitrogen in precipitation
Visibility
Lichen community structure

Reference Conditions/Values
The reference condition for air quality according to DENA (2009b) is that air quality parameters "remain stable or improve, as measured for NPS Performance Management Data System (PMDS) Goal Ia3." PMDS Goal Ia3 addresses visibility, ozone, and atmospheric deposition conditions in all national parks and is discussed in NPS 2009. The reference condition for lichen community structure has not yet been determined (DENA 2009b).

The National Park Service Air Resources Division recommends the following values for determining air quality condition (Table 40). The good condition levels are considered the reference condition for Denali.

Table 40. National Park Service Air Resources Division air quality index values (NPS 2009).

Condition	Ozone concentration[1]	Wet Deposition of N or S (kg/ha/yr)	Difference from estimated natural visibility in deciviews (dv)
Significant Concern	≥ 76 ppb	> 3	> 8
Moderate	61-75 ppb	1-3	2-8
Good	≤ 60 ppb	< 1	< 2

[1] "Ozone concentration" represents the annual 4th-highest daily maximum 8-hour average concentration averaged over five years.

Data and Methods

Ozone monitoring
Ground-level ozone is not typically emitted straight into the air but rather is formed by a chemical reaction between nitrogen oxides and volatile organic compounds (VOCs) in the presence of sunlight (EPA 2010). Ozone has been monitored at Denali since 1987.

At high concentrations, ozone can cause damage to vegetation. An assessment was conducted by the NPS Air Resources Division to determine the risk of ozone injury to plants in national parks, including the three Central Alaska Network parks and preserves. Researchers identified ozone sensitive plants in each park and preserve and used existing ozone and soil moisture data to assess the risk of ozone injury (CAKN 2004). Vascular plant species occurring within Denali that are considered particularly sensitive to ozone include Saskatoon serviceberry (*Amelanchier alnifolia*), quaking aspen (*Populus tremuloides*), and Scouler's willow (*Salix scouleriana*) (CAKN 2004). Due to Denali's low ozone levels, the NPS determined that the risk of ozone damage to vegetation at the park and preserve is low (CAKN 2004).

Atmospheric deposition monitoring (sulfur and nitrogen)
Atmospheric deposition occurs in two ways: wet deposition through precipitation or fog, and dry deposition, a complicated process similar to "dust collecting on a table" (EPA 2001). Wet

deposition has been monitored at Denali since 1980 as part of the National Atmospheric Deposition Program (NADP) while dry deposition data has been gathered since 1998 through the Clean Air Status and Trends Network (CASTNet) (NPS Air Resources Division 2008). The National Park Service uses three measures to assess nationwide condition and trends in atmospheric deposition: sulfate, nitrate, and ammonium ions in precipitation (ammonium ion measurements are included in the total nitrogen wet deposition measure) (NPS 2009).

Visibility monitoring

Visibility has been monitored at Denali through the Interagency Monitoring of Protected Visual Environments (IMPROVE) program since 1988. Analysis of samples from IMPROVE monitors allow researchers to determine the composition of haze at different times of year. The main sources of visibility-impairing haze at Denali are wildfire smoke and local, regional, and international contaminants (i.e., from Arctic haze and trans-Pacific transport) (AK DEC 2002, DENA 2009a). Wildfires result in increased levels of organic compounds in the air while international transport causes sulfur dioxide and sulfate levels to increase. From November to May, sulfates are the dominant visibility-impairing contaminant at Denali, primarily due to international transport.

Photo 23. Varying visibility conditions at Denali: clear (upper left), moderate (upper right), and hazy (above) (NPS photos, in NPS 2009).

In 1999, the EPA adopted a Regional Haze Rule to protect visibility in Class I airsheds. As part of this program, the Alaska Department of Environmental Conservation calculated natural and baseline visibility condition estimates for Denali (AK DEC 2010). The baseline estimate included both natural and anthropogenic contributions to visibility reduction during the baseline years (2000-2004). Two measures are used to determine visibility conditions for the Regional Haze Rule program: visibility on the 20% clearest days and visibility on the 20% haziest days. The methods for calculating these values for both natural and baseline conditions are discussed in AK DEC 2010. The results from this report are summarized in Table 41. The majority of "worst days" at Denali occurred between May and August while the most "best days" were between November and February. Yearly variation in visibility was most dependent on the timing, location, and severity of wildfires (AK DEC 2010). The baseline visual range for the Denali Headquarters site, from 2000 to 2004, was estimated at 307 km on the 20% best days and 126 km on the 20% worst days (AK DEC 2010).

Table 41. Summary of natural and baseline visibility conditions for the Denali Headquarters monitoring site. Baseline conditions were calculated using data from 2000-2004, as required by the Regional Haze Rule (AK DEC 2010).

	Natural visibility conditions (dV)	Baseline visibility conditions (dV)
Annual mean	3.79	5.34
20% Best days	1.77	2.42
20% Worst days	7.32	9.86

Lichen community structure

Lichens are often used to monitor air quality, since they absorb nutrients directly from their surroundings (Aptroot and van Herk 2007). Most lichens are highly sensitive to SO_2 and ammonia (NH_3), with some species declining or even disappearing at low levels of air pollution (Aptroot and van Herk 2007). Information gathered from monitoring community composition of lichen plots can therefore indicate changes in air quality.

Very little data is available on changes in lichen community structure at Denali, since periodic resampling of long-term vegetation plots has not yet occurred. A lichen species list for the park is included in Appendix F. Studies have found that sensitivity to air pollution among lichens varies by growth form. Fruticose or shrubby lichens are generally most sensitive, foliose or leafy lichens are moderately sensitive, while crustose or flat lichens are least sensitive (Blett et al. 2003). Lichens from the genera *Alectoria*, *Bryoria*, *Ramalina*, *Lobaria, Nephroma*, and *Usnea* are thought to be some of the most sensitive (Blett et al. 2003). The U.S Forest Service has conducted extensive research into the effects of pollution on lichens in the Pacific Northwest and Southeast Alaska, including species thresholds and sensitivity ratings. This information can be found at their National Lichens and Air Quality website (USFS 2010).

The WACAP report

From 2002 to 2007, the Western Airborne Contaminants Assessment Project (WACAP) studied airborne contaminants in western national parks, including several in Alaska. Their objectives were to determine if airborne contaminants were present in these parks, where they were accumulating, and which ones posed an ecological threat, as well as identifying likely sources and indicators useful for assessing contamination (Landers et al. 2008). The study focused on heavy metals, including mercury, and semi-volatile organic compounds (SOCs) including pesticides and industrial compounds. Air, snow, water, lake sediment, fish, and vegetation were all sampled at Denali. Results showed that most of the contaminants measured in samples other than fish were found at relatively low concentrations. In general, Alaska samples contained lower concentrations of contaminants than samples from parks in the lower 48 states. The results of the WACAP study are discussed in more detail in the ecosystem contaminants section of this report.

In an effort to identify likely contaminant sources, WACAP created back-trajectory maps, tracing potential atmospheric transport pathways for airborne contaminants entering Denali. The ten-day back-trajectory estimate is shown in Figure 69 below.

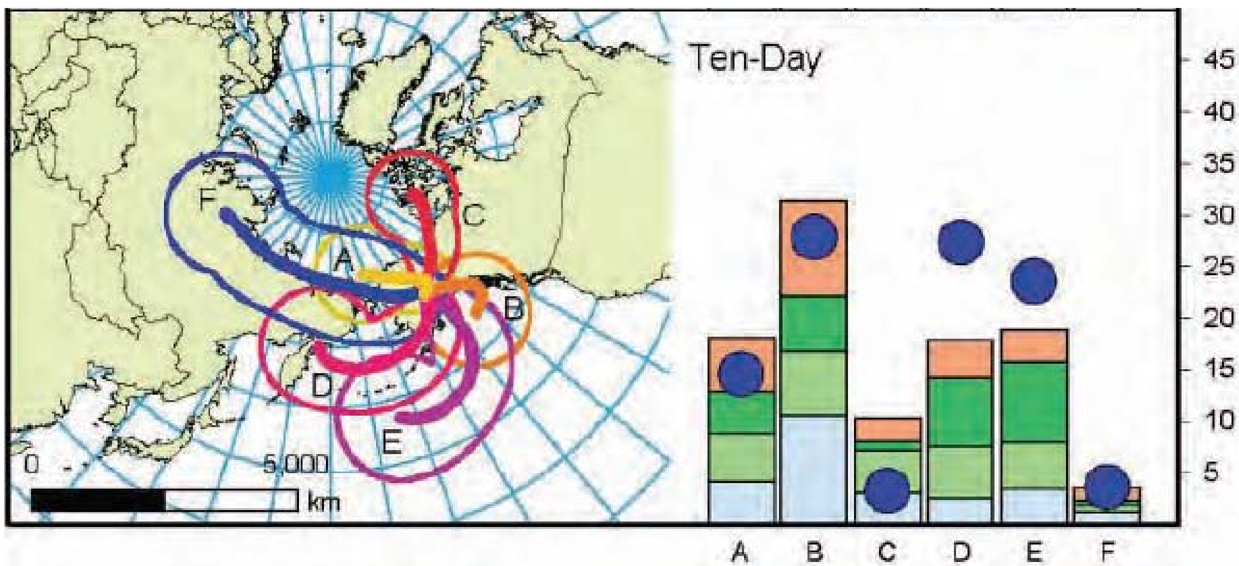


Figure 69. Ten-day cluster plot for Denali, showing potential transport pathways for airborne contaminants to the park. Clusters are sorted shortest to longest, A–F. Bars represent the percent of trajectories in each cluster out of 2,922 total (1998-2005). Light blue = winter; light green = spring; dark green = summer; orange = autumn. The dark blue dot is the percent of total precipitation for which each cluster is responsible (Landers et al. 2008).

Current Condition and Trend

Concentration of ground-level ozone

According to the National Park Service (NPS 2010a), ozone concentration at Denali is in good condition and considered stable. Figure 70 shows that the annual 4th-highest 8-hour ozone readings for Denali through 2007 are well below the EPA's national standard of 75 ppb.

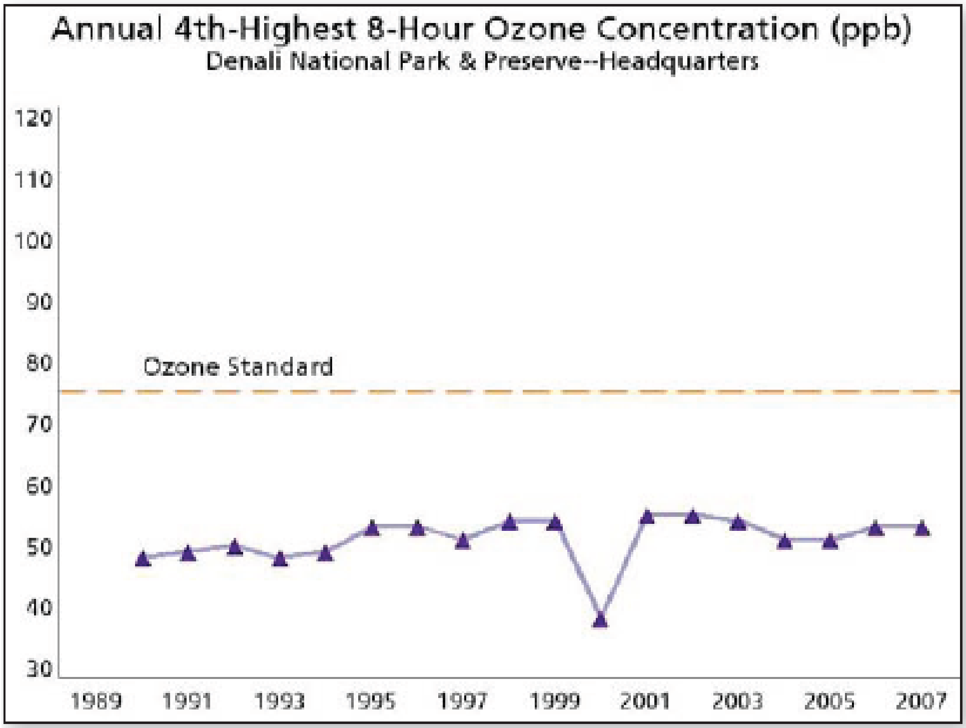


Figure 70. Annual 4th-highest 8-hour ozone concentrations for Denali through 2007 (from NPS 2009).

Atmospheric deposition of sulfur in precipitation

The condition of sulfur wet deposition at Denali is considered good with a stable trend (Figure 71; NPS 2010a). The five-year average annual deposition rate for 2005-2009, calculated from NADP measurements, was 0.59 kg/ha/yr (NADP 2010). In comparison, the five-year average for 2000-2004 was 0.71 kg/ha/yr (NADP 2010).

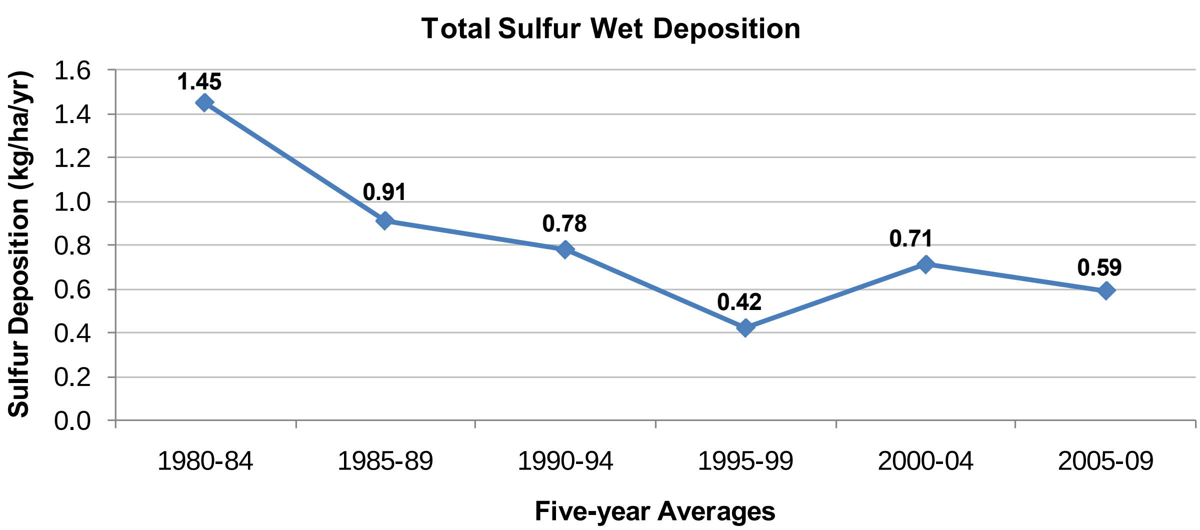


Figure 71. Five year averages for total wet deposition of sulfur (kg/ha/yr) at Denali, 1980-2009 (NADP 2010).

Atmospheric deposition of nitrogen in precipitation

Nitrogen wet deposition conditions at Denali are also considered good with a stable trend (Figure 72; NPS 2010a). The five-year average annual deposition rate for 2005-2009, calculated from NADP measurements, was 0.41 kg/ha/yr (NADP 2010). In comparison, the 2000-2004 five-year average was 0.62 kg/ha/yr (NADP 2010).

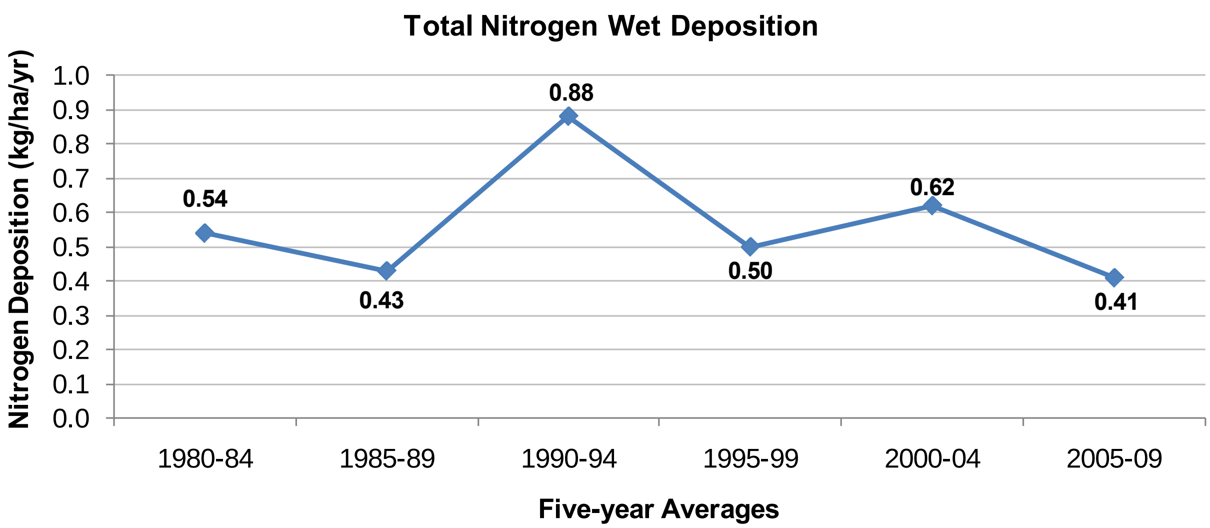


Figure 72. Five year averages for total wet deposition of nitrogen (kg/ha/yr) at Denali, 1980-2009 (NADP 2010).

Visibility

Visibility conditions at Denali are good with a stable trend (NPS 2010a). The NPS determines visibility condition by finding the difference between current and natural values. Figure 73 shows annual visibility on the 20% best and 20% worst days from 1989 through 2004, with average conditions on the best days very close to estimates of natural visibility.

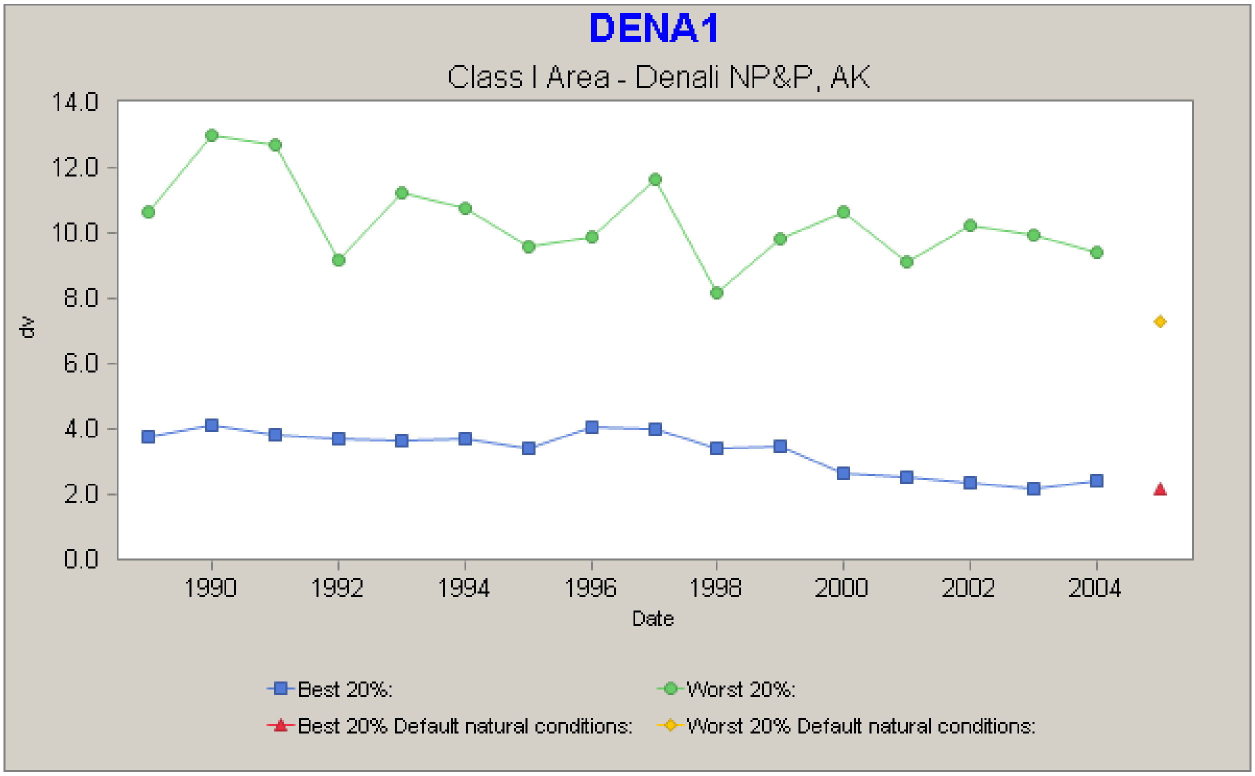


Figure 73. Annual visibility in Denali on the 20% worst days and the 20% best days, 1989-2004 (VIEWS 2010).

Lichen community structure

Currently very little is known about changes in lichen community structure within Denali. A globally endangered lichen species (*Erioderma pedicellatum*) known to be sensitive to air pollution was recently discovered in the park (NPS 2010b). The WACAP report included analysis of lichen tissue samples for airborne contaminants. Results showed that sulfur and nitrogen concentrations in lichens from Denali were within the expected range and are not considered elevated (Landers et al. 2008).

Threats and Stressor Factors

DENA (2009b) identifies the following as threats to the park and preserve's air quality: coal-fired and other types of power plants, intercontinental contaminant transport, increasing size and frequency of wildland fires in North America and Asia, increasing global population and industrialization, and local development (e.g. shallow gas wells, power, mining etc.).

Air quality stressors include naturally occurring phenomenon such as volcanic eruptions and smoke from forest fires, as well as local and regional anthropogenic sources such as motor vehicles, wood-burning stoves, unpaved roads, construction activities, and industrial facilities (AK DEC 2002). In the mid-1990s, a coal-fired power plant was constructed in Healy, less than four miles from the Denali boundary (DENA 2009a). The plant's proximity to the park generated concerns about potential impacts to the park's air quality and air quality related values (AQRVs). The plant operated from January 1998 to December 1999, but was then shut down (AIDEA 2001). However, the plant is now tentatively scheduled to be operational again sometime in the next few years (Golden Valley Electric Association 2010). Additional emission controls were built into the plant's construction and operating permits, but its operation still has the potential to affect the park and preserve's air quality (DENA 2009a).

Airborne contaminants from international sources are also expected to increase as global development accelerates (AKDEC 2002). Since weather patterns and conditions influence air circulation and haze formation (AK DEC 2002), global climate change also has the potential to affect air quality.

Data Needs/Gaps

Further sampling of the lichen community is needed before this measure can effectively be used as an indicator of air quality within the park and preserve. Lichens are included in Denali's long-term vegetation monitoring program, which will eventually provide information on any changes in lichen community structure. Continuous, real-time measurements of fine particulate matter (PM 2.5) would help characterize patterns of wildfire smoke and assist in mitigating human health risks (DENA, Blakesley, pers. comm. 2011). The impacts of airborne contaminants on aquatic environments in the expansive roadless areas of the park and preserve are also not well known (NPS Air Resources Division 2008).

Overall Condition

According to data from NPS (2010a) and NADP (2010), sulfur and nitrogen deposition conditions in Denali are good with a stable trend. Ground level ozone concentrations and visibility are also good with a stable trend (DENA 2009b, NPS 2010a). It is currently unknown if there have been any changes to lichen community structure.

Level of Confidence

Air quality data has been collected at Denali for several decades with current indices and nearly all historical measurements falling within the "good" condition levels established by the NPS Air Resources Division (Table 40).

Sources of expertise

The sources of expertise for this assessment include NPS (2010a), Alaska Department of Conservation (2002, 2010), and NPS Air Resources Division (2008).

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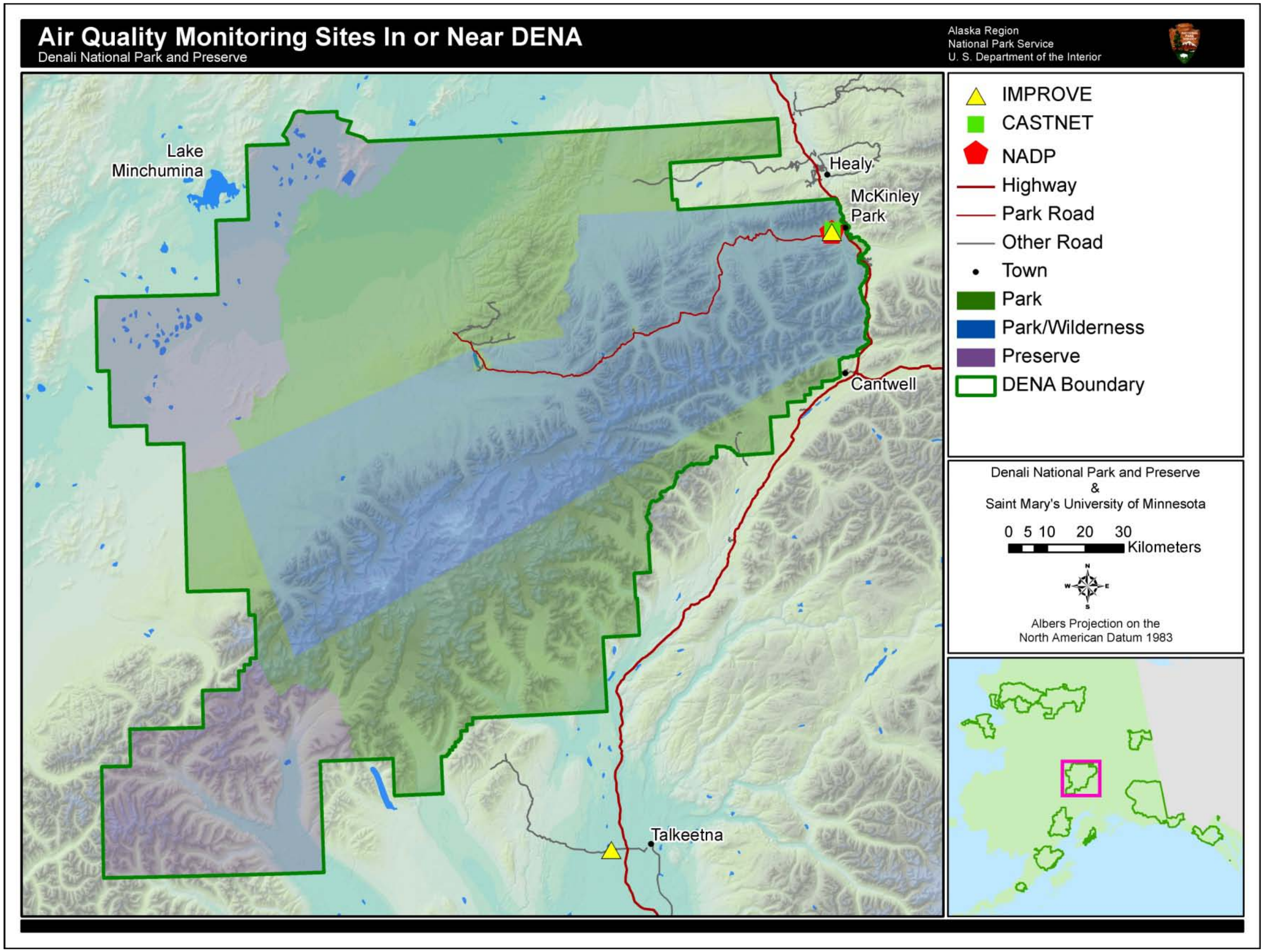
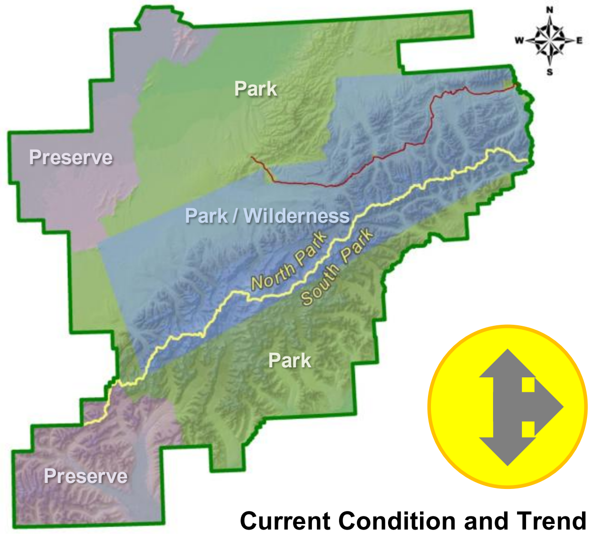


Plate 35. Ongoing air quality monitoring sites in or near DENA (NPS 2010c).

4.14 Ecosystem Contaminants



Current Condition and Trend

Description

Anthropogenic contaminants (those released from human activities) can have a significant effect on the many ecosystems and food webs that exist in Denali National Park and Preserv (Landers et al. 2008). These contaminants often become airborne and can be found in air snow, water, sediments, vegetation, and fish. These media were sampled and analyzed for contaminants in Denali and other national parks as part of The Western Airborne Contaminants Assessment Project (WACAP) (Landers et al. 2008). Anthropogenic contaminants in Denali originate from global, regional, and local sources (Landers et al. 2008). Many organizations are working to understand "the global fate, transport, and associated ecological impacts on sensitive ecosystems of airborne contaminants" (Landers et al. 2008). The ecosystem contaminants studied at Denali were semi-volatile organic compounds (SOCs), mercury (Hg), and several trace metals. The CAKN vital signs impacted by these contaminants include freshwater fish, air quality, human presence, natural resource consumption, and vegetation structure and composition (CAKN 2008).

Measures

Presence of contaminants in air, snow, lake sediment, vegetation, and fish, as measured by WACAP (Landers et al. 2008)

Reference Condition

For the purpose of this assessment, findings for Denali will be compared to results from other national parks. These findings will also be compared to established contaminant threshold levels from regulatory agencies where available.

Data and Methods

The Western Airborne Contaminants Assessment Project (WACAP) examined eight national parks in the western United States, including Denali, for concentrations of anthropogenic contaminants (Landers et al. 2008). WACAP collected data on semi-volatile organic compounds (SOCs), mercury (Hg), and a host of different metals from a variety of sample sources. These contaminants were measured in the air, snow, lake sediments, vegetation, and fish from 2003 through 2005 (Landers et al. 2008). Sample sites in Denali are shown on Plate 36.

<u>Contaminants</u>

SOCs include North American current-use pesticides, North American historic-use pesticides, combustion byproducts, and industrial/urban use compounds. They are transported through the atmosphere by human activity and have the reputation of staying in the environment for a long time (Landers et al. 2008). The WACAP study measured over 100 different SOCs, some of which are classified as persistent, bioaccumulative, and toxic (PBT) chemicals by the EPA (Landers et al. 2008). Several of the SOCs detected in Denali are described in Table 42 below.

Table 42. SOCs detected in Denali National Park and Preserve, along with their use/source, history, and regulatory status in the U.S. as of 2007 (Landers et al. 2008).

Compound Name	Use/Source	First U.S. Usage	U.S. Regulatory Status
Endosulfan I & II	Insecticide	1954	Active use
Dacthal	Herbicide	1955	Active use
a-HCH	Insecticide	1948	Banned in 1978
g-HCH	Insecticide	1948	Restricted use
Dieldrin	Insecticide	1949	Banned in 1987
Chlordanes*	Insecticide	1948	Banned in 1988
PCBs*	Industrial	1929	Banned in 1977
PAHs	Combustion	NA	NA

* classified as persistent, bioaccumaltive, and toxic by the USEPA

Mercury is an elemental pollutant with a complex life cycle in the atmosphere and biosphere, which leads to difficulty in detecting its origin (Landers et al. 2008). Anthropogenic sources such as combustion, smelting, and petroleum refining are thought to account for 75% of the mercury that enters the atmosphere, with the remainder originating from geologic and biogenic sources (Landers et al. 2008). It is suspected that mercury is entering national parks through "atmospheric deposition from local, regional, and trans-Pacific sources" (Landers et al. 2008). In Denali, long-range global sources of mercury contribute more to total deposition than regional North American sources (Landers et al. 2008). Mercury poses the largest ecological threat of all WACAP study contaminants (Landers et al. 2008). It can cause neurological damage to animals and humans, as well as damage to the reproductive, respiratory, and nervous systems (Landers et al. 2008).

Metal contaminants are emitted by human activities including fossil fuel combustion, agriculture and industry, incineration, and automobiles, and can travel over short and long distances (Landers et al. 2008). Many metals also occur naturally in the earth's crust and can be exposed by erosion and volcanic activity (Landers et al. 2008). Metals of interest in Denali include cadmium (Cd), copper (Cu), lead (Pb), vanadium (V), and zinc (Zn).

Sampling methods

Air samples were collected using passive air sampling devices (PASDs) that recorded ambient SOC levels (Landers et al. 2008). Two PASDs were deployed in Denali, both located in the Wonder Lake watershed at two different elevations: 564m and 686m. The devices collected data for one year before being sent to a lab for analysis (Landers et al. 2008). Airborne contaminant transport pathways were also modeled by analyzing the back-trajectory that an individual particle traveled over a certain period of time (Figure 74, Landers et al. 2008).

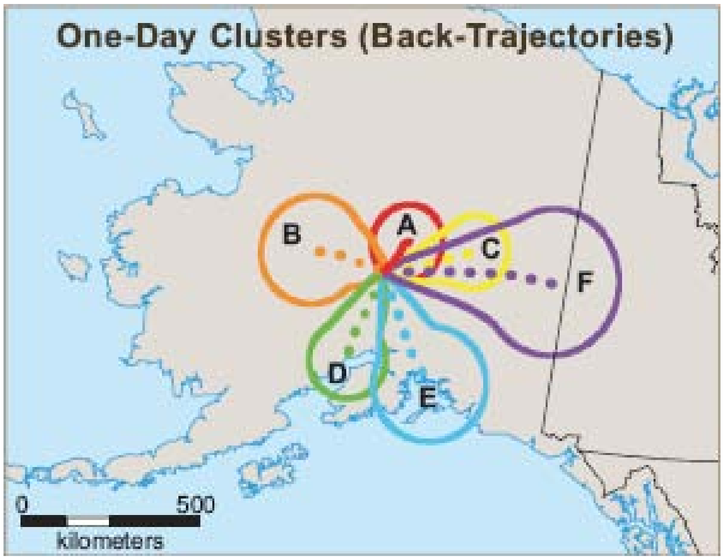


Figure 74. One-day clusters (back-trajectory models) for airborne contaminants reaching Denali National Park and Preserve (Landers et al. 2008).

Snowpack samples were taken at three sites in Denali: Wonder Lake, McLeod Lake, and Kahiltna (Landers et al. 2008). Two lake sediment cores were collected from Wonder and McLeod Lakes in 2004 to provide information on contaminant accumulations over the last ~150 years and their sources (Landers et al. 2008). Fish were also collected for this study, including lake trout (*Salvelinus namaycush*) at Wonder Lake, and round whitefish (*Prosopium cylindraceum*) and burbot (*Lota lota*) at McLeod Lake.

Vegetation was sampled at Denali in 2004 at six different sites varying in elevation from 221 meters to 1,753 meters (Landers et al. 2008). Conifer needles and lichens were selected for analysis of contaminant levels (Landers et al. 2008). Conifer needles were the main vegetation form for measuring SOC levels because samples represented a defined period of exposure (second-year needles were used) (Landers et al. 2008). Lichens were sampled for mercury, metals, and SOCs; lichens generally have higher SOC levels than conifer needles which facilitates detection of site-to-site differences (Landers et al. 2008).

Current Condition and Trend

Air

The SOCs detected in the air at Denali were similar to those detected in other arctic and subarctic Alaskan parks (Landers et al. 2008). The most common SOCs in the air at Denali were HCB and a-HCH, both historically-used pesticides (Figure 75; Landers et al. 2008). Additional SOCs found in lower concentrations included g-HCH and chlordane (historic-use pesticides), endosulfans (current-use pesticides), and polycyclic aromatic hydrocarbons (PAHs, combustion byproducts) (Landers et al. 2008).

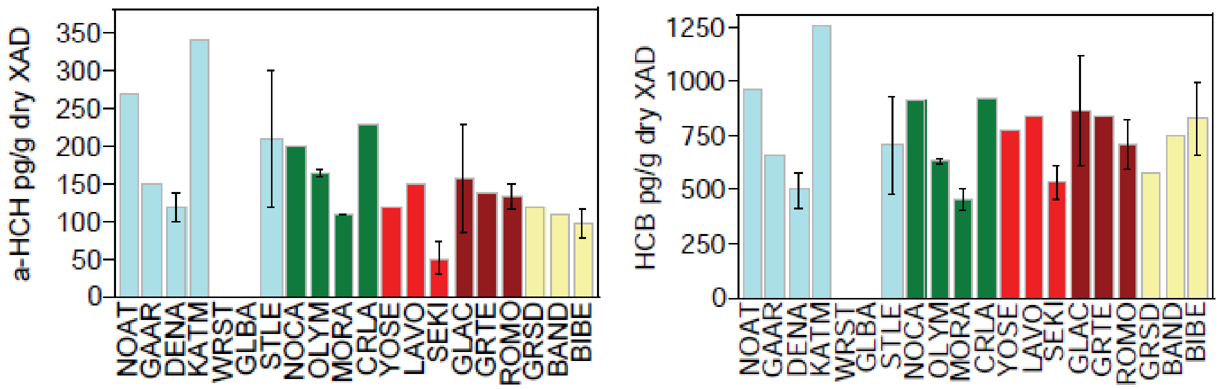


Figure 75. Regional patterns of the SOCs a-HCH and HCB in ambient air indicated by concentrations accumulated in XAD resin in PASDs. Parks are listed from north to south from Alaska (light blue) through the Pacific Northwest (green) to California (red) and from the northern (brown) to southern (pale yellow) Rocky Mountains. Error bars indicate one standard error (Landers et al. 2008).

<u>Snow</u>

Contaminant deposition fluxes in snow at DENA were among the lowest in all parks sampled (Figure 76; Landers et al. 2008). Of the three sites sampled at Denali, Kahiltna had the highest deposition fluxes of most contaminants, likely due to its higher elevation and a precipitation gradient along the mountains of the park and preserve (Landers et al. 2008). As a result, Landers et al. (2008) noted that contaminant flux measurements at a single site may not be representative of the entire park, especially when elevational gradients are present.

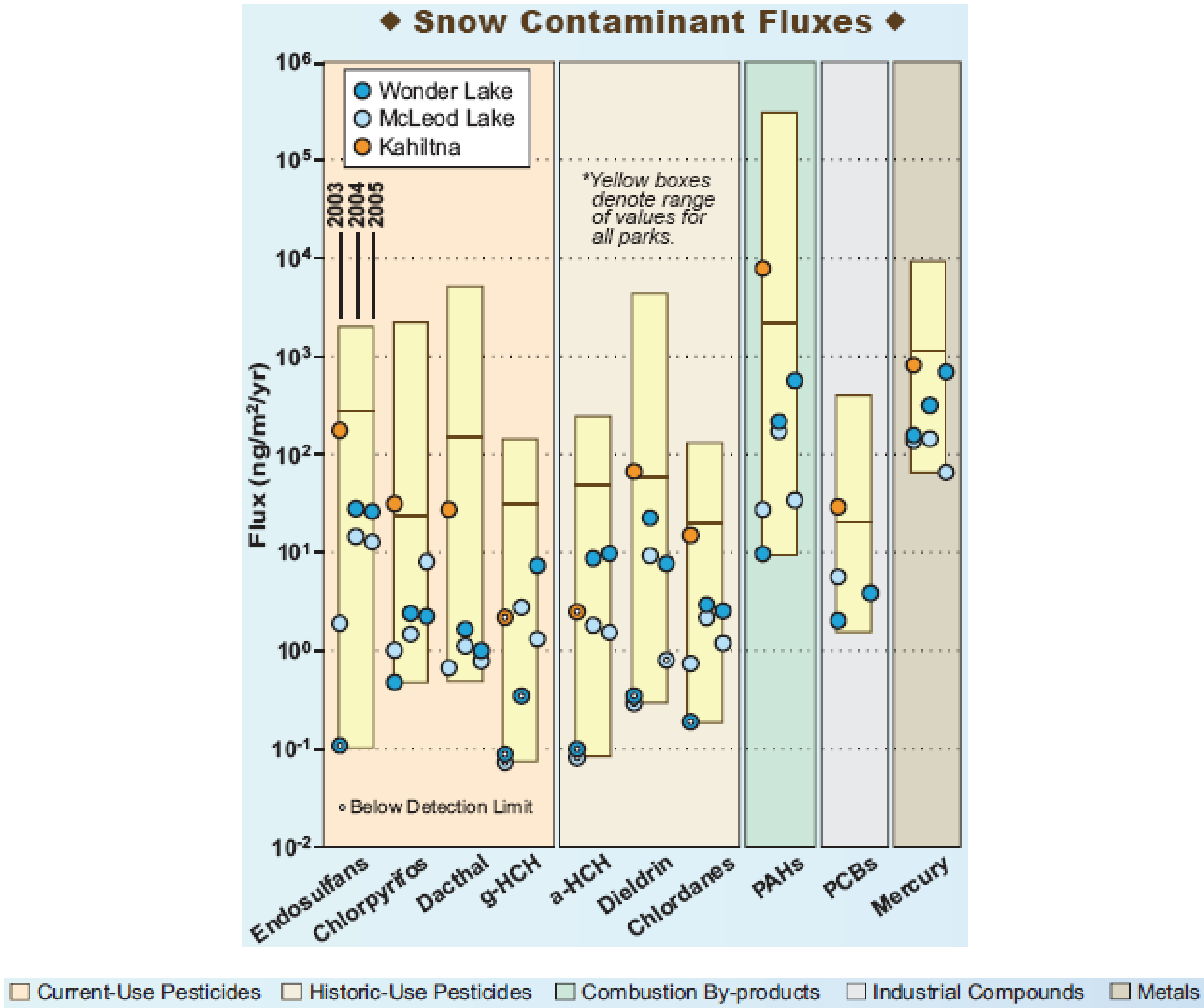


Figure 76. Snow contaminant fluxes at three DENA sampling sites. Yellow boxes show the range of values for all parks sampled and the lines inside represent the median (Landers et al. 2008).

<u>Sediment</u>

Sediment fluxes were below the detection level for most SOCs in Denali (Figure 77). However, sediment analysis showed that endosulfans have increased in McLeod Lake over time (Landers et al. 2008). PCBs were present in sediment at low concentrations, similar to levels found in other Alaska lakes (Landers et al. 2008).

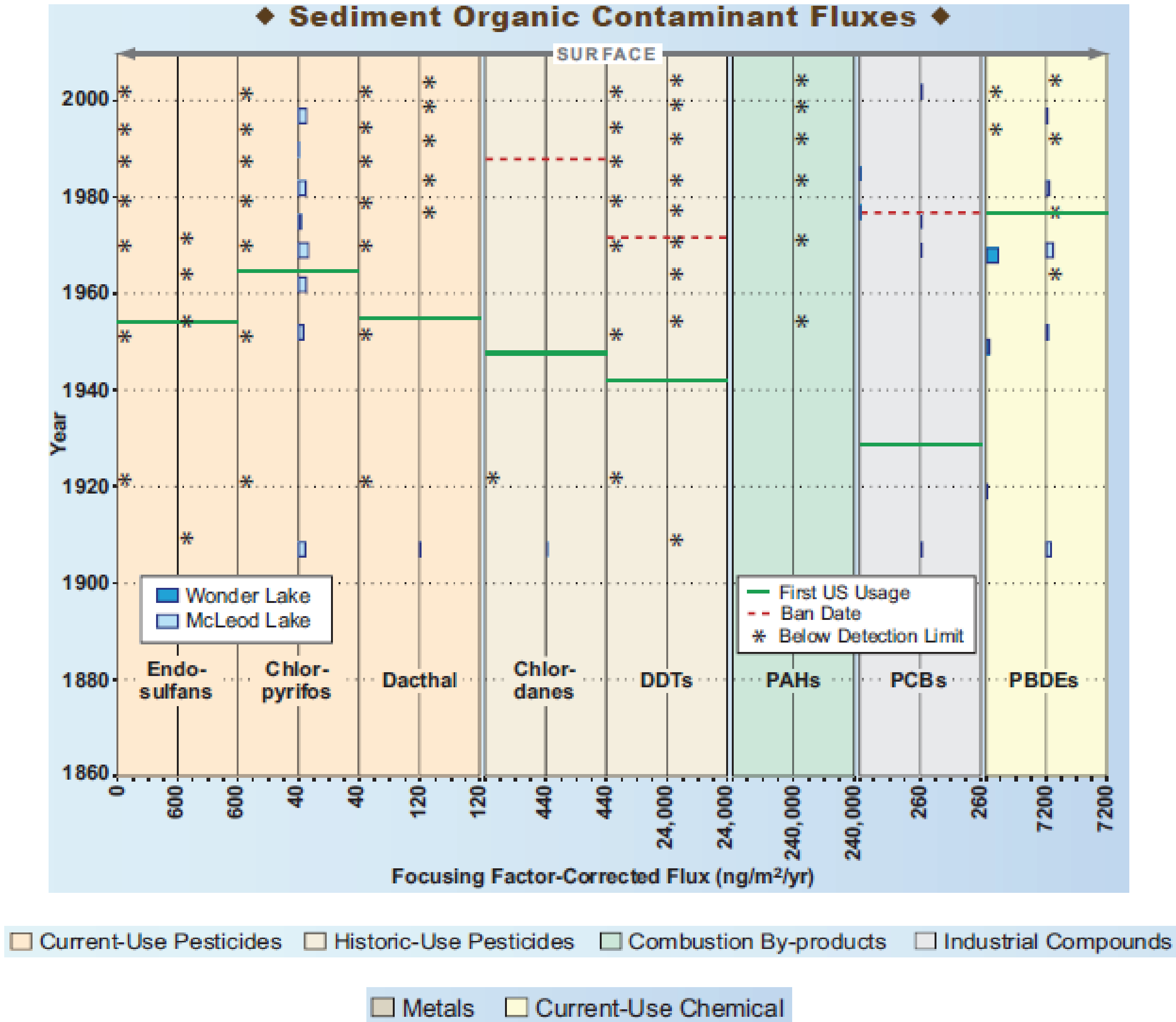


Figure 77. SOC contaminant fluxes in Wonder and McLeod Lake sediments (Landers et al. 2008).

Spheroidal carbonaceous particles (SCPs) are byproducts of fossil fuel combustion that are easily identifiable in sediment samples. They have no natural sources and are therefore "unambiguous indicators of deposition from industrial combustion of fossil fuels" (Landers et al. 2008). No SCPs were found in Denali lake sediments, although total organic carbon levels have fluctuated over time (Figure 78; Landers et al. 2008).

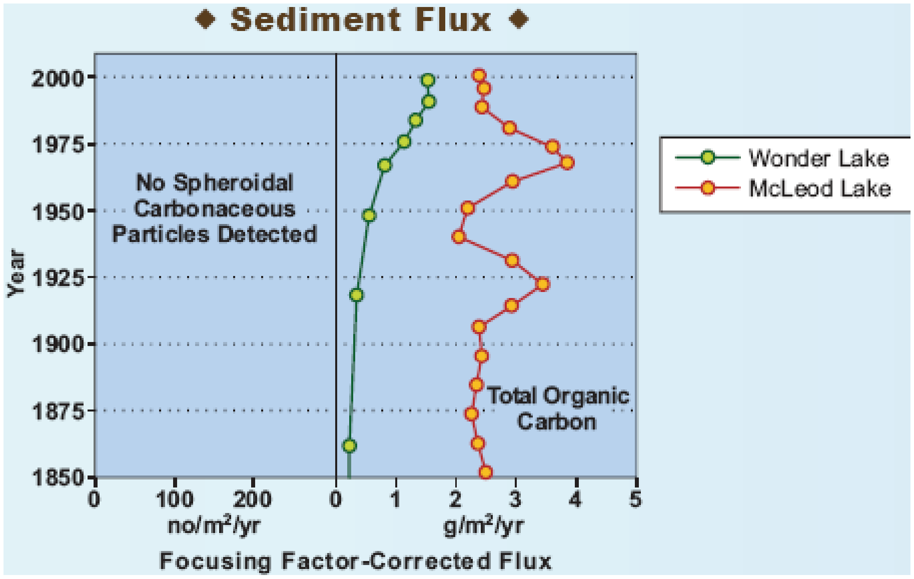


Figure 78. Sediment flux of total organic carbon in Wonder and McLeod Lakes (Landers et al. 2008).

Wonder Lake sediments showed an increase in mercury concentration levels, following a global trend throughout the twentieth century (Figure 79, Figure 80; Landers et al. 2008). Sediments collected from McLeod Lake also showed an increase in mercury but did not follow the same trend (Figure 79; Landers et al. 2008).

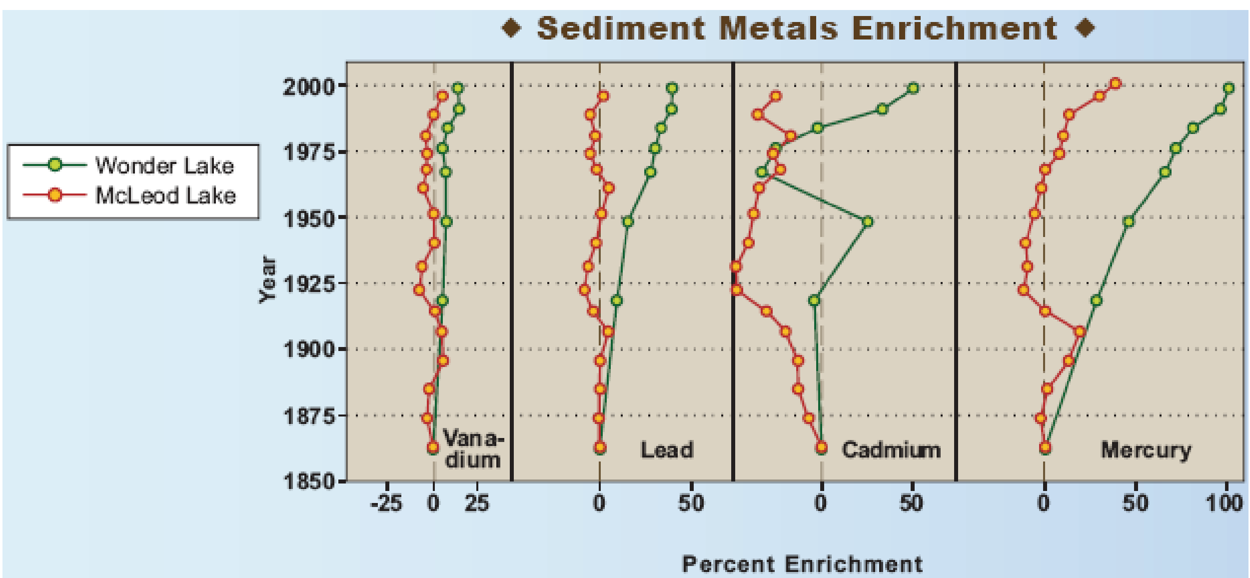


Figure 79. Sediment metals enrichment in Wonder and McLeod Lakes (Landers et al. 2008).

Several metals, particularly lead, have increased in Wonder Lake sediments over time (Figure 79, Figure 80). Sediments in McLeod Lake show two historic peaks in metal fluxes but current levels are similar to pre-1900 levels (Figure 80; Landers et al. 2008).

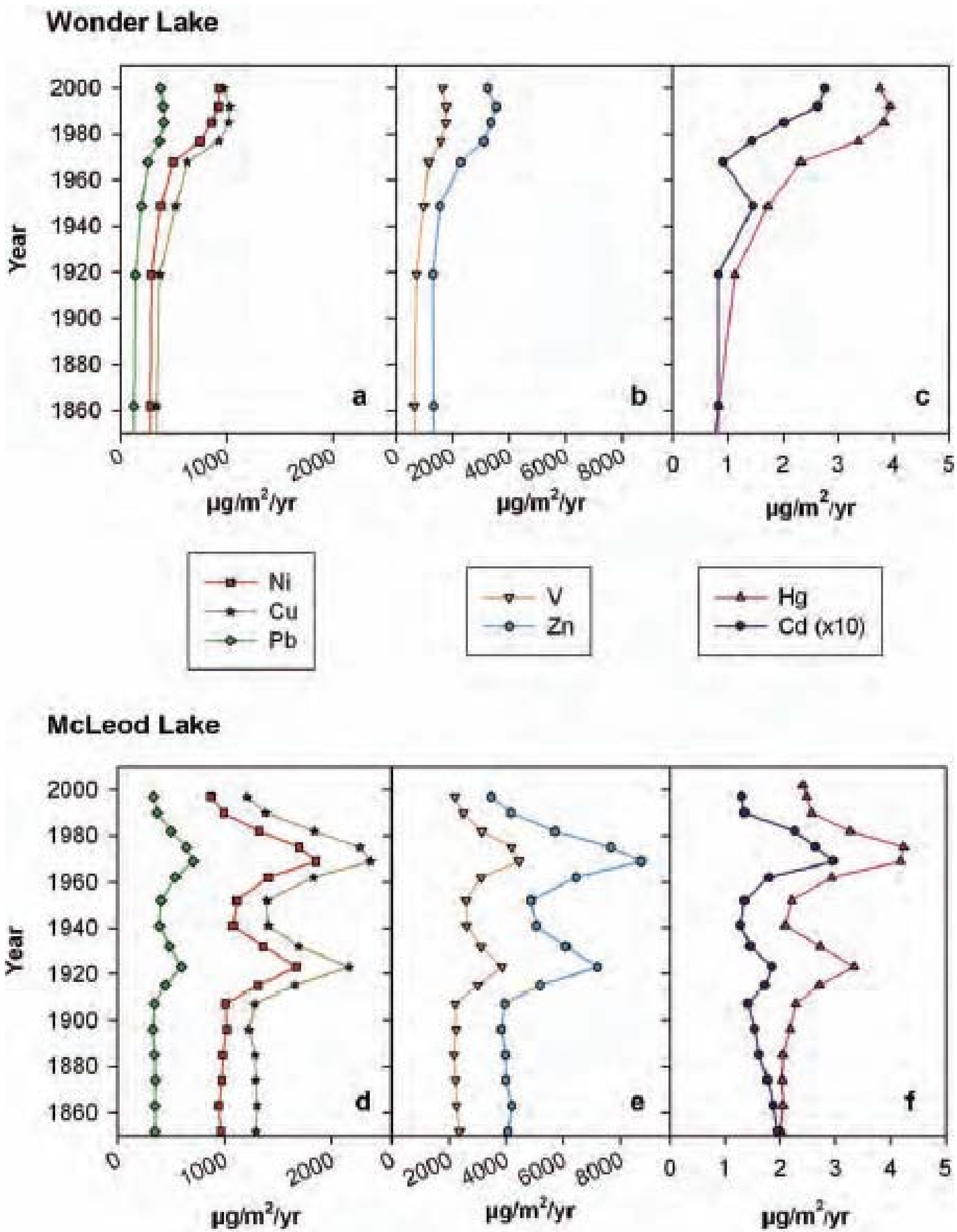


Figure 80. Focusing factor-corrected flux of nickel (Ni), copper (Cu), Lead (Pb), vanadium (V), zinc (Zn), cadmium (Cd), and mercury (Hg) (µg/m^2/yr) in sediment cores from Wonder and McLeod Lakes. Cd flux has been reduced by a factor of 10. (Landers et al. 2008).

Vegetation
According to Landers et al. (2008), SOCs can bioaccumulate in vegetation over time. Vegetation in Denali had the third lowest concentration of SOCs of all parks sampled (Landers et al. 2008). Agricultural chemicals found at low concentrations included the historic pesticides HCB and a-HCH, as well as endosulfans and dacthal which are current-use pesticides (Figure 81, Figure 82; Landers et al. 2008). Higher concentrations of PAHs were found but could possibly be explained by wildfires (Landers et al. 2008). PAH concentrations decreased as elevation increased (Landers et al. 2008). Mercury and metal concentrations in Denali's vegetation samples were the third lowest of all parks sampled in this study (Landers et al. 2008).

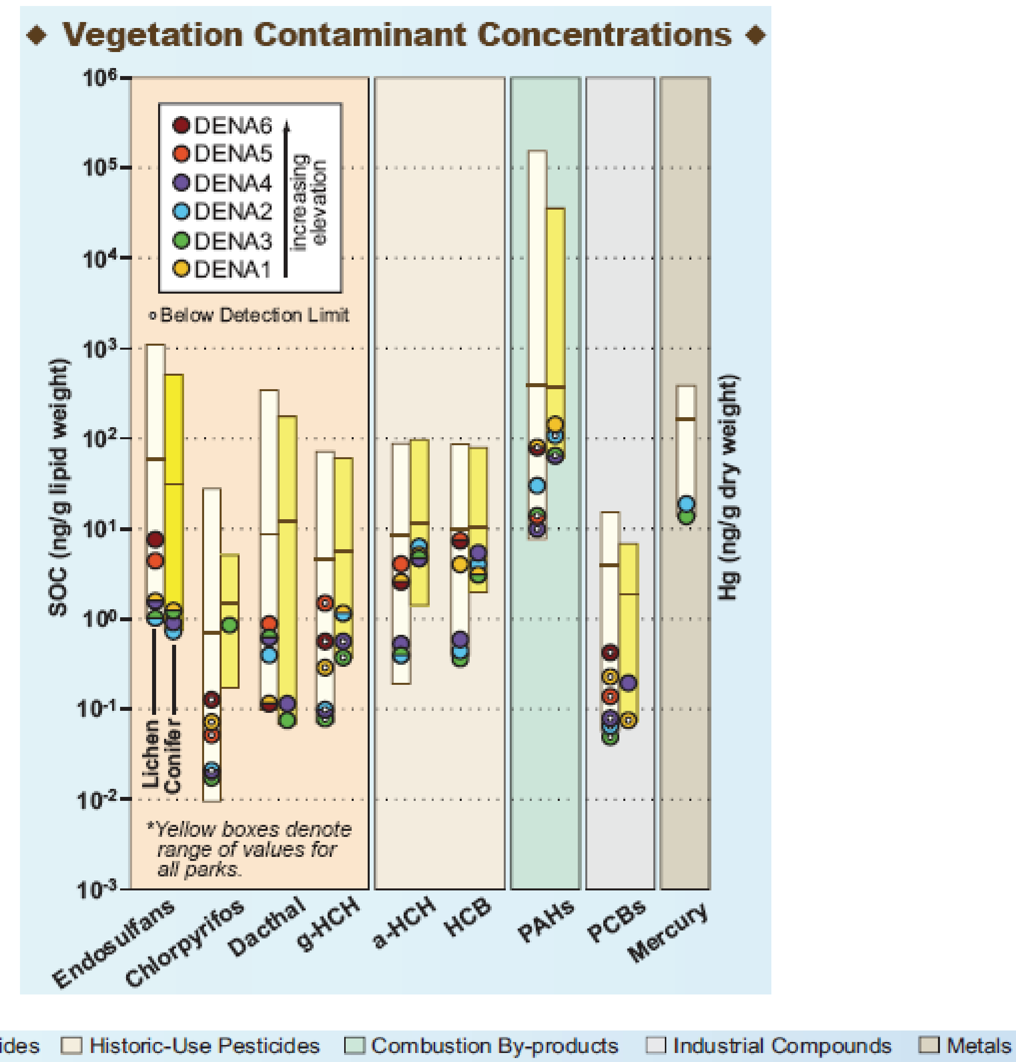


Figure 81. Vegetation contaminant concentrations at six Denali sampling sites. Yellow boxes show the range of values for all parks sampled and the lines inside represent the median (Landers et al. 2008).

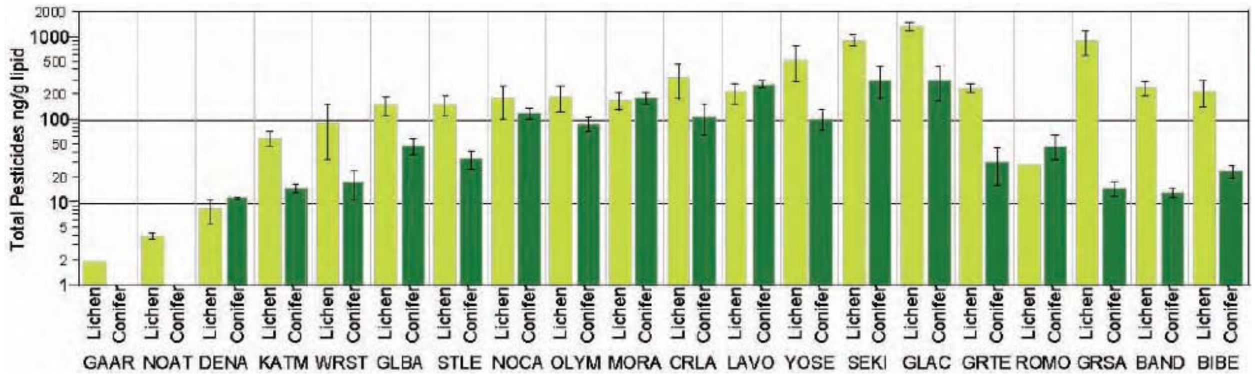


Figure 82. Comparison of total pesticide concentrations in lichen and conifer needle vegetation from WACAP parks in the Arctic (NOAT, GAAR), Interior Alaska (DENA), Coastal Alaska (KATM, WRST, GLBA, STLE), the Pacific Northwest (NOCA, OLYM, MORA, CRLA), California (LAVO, YOSE, SEKI), the Northern Rocky Mountains (GLAC, GRTE), and the Southern Rocky Mountains (ROMO, GRSA, BAND, BIBE). Note log scale; error bars indicate one standard error. No conifer samples were collected in the Arctic (Landers et al. 2008).

Fish

Fish, because of their constant immersion in water, are considered to be key indicators of contaminant bioaccumulation and can indicate impacts on the food web as a whole (Landers et al. 2008). Fish at Denali had mid to high concentrations of historically-used SOCs, but had among the lowest levels of current-use SOCs (Figure 83; Landers et al. 2008). Both Wonder and McLeod Lakes contained fish with concentrations of dieldrin that exceeded the contaminant health thresholds for subsistence fishers (Figure 84; Landers et al. 2008). Few fish were available for testing in McLeod Lake despite sampling attempts in both 2004 and 2005 (Landers et al. 2008).

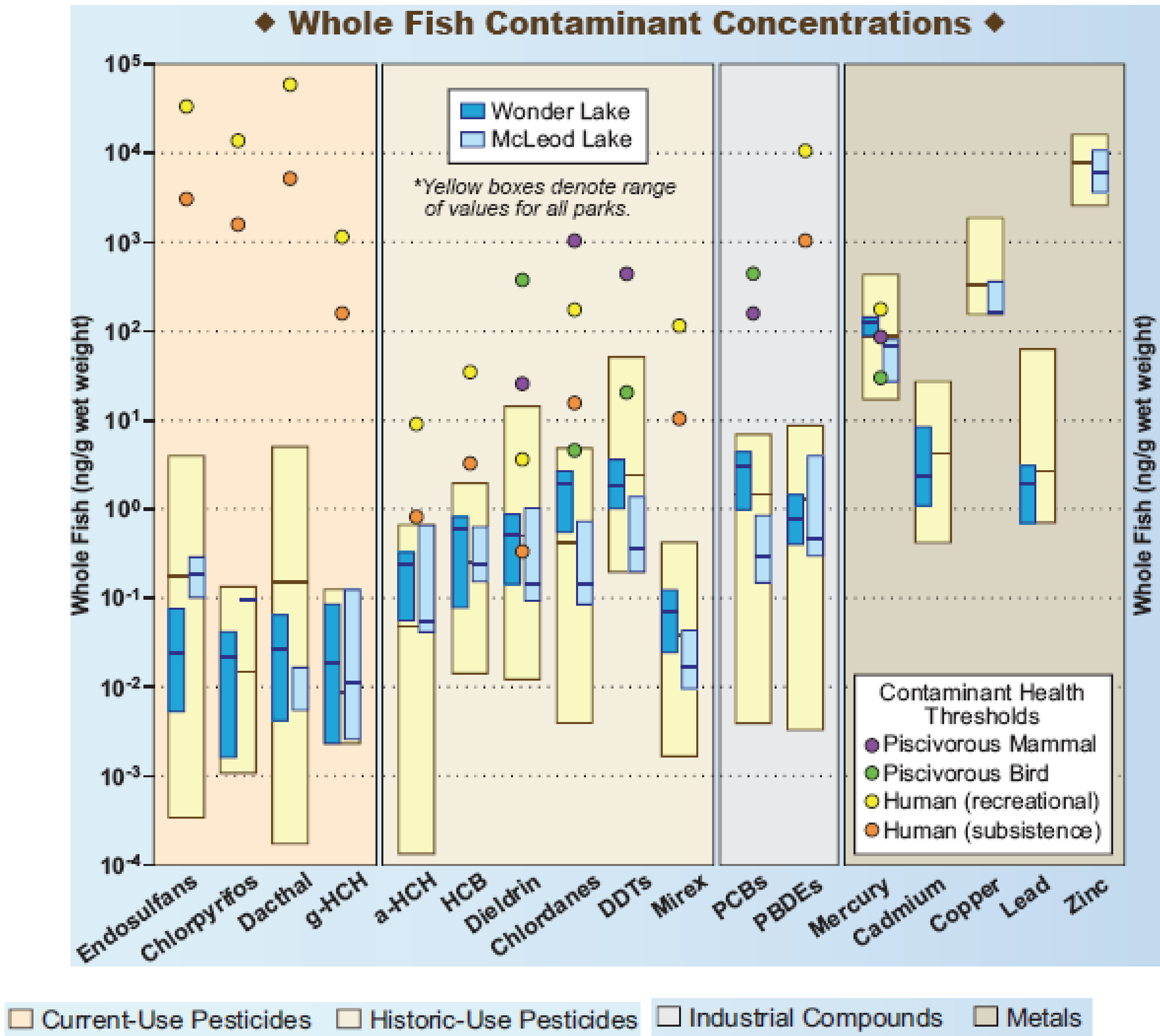


Figure 83. Whole fish contaminant concentrations. Yellow boxes show the range of values for all parks sampled and the lines inside represent the median (Landers et al. 2008).

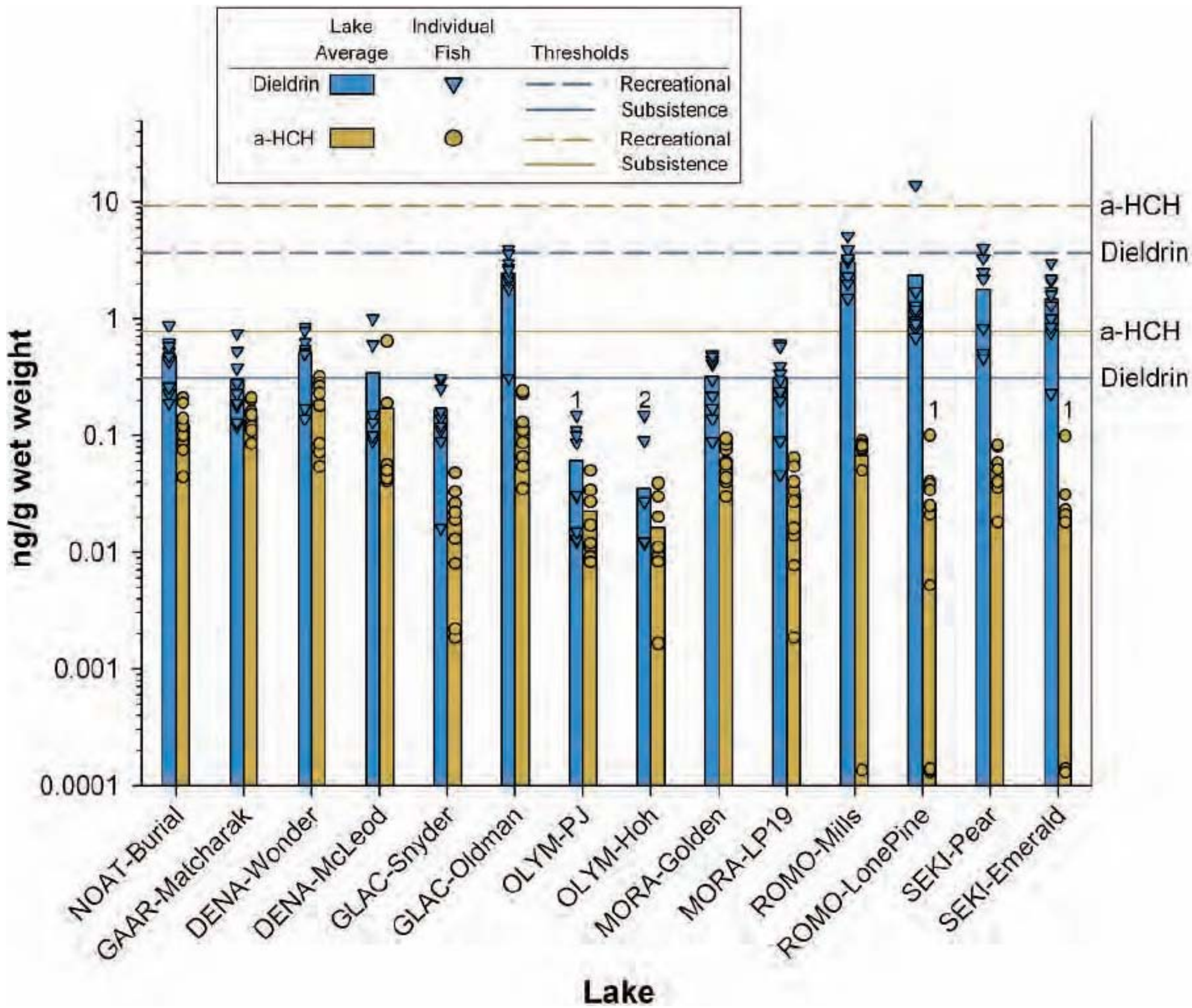


Figure 84. Concentrations of the historic-use pesticides dieldrin and a-HCH in individual fish (symbols) and fish averages by lake (bars) compared to EPA contaminant health thresholds for fish consumption by recreational and subsistence fishers. Data are plotted on a log scale. Exceedances imply that a lifetime consumption can increase the risk of developing cancer by more than 1 in 100,000. If no label is present at the top of a bar, the component was detected in at least 70% of the samples. “1” indicates the analyte was detected in 50–70% of the samples; “2” indicates the analyte was detected in less than 50% of the samples (Landers et al. 2008).

Fish sampled in Wonder Lake and McLeod Lake had mercury concentration levels that surpassed the contaminant health thresholds for fish-eating birds, and Wonder Lake fish also exceeded the contaminant threshold for fish-eating mammals (Figure 85; Landers et al. 2008). Concentrations of lead and cadmium in fish sampled from Wonder Lake were the third highest among the lakes in WACAP parks (Figure 86; Landers et al. 2008). All fish sampled in Wonder and McLeod Lakes in 2004-2005 appeared reproductively normal (Landers et al. 2008).

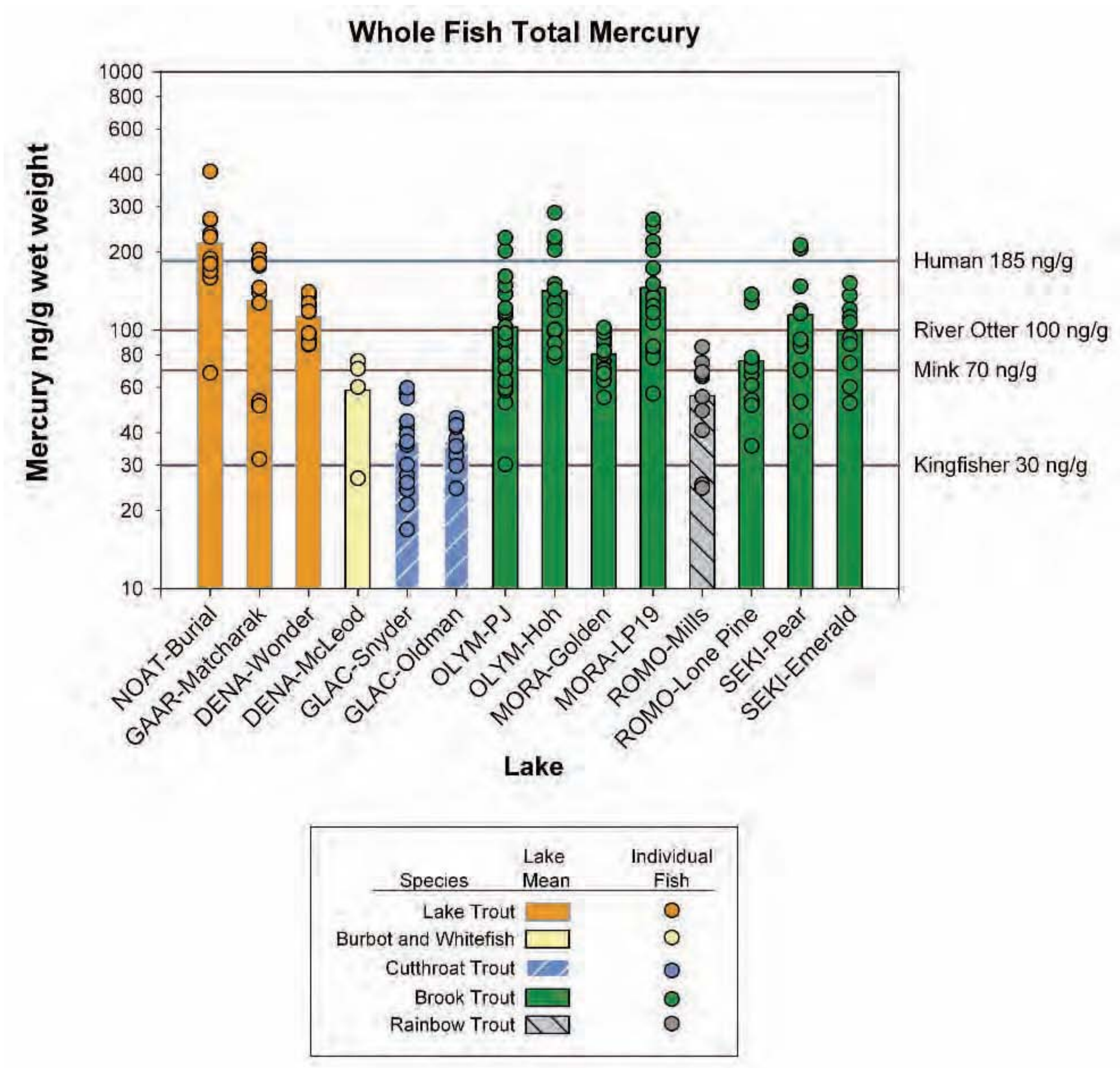


Figure 85. Fish whole-body lake mean (bars) and individual fish (symbols) total mercury and contaminant health thresholds for different organisms. Data are plotted on a log10 scale with the y-axis starting at 10 ng/g (Landers et al. 2008).

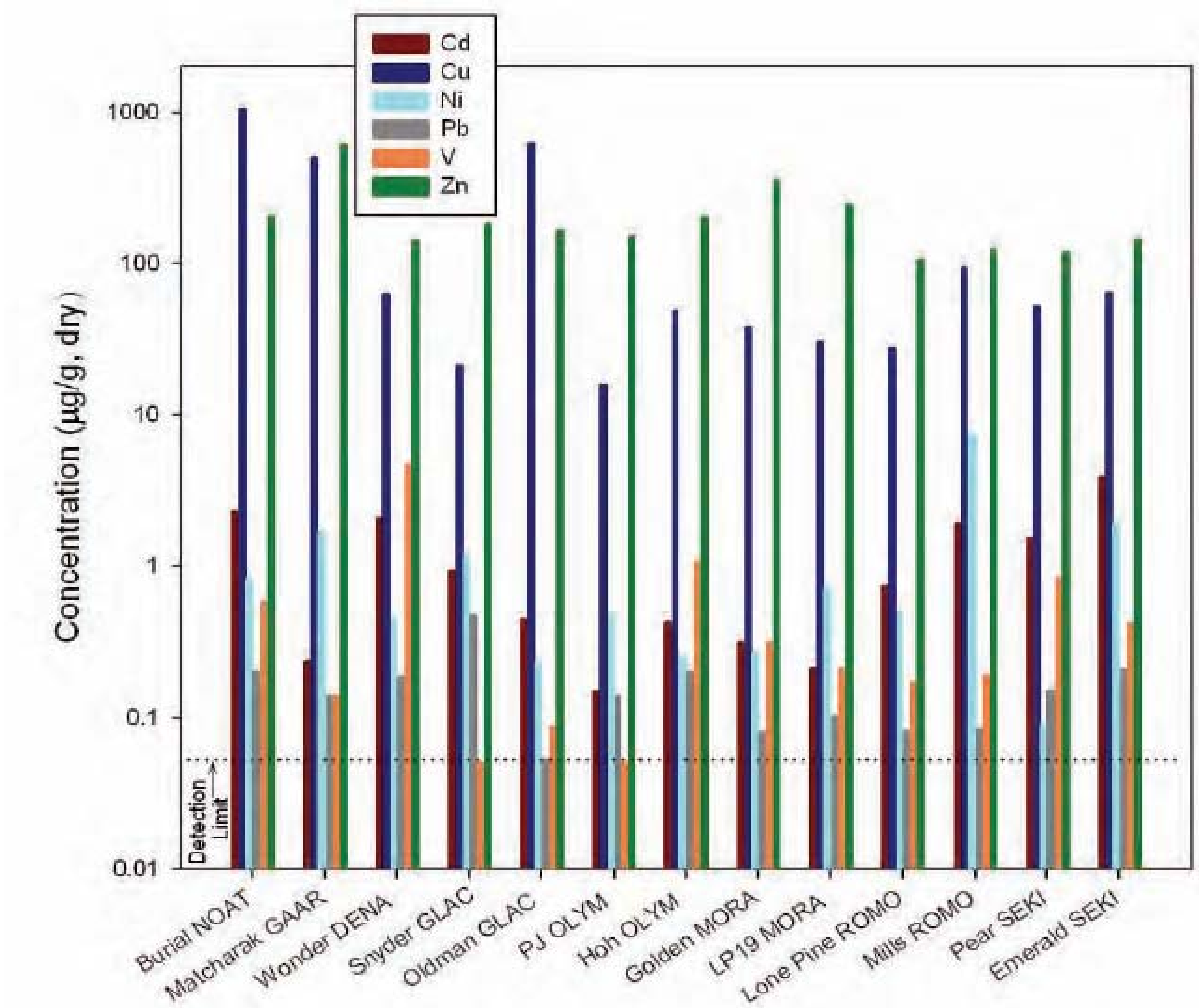


Figure 86. Distribution of trace metals in fish livers from western national park lakes. Due to small sample size, no fish from McLeod Lake in DENA were sampled for metals (Landers et al. 2008).

Threats and Stressor Factors

Ecosystem contaminants arise from human activities such as fossil fuel combustion, agriculture, and smelting, as well as natural processes such as forest fires, volcanic eruptions and rock weathering (Landers et al. 2008). Contaminant levels will likely increase due to intercontinental transport of toxic airborne contaminants, global fractionation (change in pollutant composition with increasing latitude), increasing global development, increasing global population, and local development (shallow gas exploration, etc.) (DENA 2009). Emissions of mercury, one of the contaminants of highest concern, are predicted to increase on a global scale with increased human population and concomitant development of coal resources for energy production, especially in China (Landers et al. 2008).

Dieldrin, a banned insecticide and an SOC, is also likely to pose a serious ecological threat in the western parks (Landers et al. 2008). Although dieldrin has been banned in the United States since 1987 and in Canada since 1990, concentrations were high in fish at several of the WACAP parks including Denali (Landers et al. 2008). While dieldrin is known to be somewhat persistent in the environment, researchers are unsure why dieldrin levels remain high in some locations decades after being banned (Landers et al. 2008).

Data Needs/Gaps

The data collected by Landers et al. (2008) only covers Wonder and McLeod Lakes and their small watersheds. More information is needed regarding contaminants in the rest of the park and preserve at a variety of elevations and locations to have a better understanding of the overall condition.

The WACAP report suggests greater study of contaminants at elevational gradients in Denali, due to high contaminant levels found in a Kahiltna snow sample at a high elevation (Landers et al. 2008). The high contaminant levels combined with increased precipitation at higher elevations suggests the possibility of higher contaminant loading and greater ecological effects at high elevations in Denali (Landers et al. 2008).

The shallow lakes monitoring program described by Larsen (2004, 2006) could provide an opportunity to collect additional data on contaminants in Denali, although the program is currently focused on more common nutrient and chemical parameters than the WACAP study contaminants.

Overall Condition

An overall condition statement cannot be made for the entire park and preserve regarding ecosystem contaminants based upon the small number of samples taken in two small geographic areas. The condition of the McLeod and Wonder Lake watersheds appears to be generally good, although some contaminant levels in fish were of concern.

Level of Confidence

Landers et al. (2008) included just two lakes and their watersheds within Denali, making it difficult to assess the overall condition of ecosystem contaminants park-wide. Landers et al. (2008) emphasizes that because contamination levels often fluctuate with elevation, individual samples are not necessarily representative of conditions in the surrounding area.

Sources of Expertise

The primary source of data for this component is the WACAP Report (Landers et al. 2008).

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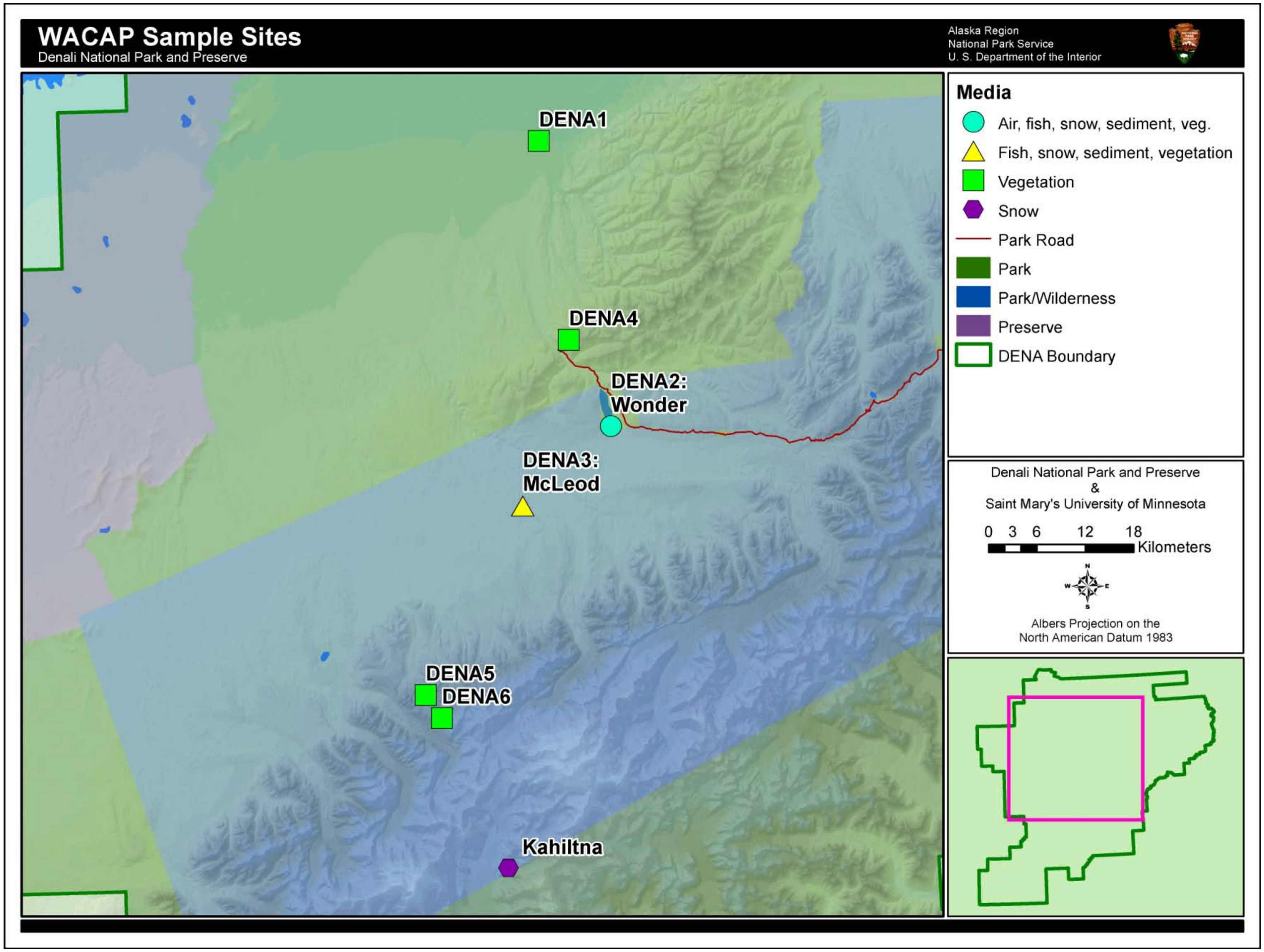
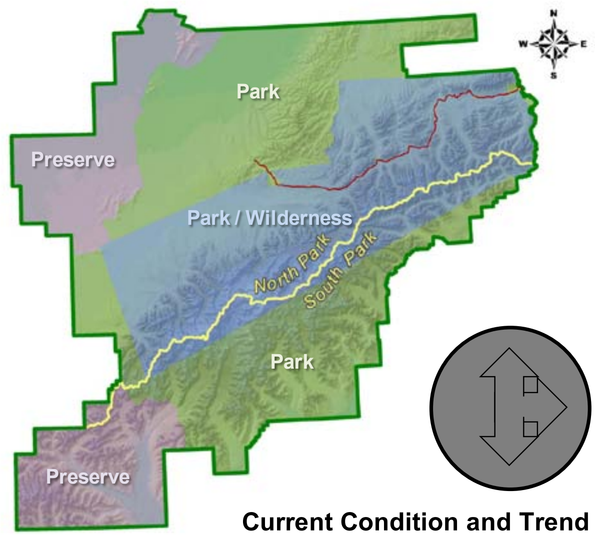


Plate 36. Sites sampled for anthropogenic contaminants in Landers et al. (2008).

4.15 Water Quality*



Current Condition and Trend

* Water quality is included in this NRCA in recognition of its ecological importance within Denali. While there is not enough data available for a full condition assessment of water quality within the park and preserve at this time, it is expected to be a key component in future NRCAs.

Description

Water is one of the most important components of the Denali ecosystem. Its availability and quality are “critical determinants” of the park and preserve’s overall natural resource condition (DENA 2010a). Poor water quality can cause ecological system deterioration and human health hazards, affecting the aesthetic and recreational value of an area (Deschu and Kavanagh 1986). Denali’s surface and subsurface waters are generally considered to be “very high quality, with the exception of some localized impact areas” (Mangi Environmental Group 2005). There are three major factors that influence the water quality of streams and rivers within the park and preserve: water source (glacial or non-glacial), underlying geology, and mining history (Mangi Environmental Group 2005).

One of the areas in Denali where water quality has been a serious concern is in the Kantishna Hills. Mining was extensive there from the early 1900s until 1985. The Kantishna Hills were formed by rapid uplift during the late Quaternary Period (Deschu 1985). It is a highly mineralized area where quartzite, marble, schist, and metavolcanic rocks are common. Permafrost is present at shallow depths, resulting in the slow weathering of underlying materials and limited permeability. Soils in the Kantishna Hills are therefore thin with little organic matter (Deschu 1985). Streams in the area originate on scree and tundra hillsides and are fed by precipitation and groundwater. This means they run clear year-round when undisturbed, unlike the glacier-fed streams in much of the park and preserve, making them excellent salmon spawning and rearing habitat (Deschu 1985, Meyer and Kavanagh 1983).

Gold was discovered near the present-day town of Kantishna in 1904, leading to a “stampede” of miners in 1905 (Mangi Environmental Group 2005). Placer mining for gold and lode mining for other minerals occurred sporadically over the years, with a peak in activity in the early 1980s when up to 12 placer mines involving around 100 miners were in operation (Deschu 1985). The Kantishna Hills lie outside the original Mount McKinley Park boundary but became part of the new Denali National Park and Preserve with the passage of ANILCA in 1980 (DENA 2010b). Studies of the Kantishna area’s water resources and mining impacts began at this point, with initial results leading to a 1985 injunction on mining activity until NPS could complete an Environmental Impact Statement (EIS) on the cumulative effects of mining in Denali (DENA 2010b). As a result of the EIS, the NPS began acquiring mining claims in the Kantishna area in 1990 and required environmental assessments for any mining proposals they received (DENA 2010b). Since 1990, the NPS has received 19 mining proposals, only one of which was approved. However an actual permit for mining has not been issued to the operation "due to lack of a reclamation costs security deposit" (Mangi Environmental Group 2005). As of 2005, Denali had purchased nearly 40 mining claims and another 20-30 claims had been abandoned or declared null and void (Mangi Environmental Group 2005).

Water quality has been studied in other parts of Denali (NPS 1995, Edwards and Tranel 1998, Brabets and Whitman 2002, Simmons 2009 and 2010), but little analysis has been done to determine the overall condition or trends in water quality within the park and preserve. Rather than completing a full condition assessment for water quality, Denali National Park and Preserve has chosen to focus on the Kantishna Hills area at this time. A summary of research conducted in the early 1980s with some comparisons to recent data as well as descriptions of many Kantishna area streams can be found in Appendix B of this document.

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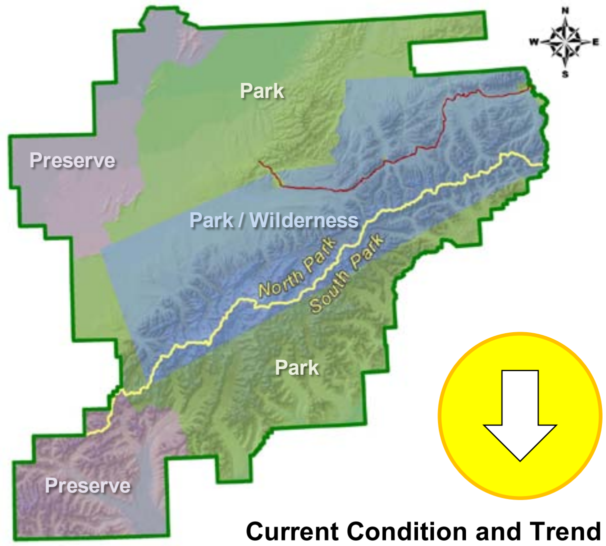
4.16 Glaciers

Description



Glaciers are major geological features in Denali, making up 17% or approximately one million acres of the landscape (Adema 2007). The glaciers of Denali National Park and Preserve are large and complex (Adema and Bucki 2003). Glaciers on the south slope of the Alaska Range are in a transitional maritime climate with moderate temperatures and more snow while those on the north slope are in a continental climate with a wider range of temperatures and less snow (Adema and Bucki 2003). Backcountry glaciers are popular areas for mountaineering, skiing and camping, and provide access to scenic views including the summit of Mount McKinley, the Great Gorge, and the North Face of Mt. Huntington (Valentine 2000; Photo 24). Many of Denali's glaciers are described in "Glaciers of Alaska", a USGS professional paper by Bruce Molnia (Molnia 2008).

Photo 24. A 1966 oblique aerial photo of the Great Gorge and Ruth Glacier with Mt. McKinley in the background (Molnia 2008).

Glaciers are highly sensitive to changes in temperature and precipitation (Adema et al. 2007) and are, therefore, a valuable measure of the rate and impact of climate change (Adema 2007). Changes to Denali's glaciers in turn impact the physical landscape, the local hydrologic regime, and the diversity and spatial distribution of biological communities within the park (Adema et al.

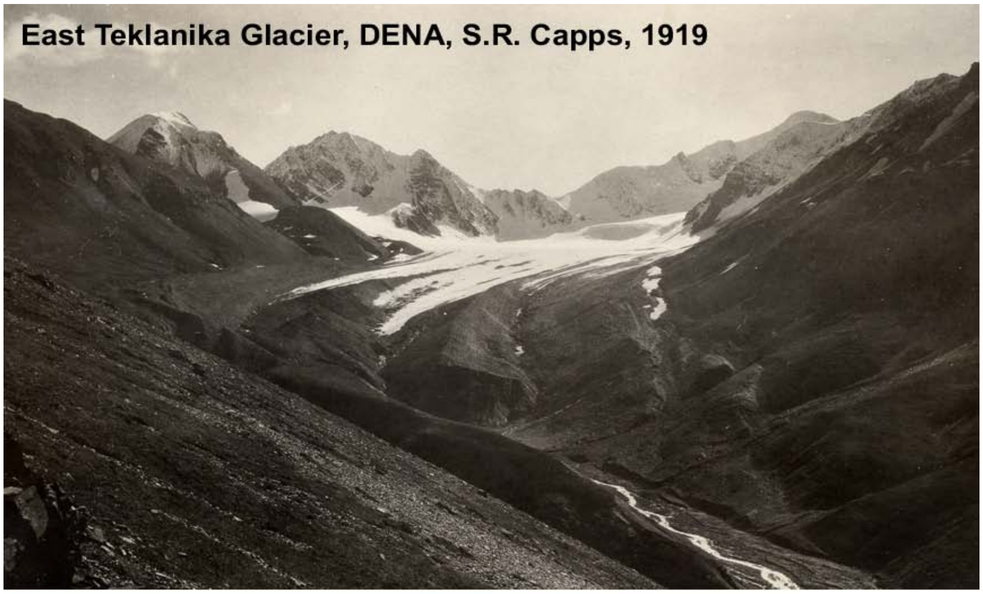
2007). Changes in glacier volume and discharge will particularly affect stream dynamics and sedimentation characteristics (Adema et al. 2007). Research suggests that melting of glaciers also contributes to a global rise in sea levels (Burrows and Adema 2010a, Arendt et al. 2002).

Measures
Total glacier-covered area
Extent and volume of selected glaciers

Reference Conditions/Values
DENA (2009) lists the reference condition for glaciers as "change is driven by non-anthropogenic processes".

Data and Methods
The glacier monitoring program at Denali began in 1991 as part of the NPS Long Term Ecological Monitoring (LTEM) program (Adema 2007). The current goals of the program are to monitor the extent of all glaciers in the park every 10 years through remote sensing, to monitor the extent of selected glaciers through terminus surveys approximately every 10 years as well as through comparative photography, and to gather data on two permanent index sites on a yearly basis (Burrows and Adema 2010a, Adema 2007).

Comparative photography
Through cooperation with the USGS and the University of Alaska-Fairbanks, Denali has been acquiring historical photographs of selected glaciers in the park as far back as the early 1900s (Adema et al. 2007). By comparing these photos with recent photos of the same locations, scientists can estimate changes in glacier volume and extent (Adema 2007; Photo 25). In 2010, high resolution digital panoramic photographs were taken at East Fork Toklat Glacier, West Fork Cantwell Glacier, Muldrow Glacier, Traleika Glacier, and Kahiltna Glacier (Burrows and Adema 2010a). These photos can be viewed on-line at http://www.gigapan.org/profiles/27054/.



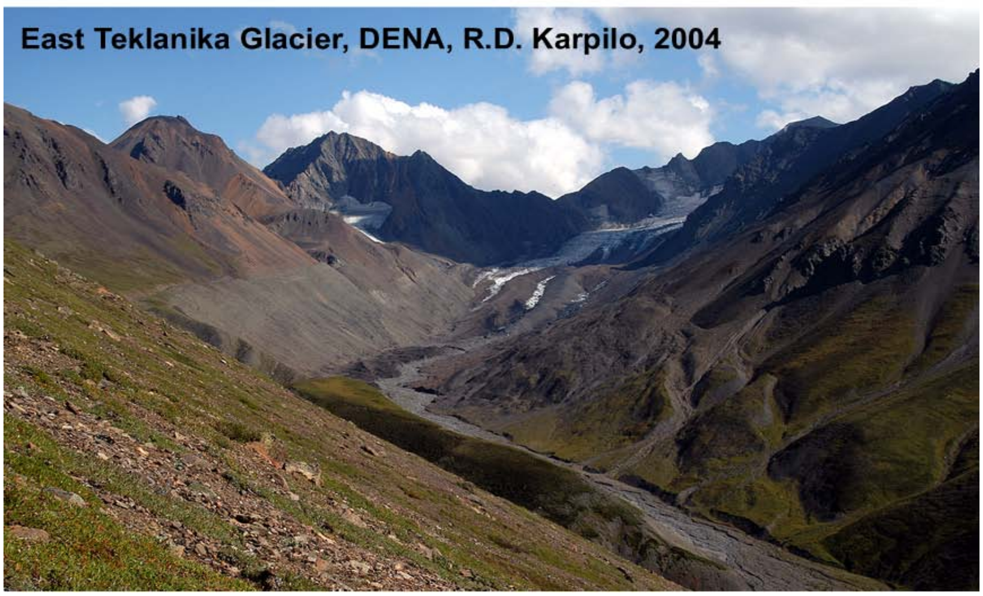


Photo 25. Photos of the East Teklanika Glacier in the northeastern part of Denali from 1919 and 2004 clearly show its retreat over time. This glacier has thinned by approximately 300 m (Adema et al. 2007).

<u>Index sites</u>

In order to keep the long-term glacier monitoring program simple and sustainable, researchers chose to establish two index sites that would be monitored twice each year. An index site is a single fixed point on a glacier near its equilibrium line where a stake or pole, nine to twelve meters long and five centimeters in diameter, is placed in the ice (Adema 2007). Glaciers selected for index sites generally have simple geometry, a large elevational range, lie in a distinct climatic region, and are representative of other glaciers in the area (Adema 2007). At Denali, researchers also looked for glaciers that were not subject to surges (sudden and dramatic periods of acceleration in glacier movement). For these reasons, the Kahiltna Glacier (Figure 87) was chosen to represent the climatic zone south of the Alaska Range and the Traleika Glacier (Figure

88), a tributary of the larger Muldrow Glacier, was selected north of the range (Mayo 2001). Current physical characteristics of these glaciers are included in Table 43.

These index sites were established in 1991 and have been visited nearly every year since to measure mass balance (the difference between accumulation and loss of ice), volume change, and rate of ice flow (Adema 2007). Specific measurements taken at index sites include winter and summer balance (from which net balance can be calculated), surface elevation, and surface velocity (Burrows and Adema 2010a). Procedures used for data collection at index sites and later analysis are described in detail in Mayo 2001 and Burrows and Adema 2010a.

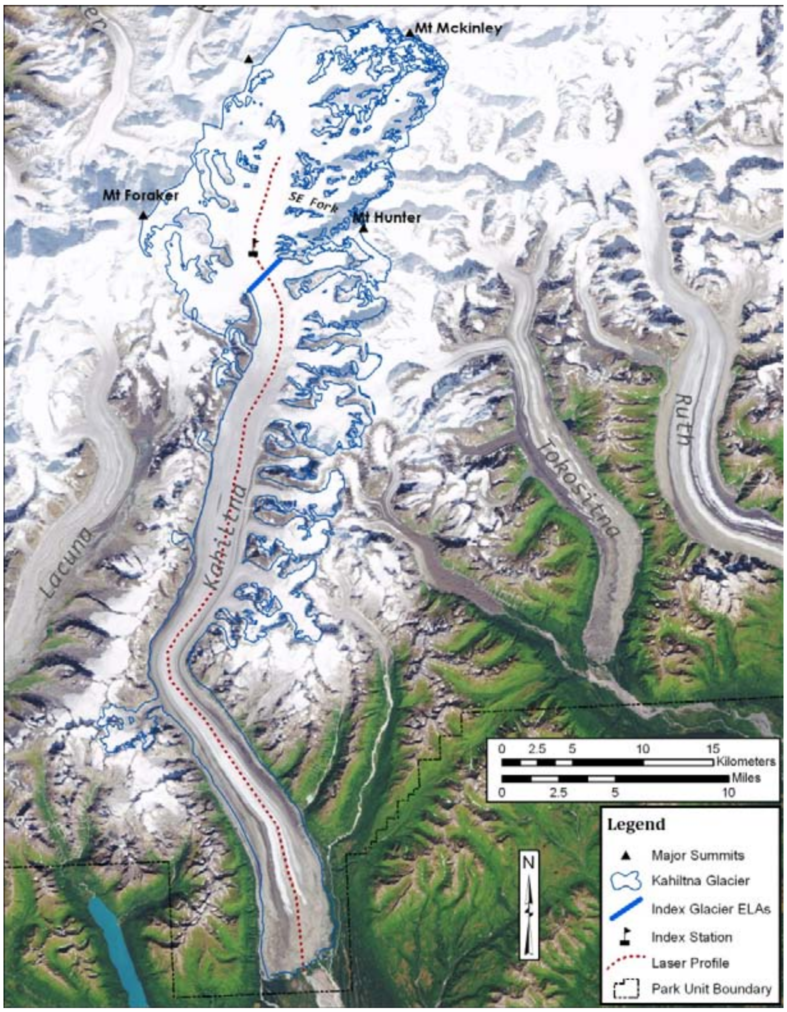


Figure 87. A 2000 Landsat image of the Kahiltna Glacier and its suroundings, showing its extent, equilibrium line altitude (ELA) and the index site location (Burrows and Adema 2010a).

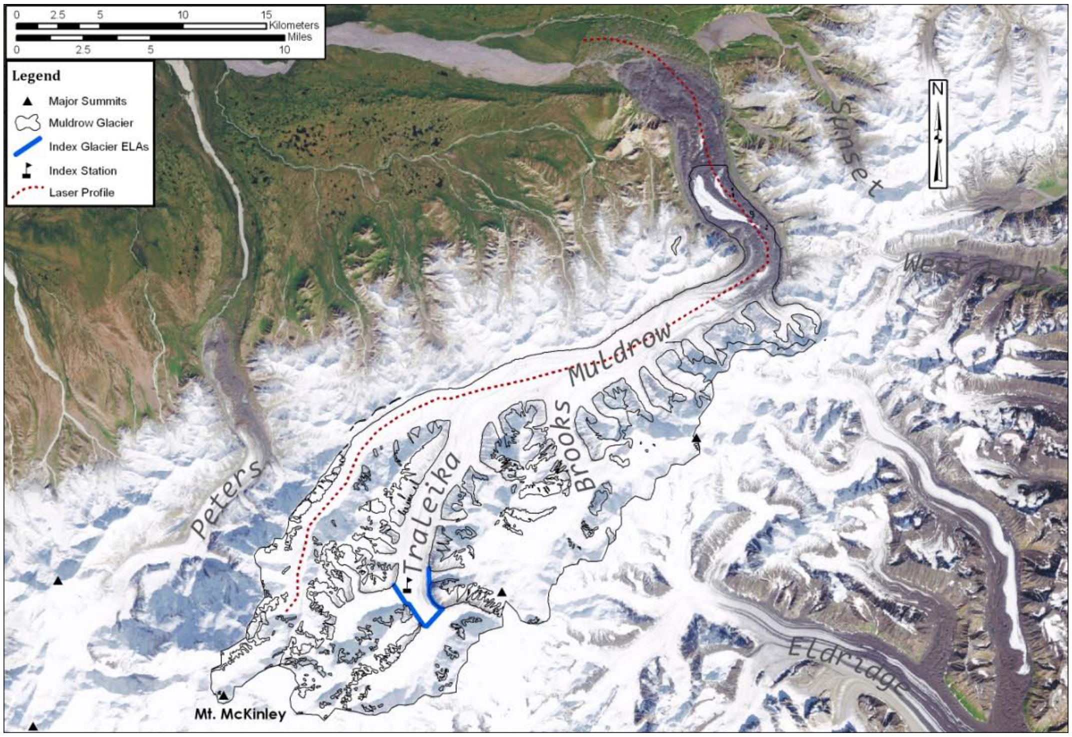


Figure 88. A 2000 Landsat image of the Muldrow Glacier and its suroundings, including the Traleika tributary and its index site location (Burrows and Adema 2010a).

Table 43. Physical characteristics of the Kahiltna and Traleika Glaciers as of 2010 (Burrows and Adema 2010b).

Glacier Name	Drainage Basin	Area	Length	Altitude Range
Kahiltna Glacier	Susitna River	519 km^2	76 km	6,190-300 m
Traleika Glacier	McKinley River	340 km^2 (entire Muldrow system)	19.3 km	6,194-1,730 m

Other NPS monitoring

In 2010, a GPS survey was conducted on the East Fork Toklat glacier and the results were compared with 1954 USGS maps (Burrows and Adema 2010a). Researchers found substantial thinning below 1860 m elevation along the approximate centerline of the glacier, as well as over 120 m of thinning in its terminus area (Burrows and Adema 2010a).

Terminus surveys are conducted on the following glaciers: Kahiltna, Muldrow, Polychrome, Cantwell, E. Fork Toklat, Middle Fork Toklat, Straightaway, Foraker, Tokositna, Tintina, and Cul-de-sac (Adema and Bucki 2003). In 2002, terminus surveys were conducted on the Cantwell and Middle Fork Toklat Glaciers. The results were compared to 1950s USGS maps and similar terminus surveys in the early 1990s to determine change in glacier extent. Researchers found that the Cantwell and Middle Fork Toklat Glaciers were retreating at approximately 10 m/yr and 24 m/yr respectively (Figure 89; Hults 2002a, b). Volume changes were also calculated for the Middle Fork Toklat and showed that the glacier's volume decreased an estimated $3.30x10^8$ m^3 between 1954 and 2002. The rate of volume change was estimated at $-6.88x10^6$ m^3 per year (Hults 2002b).

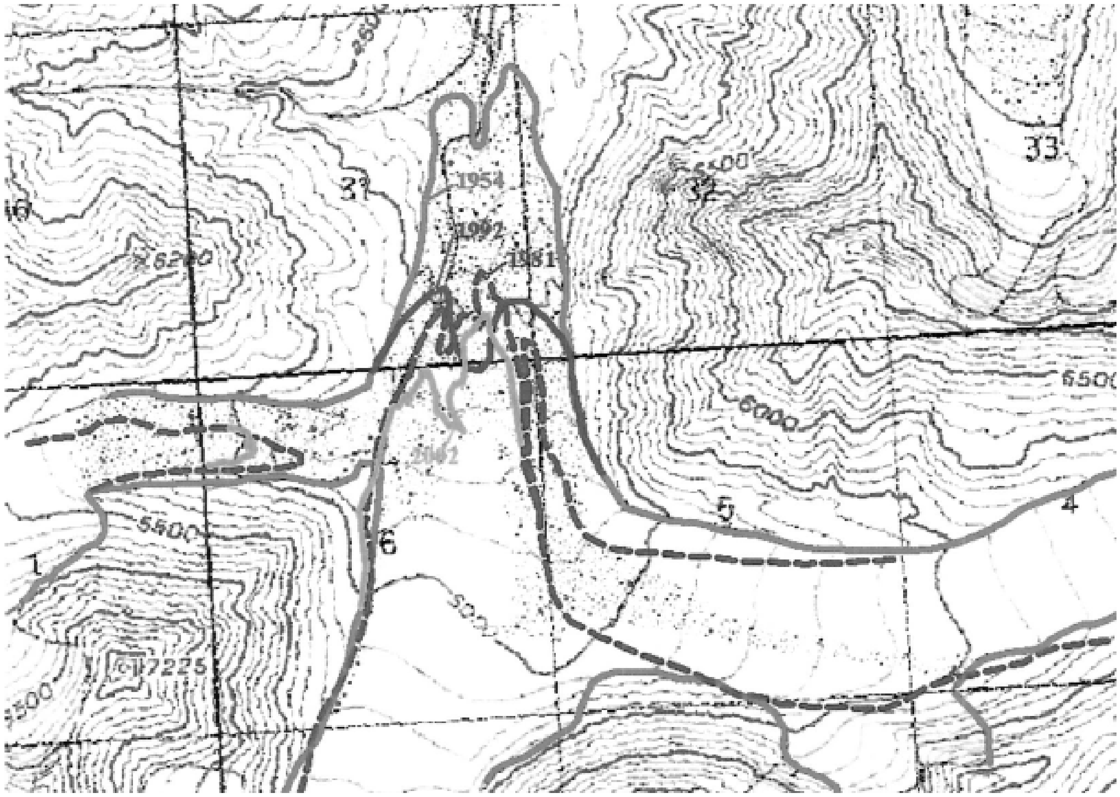


Figure 89. Location of the Middle Fork Toklat Glacier terminus over time (Hults 2002b).

Researchers are also interested in monitoring the behavior of surging glaciers in Denali. During the Tokositna Glacier's surge in 2001, maximum ice velocities of over two meters per day were measured (Adema 2007). One of the most visible surge-type glaciers is the Muldrow Glacier, which can be seen from the Eielson Visitor Center. It last surged in 1956 and scientists believe it could surge again in the near future (Adema 2007). In preparation for the research opportunity this event would present, scientists have installed movement targets and a discharge gauge, created photopoints, and created a digital elevation model of the glacier's surface through remote sensing (Adema 2007). Other sites monitored regularly for surge behavior are the Peters, Lacuna, and Slippery Glaciers (Adema and Bucki 2003).

Additional Research

Arendt et al. (2002) analyzed changes in glacier volume across southern Alaska and included three Denali glaciers in their study: Kahiltna, Polychrome, and Toklat. By comparing airborne laser altimetry estimates from 1994 to aerial photos from the 1950s, they found that all three of these glaciers, like the majority of glaciers in southern Alaska, had thinned over time (Arendt et al. 2002; Table 44). The terminus of the Toklat Glacier was also estimated to be retreating at an average rate of 13 m/yr (Arendt et al. 2002).

Table 44. Changes in volume and thickness of three Denali glaciers over time (from Arendt et al. 2002).

	Kahiltna	Polychrome	Toklat
Date of historic aerial photo	1951	1957	1950
Volume change (10^6 m^3/year, water equivalent)	-212.6 ± 42.7	-0.4 ± 0.3	-14.7 ± 0.7
Thickness change (m/yr, ice equivalent)	-0.46 ± 0.11	-0.23 ± 0.17	-1.82 ± 0.09

Current Condition and Trend

Total glacier-covered area

Researchers have recently compared digitized satellite images of glaciers in Denali between 2003 and 2010 to USGS aerial photos from the early 1950s. The total glacier-covered area within Denali in 1952 was an estimated 4,126 km^2. From 2003-2010, total glacier-covered area was estimated at 3,779 km^2, a loss of 347 km^2 in approximately 55 years (DENA, Adema, pers. comm. 2011). Most glaciers in the park and preserve lost area during this period (Figure 90), although the trend is complicated by the unique dynamics, geometry, and surface cover of each individual glacier. For example, “nearly all of the glaciers on the north side of the mountain system are surge-type, periodically transporting large amounts of accumulated mass from an upper reservoir area to the lower terminus area” (DENA, Adema, pers. comm. 2011). During the studied time period, both the Muldrow and Peters Glaciers experienced surge events, causing terminus advance (Figure 90; DENA, Adema, pers. comm. 2011).

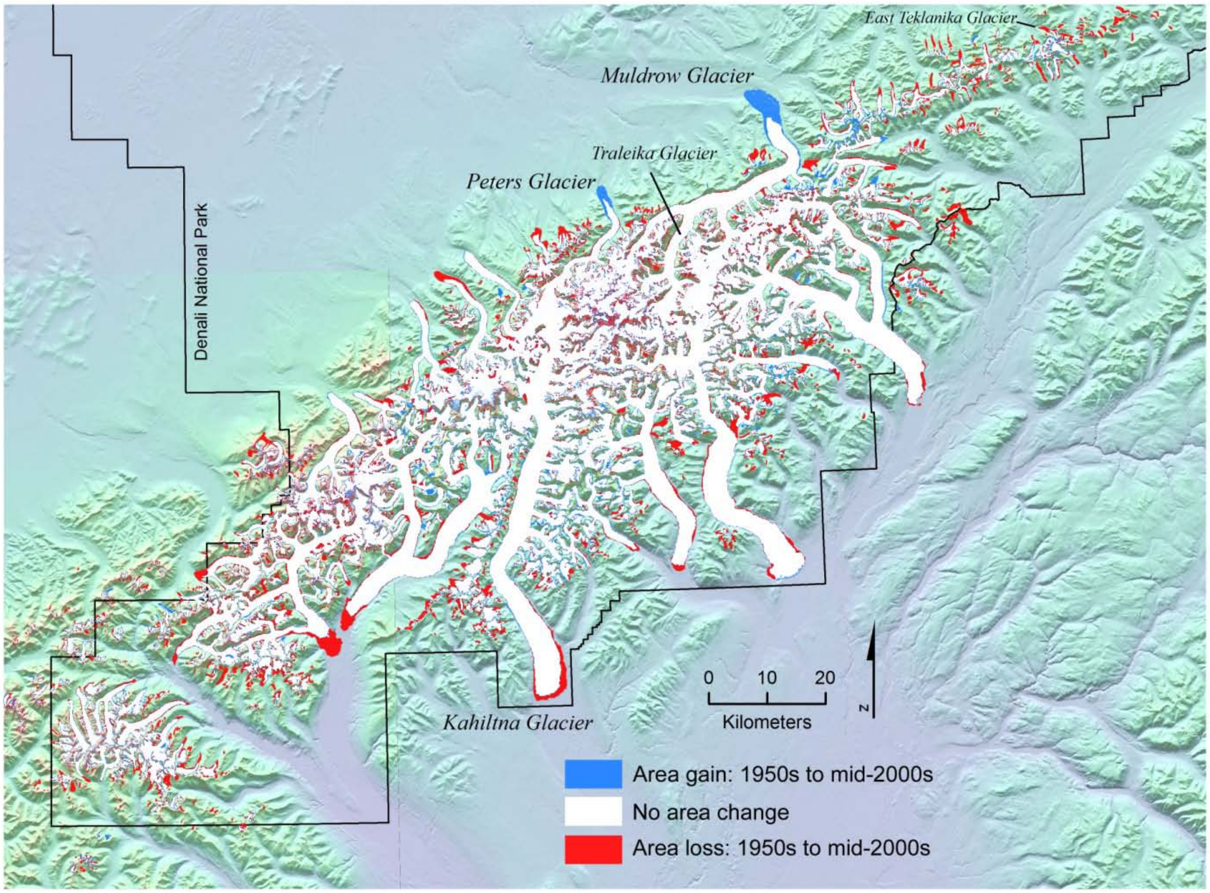


Figure 90. Glacier extent within Denali National Park and Preserve (University of Alaska-Fairbanks, Arendt and Herreid, pers. comm. 2011).

Extent and volume of selected glaciers

In 2010, both the Kahiltna and Traleika index sites showed a negative net balance, indicating that the glacier lost mass during the year (Table 45; Burrows and Adema 2010a). The equilibrium line altitudes at both sites were also above the long-term averages (1982 m for Kahiltna and 2216 m for Traleika, Burrows and Adema 2010a). Net balance measurements at the long-term ELA from 1991 to 2010 are shown in Figure 91.

Table 45. 2010 index site measurements. All balance measurements are in meters water equivalent (m.w.e.) (Burrows and Adema 2010a).

Glacier Name	Winter balance	Summer balance	Net balance	Equilibrium Line Altitude (m)
Kahiltna	0.63	-1.03	-0.41	2104
Traleika	0.53	-2.04	-1.51	2427

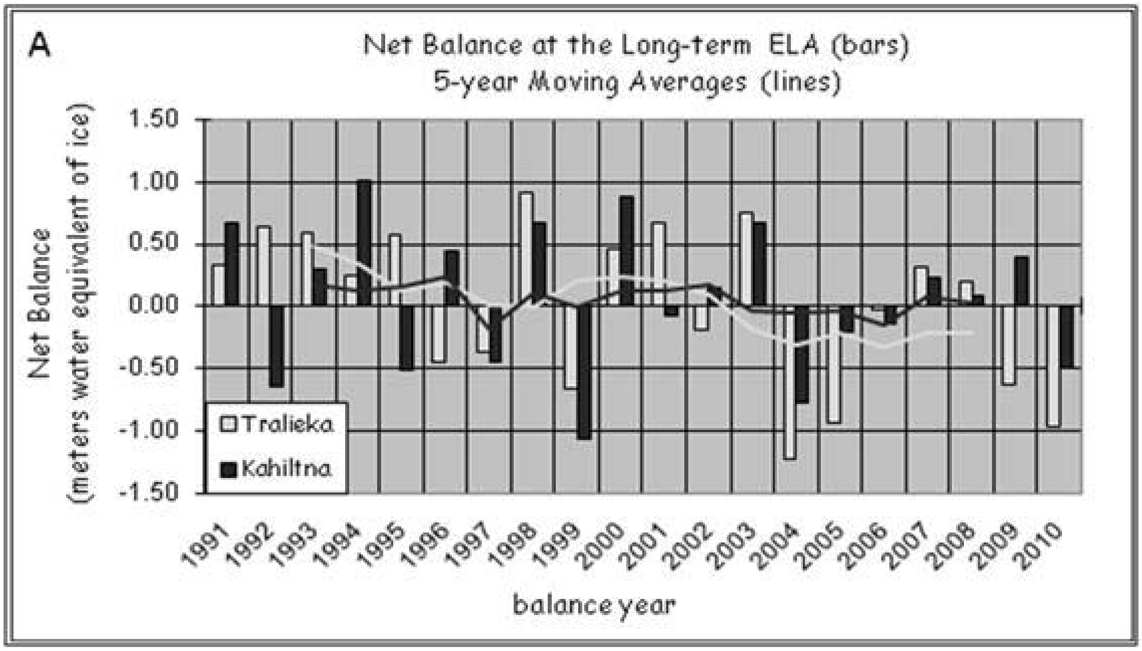


Figure 91. Net balance at the ELA of Denali's index glaciers over time (DENA, Burrows, pers. comm. 2011).

Since monitoring began, the Kahiltna index site has shown an overall slightly positive mass balance (Adema 2007, Figure 92). However, it has lost an estimated 3 m of thickness since 1991 (Adema 2007). The Traleika glacier has shown an overall negative mass balance since 1991, but has thickened about 25 m during this time (Adema 2007, Figure 92). Researchers are unsure why Traleika has thickened despite a negative mass balance and increased flow rates, but theorize that it may be "storing" ice in advance of the anticipated Muldrow Glacier surge (Adema 2007).

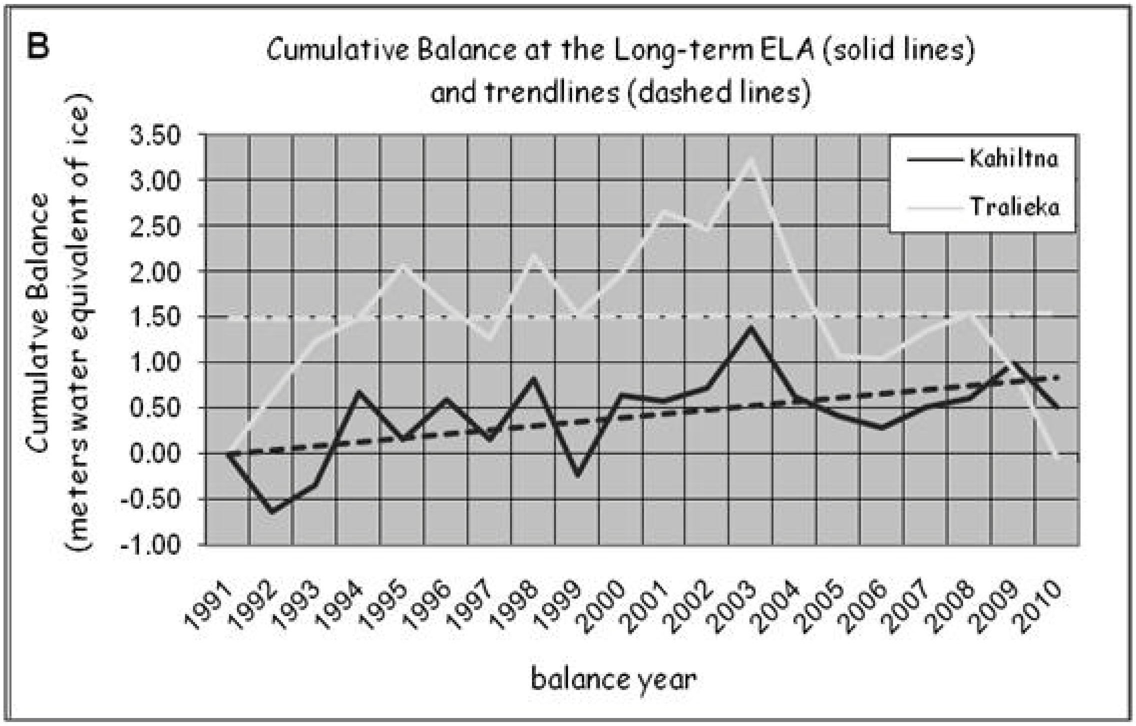


Figure 92. Cumulative mass balance at the ELA of Denali's index glaciers over time (DENA, Burrows, pers. comm. 2011).

<u>Threats and Stressor Factors</u>

The most significant threat to Denali's glaciers is climate change (DENA 2009). Temperatures at the park are projected to increase by an average of 1° F per decade, resulting in a transition from average annual temperatures below freezing to near or above the freezing point (SNAP et al. 2009). Precipitation is expected to increase and, due to the warming temperatures, more may fall as rain than snow.

<u>Data Needs/Gaps</u>

There has not been a formal park-wide glacier inventory in Denali. This would help scientists better understand and analyze any future changes (DENA 2009). More research is also needed into how climate change will affect glaciers as well as how glacier changes will affect other park ecosystem components (Giffen et al. 2010). Many of these needs will be addressed by a new cooperative project between the NPS and the University of Alaska-Fairbanks beginning in 2011. University researchers will be mapping glacier extent in all Alaska national parks for two time periods (1950s and 2000s) and analyzing changes in glacier extent (Giffen at al. 2010). They will also be estimating glacier volume and mass balance change for all NPS glaciers with existing repeat glacier elevation profiles. Finally, researchers will produce a detailed timeline of change in extent, volume, and mass balance for several individual glaciers with extensive study histories (Giffen et al. 2010). In Denali these focus glaciers will be Kahiltna, Toklat, and Muldrow/Traleika.

<u>Overall Condition</u>

According to DENA (2009), the current condition of glaciers park-wide is unknown. However, research from index glaciers suggests that their condition is moderate but declining. No named glaciers in Denali are advancing and most appear to be actively retreating, some at a rapid pace (Adema 2007). The climate changes anticipated in Alaska in the coming years pose a serious threat to the health of glaciers state wide.

Level of Confidence

While the overall current condition of glaciers park-wide in Denali is somewhat uncertain due to lack of data, the declining trend is clear.

Sources of Expertise

The primary sources of expertise for this assessment were Adema 2007 and Burrows and Adema 2010a.

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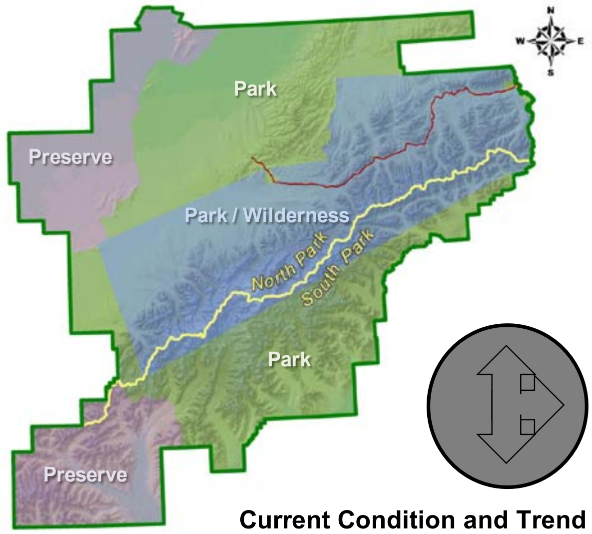
4.17 Permafrost *



* Permafrost is included in this NRCA in recognition of its ecological importance within Denali. At this time there is not enough data available for a full condition assessment of permafrost within the park and preserve. This assessment will focus instead on the existence and usefulness of permafrost-related data.

Description

Permafrost is defined as “soil or rock that remains below 0ºC for at least two consecutive years” (DENA 2006). The overlying ground surface layer that freezes and thaws each year is called the “active layer”. The presence of permafrost affects, either directly or indirectly, many other ecosystem components including hydrology, vegetation patterns, and wildlife communities (DENA 2006). Within Denali, permafrost is common and widespread north of the Alaska Range but is rare in the southern portions of the park and preserve. The distribution of permafrost is impacted not only by climate but also by soil type, snow cover, vegetative cover, and fire history (DENA 2006). A soil’s ability to retain moisture and form permafrost is affected by soil grain size and organic matter content. Permafrost is extensive in loamy soils with silt and organic matter but is rarely seen in gravelly soils (DENA 2006). Snow cover insulates soils from the cold winter temperatures often necessary for permafrost development while vegetative cover protects permafrost from warm summer temperatures (Osterkamp 2007a). Wildland fire disturbs this protective ground layer leading to warmer soil temperatures and localized thawing of permafrost (DENA 2006).

When permafrost thaws, the ground often sinks by several meters because the ice-rich soils become a “mud slurry” that can no longer support the weight of the overlying soil and vegetation (Photo 26; DENA 2006). This process, called thermokarsting, can dramatically affect the ground surface, hydrologic systems, and plant distribution and productivity (DENA 2006).

Photo 26. The Wigand Creek Thermokarst in the Toklat Basin from the ground (left, photo by C. Hults, in Yocum et al. 2007) and from the air (right, NPS photo, in DENA 2006).

Measures
Existence and usefulness of data

Reference Conditions/Values
The NRCS soil survey completed in 2004 (Clark and Duffy 2006) gathered data on the extent of permafrost throughout Denali National Park and Preserve which can be used as a baseline for future analyses.

Data and Methods
The NRCS soil survey (Clark and Duffy 2006) provided the most extensive information available regarding permafrost in Denali. Soil mapping allowed scientists to estimate that 930,780 hecatres of the park and preserve contain soils with permafrost (Clark 2007). Permafrost is generally categorized as continuous (permafrost in >80% of soils), discontinuous (20-80% of soils), or sporadic (5-20% of soils). In Denali, continuous permafrost covers approximately 21% of the park and preserve, discontinuous permafrost 22%, and sporadic permafrost 14% (Plate 37; DENA 2006).

Soil survey data also allowed researchers to determine where permafrost is most sensitive to thawing or other disturbance. It is estimated that around 118,170 hectares or 4% of the park contains highly sensitive permafrost. Areas with moderate and low permafrost sensitivity comprise approximately 445,150 hectares (18%) and 391,735 hectares (16%) of the park respectively (Figure 93; Clark 2007).

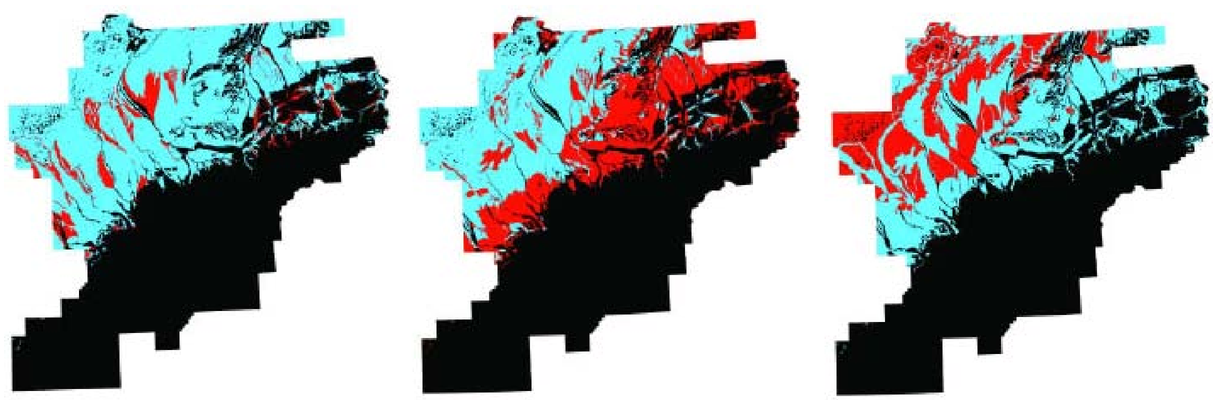


Figure 93. Permafrost with high sensitivity (left), moderate sensitivity (middle), and low sensitivity (right) are shown in red. Blue indicates map units with over 15% permafrost soils (from Clark 2007).

During 2003-2004, Yocum et al. (2007) conducted a geological reconnaissance inventory of the Toklat Basin in the northeastern part of Denali, focusing on permafrost and associated features. Their observations at 75 sites included soil pit analysis, geomorphology descriptions, and depth to frozen ground measurements. Many permafrost-related features were found in the basin, particularly areas of thermokarst where frozen ground had thawed and collapsed. They also created a color contour map of depth to frozen ground in the Toklat Basin. This map and details on their inventory can be found in Yocum et al. 2007.

A long-term study of permafrost across the state of Alaska included a borehole site near Healy, east of Denali (Osterkamp 2005a). Data gathered from this borehole showed that permafrost in the area "has been thawing at the top since the late 1980s at about 10 cm/yr" (Osterkamp 2005a). When the hole was drilled in 1985, there was no apparent thermokarst terrain, but researchers report that thermokarst is now common in the landscape with a maximum thaw settlement of about 1.2 meters (Osterkamp 2005a). The temperatures at various depths within the borehole over time are shown in Figure 94.

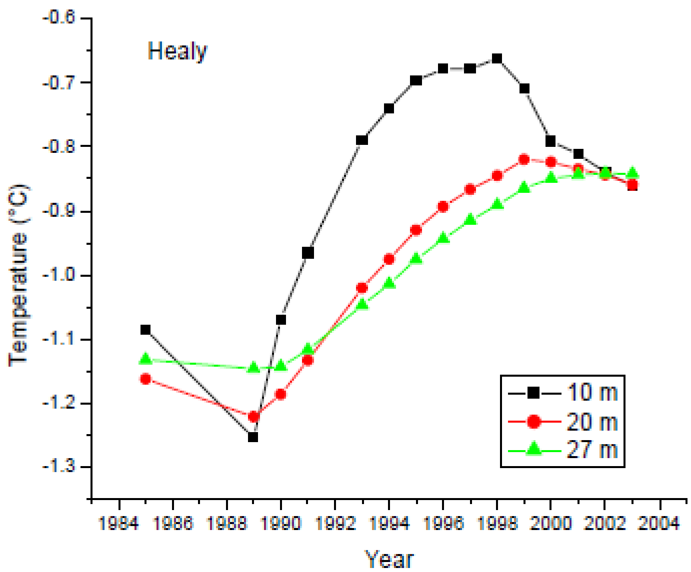
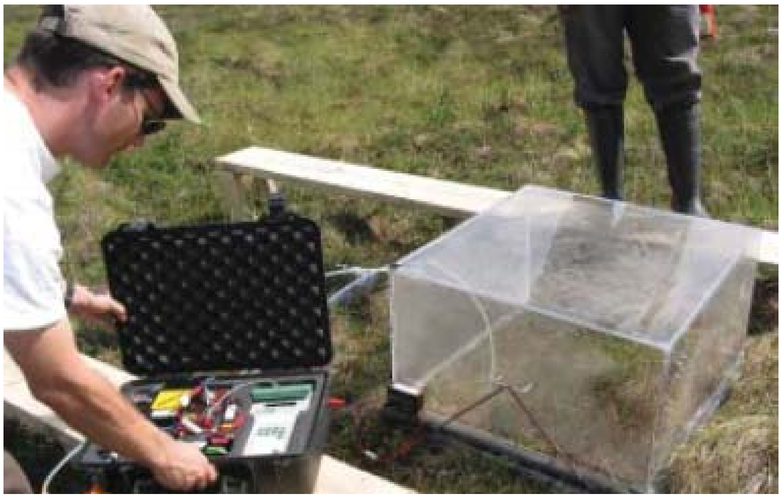


Figure 94. Temperature at various depths of the Healy borehole site, 1985-2003 (Osterkamp 2005b).

Dr. Ted Schuur from the University of Florida has been studying the relationship between climate change and permafrost thawing just northeast of Denali (DENA 2009). He has gathered data from representative sites on vegetation cover, vegetation height, soil moisture, depth to active layer, and CO_2 flux to monitor changes in ecosystem carbon balance at sites with varying levels of permafrost thawing (DENA 2009). While warming leads to increased plant growth which sequesters carbon from the atmosphere, the permafrost thaw from warming can stimulate microbial decomposition of soil organic matter, causing an increase in CO_2 emissions. Early results suggest that moderate permafrost thaw causes increased carbon sequestration while extensive permafrost thawing leads to a net release of carbon into the atmosphere (Figure 95; DENA 2009). Sampling methods and preliminary results for this study are discussed in Schuur and Vogel (2006).



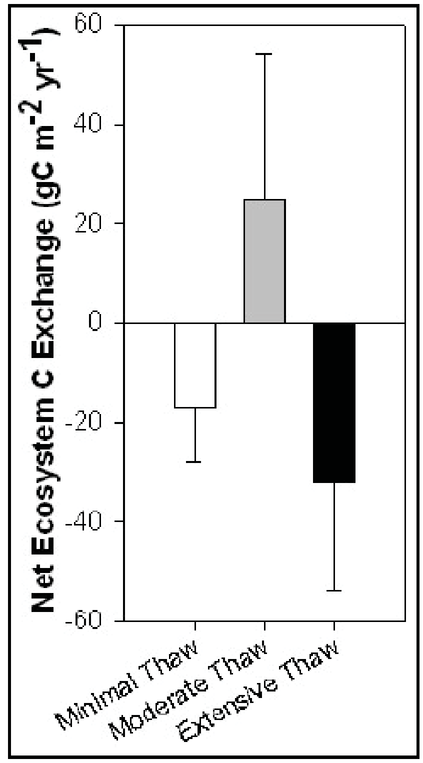


Figure 95. Dr. Ted Schuur measures CO_2 emissions from soil and plants using a portable chamber connected to an infra-red gas analyzer (left, photo by J. Vogel); net ecosystem carbon balance from three sites with varying levels of permafrost thaw, 2004-2006 (right). Positive values indicate a carbon sink and negative values show a carbon source (DENA 2009).

Dr. Kenji Yoshikawa has worked with several schools in Alaska to develop a coordinated permafrost monitoring program using frost tubes (Yoshikawa 2010). The frost tubes are used to measure the timing and depth of soil freezing. At least two of the participating schools are near Denali: Cantwell School in Cantwell and Tri-Valley School in Healy. The data has not been analyzed in relation to permafrost in Denali; however, this data could be a useful resource for better understanding permafrost extent near the park and preserve.

A portion of climate monitoring stations in Denali collect soil temperature data. Known locations include Stampede, Toklat, and Dunkle Hills (Plate 37). Ground surface temperatures are usually several degrees warmer than permafrost temperatures, but the two can be related using modeling techniques (Osterkamp 2005b). The soil temperature data has not been analyzed for temporal change at this time.

Current Condition and Trend

<u>Existence and usefulness of data</u>
The NRCS soil survey (Clark and Duffy 2006) provides excellent data on the extent of permafrost throughout Denali National Park and Preserve. However information on thermokarst and permafrost terrain features as well as ground temperatures and active layer depths is currently only available for the Toklat Basin (Yocum et al. 2007), a relatively small area of the park and preserve. Long-term data has been gathered from a single borehole just outside the park

and preserve (Osterkamp 2005a), but findings from this site may not be representative of conditions in the park as a whole.

Threats and Stressor Factors

The greatest threat to permafrost in Denali and across Alaska is climate change. Temperatures at the park are projected to increase by an average of 1° F per decade, resulting in a transition from average annual temperatures below freezing to near or above the freezing point (SNAP et al. 2009). This is likely to have a significant impact on permafrost at Denali since recent measurements at the borehole just outside the park and preserve boundary suggest that some of the region's permafrost may be within a degree of thawing (DENA 2006).

Changes in precipitation, particularly the timing and amount of snow, will also affect permafrost (Osterkamp 2007a). During the 1990s, mean air temperatures decreased slightly in the Healy area yet the temperature of permafrost 10 m deep at the nearby borehole continued to increase (Osterkamp 2007b). Annual snow depths were often above average during this same period, leading researchers to conclude that "snow cover effects were almost entirely responsible for warming and thawing permafrost at Healy" during that time (Osterkamp 2007b).

Wildfires cause soils to warm, both from the fire's initial heat and as a result of increased insolation. This is a natural process that temporarily reduces permafrost and increases the active layer depth, leading to an increase in ecosystem productivity (DENA 2006). However any increase in the frequency or intensity of fires may affect the ability of permafrost to recover from this disturbance.

Data Needs/Gaps

More information is needed on the condition of permafrost (soil temperatures, active layer depths, carbon balance) and thermokarst features throughout the park and preserve, as well as how any changes in permafrost are affecting other ecosystem components. Karle and Jorgenson (2004) recommended using remote sensing to monitor changes in the abundance and distribution of thermokarst features. Osterkamp (2005b) warns that permafrost thawing in boreal forest ecosystems "is not just a slight shift in the nature of the ecosystem but rather partial or total destruction of the ecosystem and its replacement by a new ecosystem." CAKN is currently finalizing a permafrost monitoring protocol that will address many of these data needs. Monitoring efforts will focus on three components: thermal state of permafrost, physical state of permafrost including thermokarst, and carbon pools and hydrologic carbon export from permafrost areas (Schuur et al. 2008). The first phase is scheduled for implementation during 2011, pending funding (DENA, Adema, pers. comm. 2011).

Overall condition

Data on permafrost extent within the park and preserve is good, but information on other permafrost measures is still limited to small areas of the park and preserve. There is not enough data available at this time to assess the current condition of permafrost itself.

Level of confidence

While confidence is high with respect to permafrost extent, the many variables and interpretations regarding the implications of climatic change for permafrost results in a low confidence level with respect to the overall status of permafrost.

Sources of expertise
The primary source of expertise for this document was DENA 2006, which relied heavily on data from Clark and Duffy 2006.

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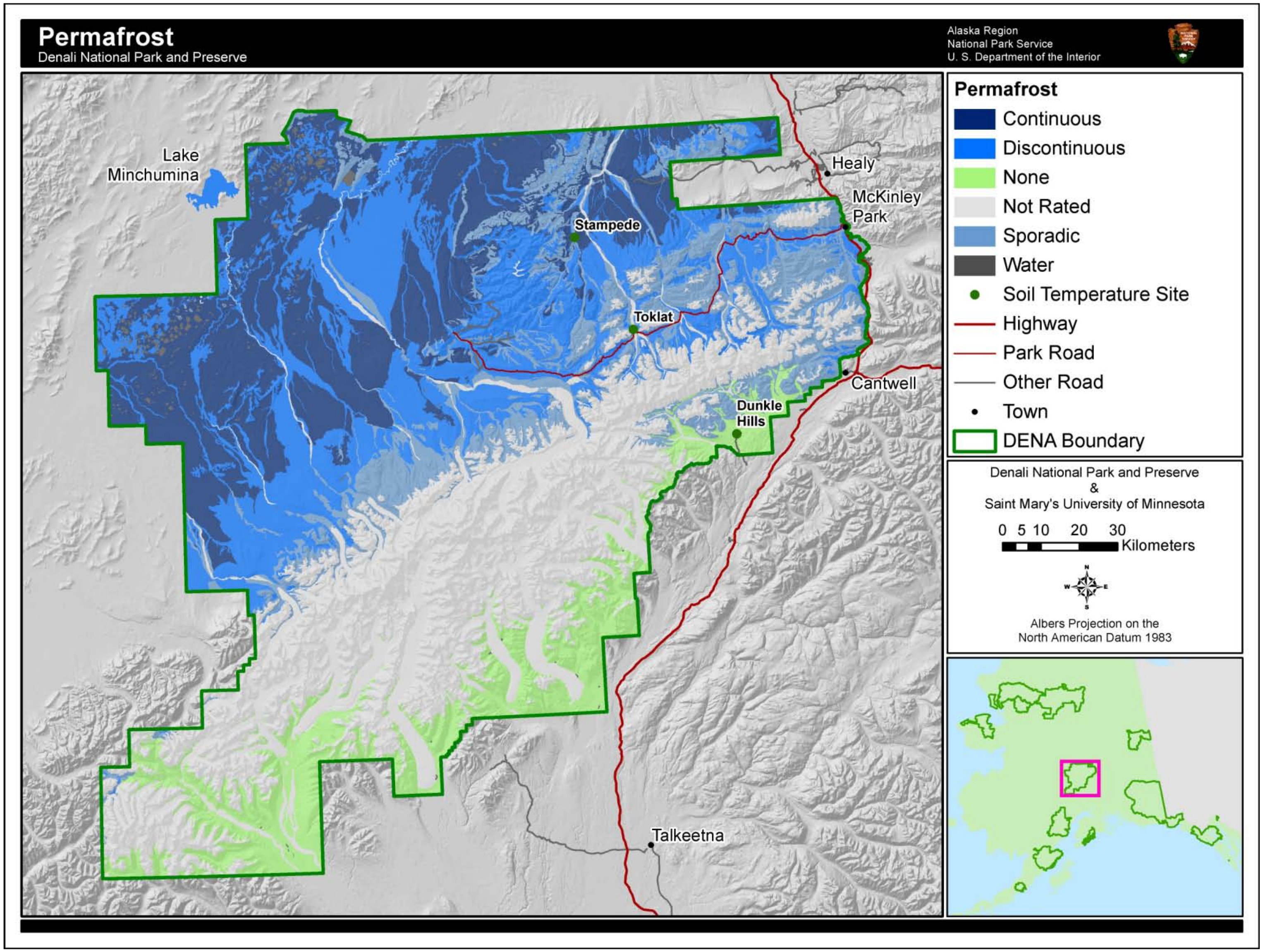
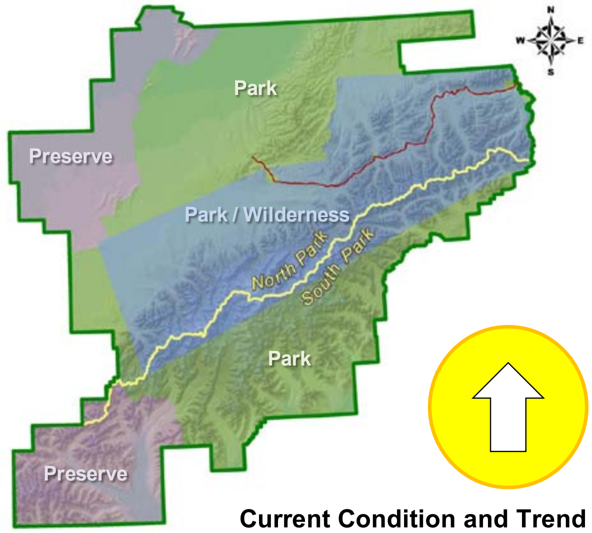


Plate 37. Map of permafrost coverage in Denali National Park and Preserve and soil temperature monitoring sites (NPS 2010).

4.18 Paleontological Resources



Current Condition and Trend

Description

Until recently, most paleontological finds within Denali National Park and Preserve consisted of marine and plant fossils from the Paleozoic and Mesozoic Eras, 100 to 500 million years ago. These included ammonites, trilobites, radiolarians, and a new species of brachiopod (*Myrospirifer breasei*) identified by Robert Blodgett in the late 1990s (DENA 2010a). Then in June of 2005, Paul McCarthy and Susi Tomsich of the University of Alaska-Fairbanks discovered a three-toed dinosaur track near Igloo Creek (Figure 96; DENA 2006). The approximately 70 million year old fossil provided the first evidence of dinosaurs in Interior Alaska (DENA 2006). Paleontologists determined that the track was from a theropod, a meat-eating dinosaur approximately 10 feet long that walked on its back legs (DENA 2006). This first track, nearly nine inches long and six inches wide, is now displayed at the Murie Science and Learning Center in Denali.

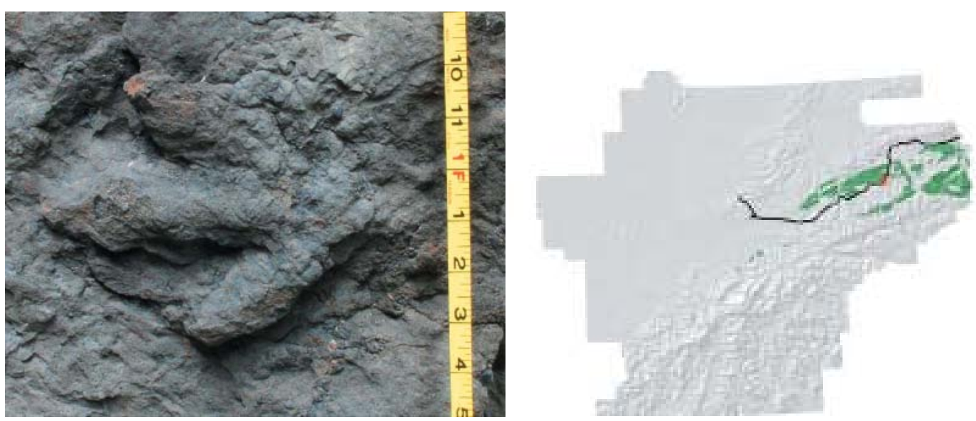


Figure 96. The first dinosaur track (left, NPS photo) and its approximate location in Denali (right). The green shaded area shows the extent of the Cantwell formation within the park and preserve (from DENA 2006).

Since 2005, thousands of trace fossils from the late Cretaceous Period have been discovered in the Cantwell Formation within Denali (Figure 96). Trace fossils include tracks, burrows, borings, coprolites (fossilized feces), and other evidence of biological activity, but not actual animal remains. Dinosaur trace fossils at Denali include many sizes of theropod and hadrosaur (duck-billed plant eater) tracks as well as possible ceratopsian (beaked plant eaters) tracks (DENA 2010a). In the summer of 2008, scientists discovered the handprint of a pterosaur (winged dinosaur), the first known occurrence of this reptile group in Alaska (Photo 27; Fiorillo et al. 2009). The best known and most visited location of dinosaur tracks is known as the "Cretaceous Dancefloor" and is just a two and a half mile hike from the park road (DENA 2010a). Although no dinosaur bones or tissues have been found in the park and preserve to date, scientists expect that they will be found eventually (DENA 2010a). In addition to dinosaur fossils, paleontologists have also discovered at least 10 different avian trace fossil types, fish trace fossils, and about 30 invertebrate (insects, worms, and crustaceans) trace fossil types (DENA 2010a).

Scientists have also been studying flora fossils in the Cantwell formation in an effort to reconstruct the late Cretaceous environment (Photo 27; Tomsich et al. 2010). Leaf fossils can actually be used to estimate prehistoric climate parameters. During the Cretaceous period, the Cantwell formation supported a broad-leaved forest in a temperate climate, much warmer than current conditions (Tomsich et al. 2010). Some scientists even suggest that "understanding the Late Cretaceous ecosystem may aid in understanding modern climate change" (DENA 2010b).

Photo 27. The pterosaur handprint (left, photo by A. Fiorillo) and a gymnosperm leaf fossil (right, photo by D. Sunderlin) found in Denali's Cantwell formation (from DENA 2008a and 2008b).

The diversity of fossil evidence found within Denali has led some paleontologists to believe that the park and preserve is "second only to Dinosaur National Monument in terms of national park importance for the study of dinosaurs and their associated ecosystems" (DENA 2008a). As a result of recent findings, Denali has seen an increase in both visitor interest in fossils and paleontology focused research proposals (DENA 2010a). Paleontological resources may emerge as one of the most significant assets of the park and preserve. In the past few years park staff have intensified fossil inventory efforts and are working on a Paleontology Resource Management Plan.

Although knowledge of Denali's paleontology resources is considered far from complete, eight "paleontological localities of management concern" or PLMCs have been identified (DENA 2010a). A PLMC is a rock unit or site that is "specifically valuable for typical science reasons (unique specimens, unique preservation, specimen concentrations, example or official type sections) and/or are in need of attention on the basis of environmental risk or natural threat reasons (site fragility, threat of erosion), and/or concerns regarding human disturbance or destruction (specimen desirability, specimen recognition, site accessibility)" (DENA 2010a). These sites are described in Table 46.

Table 46. Paleontological localities of management concern (PLMCs) for Denali National Park and Preserve (from DENA 2010a).

PLMC Areas	Location	Approximate Size	Notable Finds	Condition	Accessibility	Protection Concern
Shellabarger Pass	Southern Preserve	8-km radius	Trilobites and the brachiopod *M. breasei*	Good to poor	Helicopter	Low
Mount Dall	Southern Preserve	8-km radius	Permian flora	Good to poor	Helicopter	Low
Chulitna Terrane	Southeast Park near Golden Zone Mine	3-5-km long, 1.5 km wide	ammonites	Good to poor	Hiking from Golden Zone Mine	Low
Upper Windy-Sanctuary	East Park, south of park road	4-km long, 1.5-km wide	Paleo- and Mesozoic marine fossils	Good to poor	Likely helicopter	Low
Upper East Forks – Toklat River	East Park, near park road	3 km-long, 1 km wide	Bivalves found in 2010	Good to poor	Helicopter and hiking	Low
Sable Mountain/Tattler Creek	East Park, just north of park road	3-5-km radius	Dinosaur and bird tracks	Very good to vulnerable	Hiking	High
Double Mountain	East Park, southeast of park road	3-km radius	Dinosaur and fish trace fossils	Very good to OK	Helicopter	Moderate, due to landslide
Cabin Peak	East Park, north of park road	120 m x 25 m	Dinosaur tracks and other trace fossils	Exceptional to poor	Hiking	Moderate, due to landslide

Measures
Percentage of sites effectively protected by management plan
Percentage of documented paleontological sites that have a good evaluation
Paleontological inventory

Reference Conditions/Values
DENA (2009) identifies the reference condition for paleontological resources as 100% of sites protected and a completed paleontological inventory. The reference condition for percentage of sites of good quality is still to be determined.

Data and Methods
The first effort to compile and catalogue information on Denali's paleontological resources occurred in 1997. At that time there were 276 known fossil localities, 80% of which could be located on maps (Brease 1998). After the 2005 dinosaur track discovery, the NPS initiated a full paleontological investigation of the Cantwell formation, in cooperation with Anthony Fiorillo of the Dallas Museum of Nature and Science in Texas (DENA 2009). This study has already yielded significant findings in the Sable Mountain, Double Mountain, and Cabin Peak areas (DENA 2010a) and will continue through at least 2015 (DENA 2010b). In 2010, GeoCorps interns created an electronic database to incorporate all the information collected on the Cantwell formation since 2006. The database contains over 210 fossil sites and more than 340 individual specimens (Reitman and de Moor 2010). Some of these locations are mapped in Figure 97.

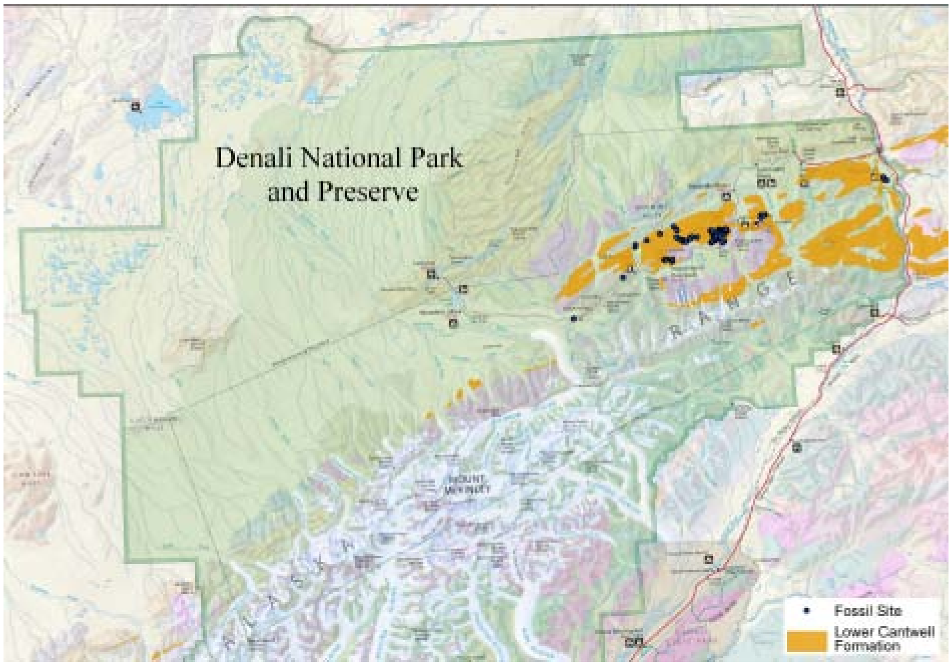


Figure 97. Fossil sites within the Cantwell Formation of Denali National Park and Preserve (Reitman and de Moor 2010).

Denali National Park and Preserve is nearing completion of a Paleontological Resource Management Plan (PRMP) and also has several "fact sheets" describing paleontological discoveries and research available on their website. Research interest in the Cantwell formation is high and knowledge of Denali's paleontology is expected to continue growing.

Current Condition and Trend

<u>Percentage of sites effectively protected by management plan</u>

According to DENA (2009), none of the park and preserve's paleontological sites are currently protected. The Draft PRMP lists several management options for these sites: no action, monitoring, cyclic prospecting (regular rechecking in high erosion areas), stabilization/reburial, erecting protective structures, excavation, closure, patrols, and confidentiality agreements with researchers/discoverers (DENA 2010a).

Management actions are recommended for several of the park and preserve's PLMCs. For example, Cabin Peak should be monitored at least annually since several areas are threatened by landslides (DENA 2010a). The area perhaps most in need of protection is Upper Tattler Creek where the "Cretaceous Dancefloor" is located. The Draft PRMP recommends limiting visitation to 8 groups a year led by NPS staff members as well as annual monitoring (DENA 2010a).

The Draft PRMP also recommends maintaining all paleontological finds *in situ*, unless a specimen is recognized by experts as scientifically significant, is at imminent risk of damage or loss, and a federally authorized repository has agreed to assume responsibility for its curation (DENA 2010a).

Percentage of documented paleontological sites that have a good evaluation

Methodologies for evaluating paleontological sites at Denali are still being developed and standardized. According to DENA (2009), the percent of paleontological sites in good condition is currently unknown. A review of the Cantwell paleontological sites database by GeoCorps intern Nadine Reitman in 2010 provided the condition information presented below in Table 47.

Table 47. A summary of the condition evaluations for five different characteristics of the 212 sites in the Denali paleontology database as of 14 October 2010. For the first four characteristics, there were an additional 10 sites with no data available and there were 15 sites with no fossil quality data available. (NPS, Reitman, pers. comm. 2010)

Evaluation	Rating	Number of Sites
Human disturbance	None	172
	Some	27
	Extensive	3
Potential human disturbance	High	4
	Moderate	51
	Low	147
Natural Fragility	High	81
	Moderate	84
	Low	37
Access	Easy	23
	Moderate	129
	Difficult	50
Fossil Quality	High	40
	Moderate	91
	Low	66

Paleontological inventory

DENA (2009) set a goal to complete "a formal park-wide inventory of known paleontological resources and document their location, abundance, ease of access, risk factors and disturbance, baseline condition, fragility, and protection measures needed, if any". While significant progress has been made toward this goal, the inventory is far from complete. Field work is expected to continue every summer for the foreseeable future (DENA 2010a).

Threats and Stressor Factors

Threats to paleontological resources as identified by DENA (2009) include park development and other management actions, visitor impacts (access to and advertisement of sites, fossil hunters), and erosion and other natural processes (acid rain, run-off, etc).

Fossils are considered non-renewable resources that are regularly lost to erosion and other destructive chemical and physical processes (DENA 2010a). Landslides, solifluction (downhill sediment movement), and seismic activity can either expose or cover and even destroy fossil sites (DENA 2010a). Several trace fossil sites in the Cantwell formation are currently threatened by neighboring landslides. The cracking of trace fossils due to regular freezing and thawing has also been observed in the park and preserve (DENA 2010a).

Some of the highest trace fossil concentration areas can be found near the park road, making human disturbance a definite risk. "Advances in GPS technology combined with the ability to distribute information via the Web means that these sites can be easily pinpointed and quickly exposed to many people" (DENA 2010a). Some trace fossils, most notably at the Cretaceous Dancefloor, are loose and could easily be removed by fossil hunters. Factors as simple as human touch or trail formation due to increased visitation could accelerate erosion and increase damage to paleontological sites (DENA 2010a).

<u>Data Needs/Gaps</u>

The Draft PRMP makes several recommendations to address baseline data needs: 1) acquire geologic data, such as analysis of stratigraphy and depositional environments, to better understand the context of paleontological finds, 2) expand inventory & catalogue efforts beyond the Cantwell formation & Cretaceous Period, 3) continue searching for information about or actual materials that were discovered in the park and preserve and removed (unpublished government and private industry documents, USGS warehousing, University of Alaska museum archives), and 4) create park-wide GIS data layers & attribute databases for paleontological data (DENA 2010a).

In addition the Draft PRMP (DENA 2010a) mentions several specific areas in need of attention. The Farewell Terrane is poorly studied and in need of additional mapping and inventory, particularly at Shellabarger Pass. More research is also needed in the McKinley and Pingston terranes to better understand the paleotectonics and depositional history of the area. Finally, areas that are considered potential PLMCs, although no ground discoveries have yet been made, include North Galen, Fang Mountain, and Mount Sheldon (DENA 2010a).

<u>Overall Condition</u>

Despite a recent intensification in inventory and monitoring efforts, the state of knowledge concerning paleontological resources within the park and preserve is still considered to be low. Based on the measures established in DENA (2009), overall condition of this component is moderate but improving. As inventory and research efforts expand, the condition will continue to improve.

Level of Confidence

Relatively little is known about the paleontological resources of Denali and Central Alaska (DENA 2010a). The discoveries of the last five years have likely just scratched the surface of the geological and paleontological knowledge that can be acquired from Denali National Park and Preserve.

Sources of Expertise

The primary source of expertise for this assessment was the Draft Paleontological Resource Management Plan (DENA 2010a).

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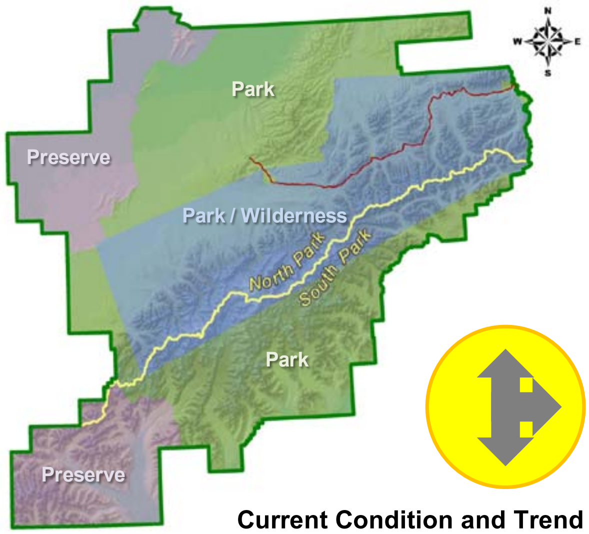
4.19 Soundscape

Description



Current Condition and Trend

The sounds of nature are often one of the key elements that draw visitors to national parks. Many visitors strongly associate the natural sounds they hear – whether it’s wolves howling, the rush of a glacial river, or simply wind rustling through the trees – with their park experience, creating memories that will last a lifetime (DENA 2010a). Natural sound levels are also of vital importance to many wildlife species. Unusual noises can prevent animals from detecting predators and disrupt natural behaviors such as migration, establishing territory, courtship, and rearing young (DENA 2010a). In extreme cases, certain sounds could trigger physiological or behavioral responses that affect an animal’s ability to survive and reproduce (DENA 2010a).

The natural soundscape consists of two types of sound: biological and physical (Hults and Burson 2006). Biological sounds are those produced by living things such as birds, frogs, and insects. Physical sounds include wind, rain, rivers, and rockslides. In the late 1990s, Denali park managers recognized that the park and preserve’s soundscape was becoming increasingly influenced by human-generated sounds (DENA 2010a). Backcountry visitors were voicing complaints about aircraft noise (Peacock 2006). This concern initiated efforts to study Denali’s natural soundscape and the impacts of anthropogenic noise. In 2000, Director’s Order 47 (DO-47) instructed park staff to “1) measure baseline acoustic conditions, 2) determine which existing or proposed human-made sounds are consistent with park purposes, 3) set acoustic management goals and objectives based on those purposes, and 4) determine which noise sources are impacting the park and need to be addressed by management.” It also required park managers to “evaluate and address self-generated noise, and constructively engage with those responsible for other noise sources that impact parks to explore what can be done to better protect parks” (Withers 2006).

The importance of soundscape was again emphasized in the 2006 Backcountry Management Plan, stating that park staff “will restore to the natural condition wherever possible those park soundscapes that have become degraded by unnatural sounds (noise), and will protect natural soundscapes from unacceptable impacts” (NPS 2006). They will also “monitor human activities that generate noise that adversely affects park soundscapes, including noise caused by mechanical or electronic devices,” and “take action to prevent or minimize all noise that through frequency, magnitude, or duration adversely affects the natural soundscape or other park resources or values, or that exceeds levels that have been identified through monitoring as being acceptable to or appropriate for visitor uses at the sites being monitored” (NPS 2006).

The Denali soundscape can be divided into three acoustical zones: scrub/forest, subalpine, and alpine. The sounds heard in each zone are influenced by the vegetation, presence and type of animals, seasonal and climatic conditions, topography and altitude, and proximity to water (DENA 2010a). Data collected through 2005 show that wind is the most common natural sound across the park and preserve while the most common human generated sound is from aircraft overflights (Hults and Burson 2006). These audio recordings have also been used to supplement ongoing bird surveys and could prove helpful in determining the presence and distribution of other animal species (Hults and Burson 2006).

Measures

Maximum percent of motorized noise heard per hour
Maximum number of motorized noises per day that exceed natural ambient sound level
Maximum motorized sound pressure level (dBA)
Natural ambient sound level

Reference Conditions/Value

The Denali Backcountry Management Plan (BCMP) establishes four separate zones for the purpose of soundscape management (Figure 98). Target conditions vary for each of these management areas and are summarized in Table 48. The natural ambient sound level park-wide at Denali is estimated to be approximately25 dBA (Hults and Burson 2006).

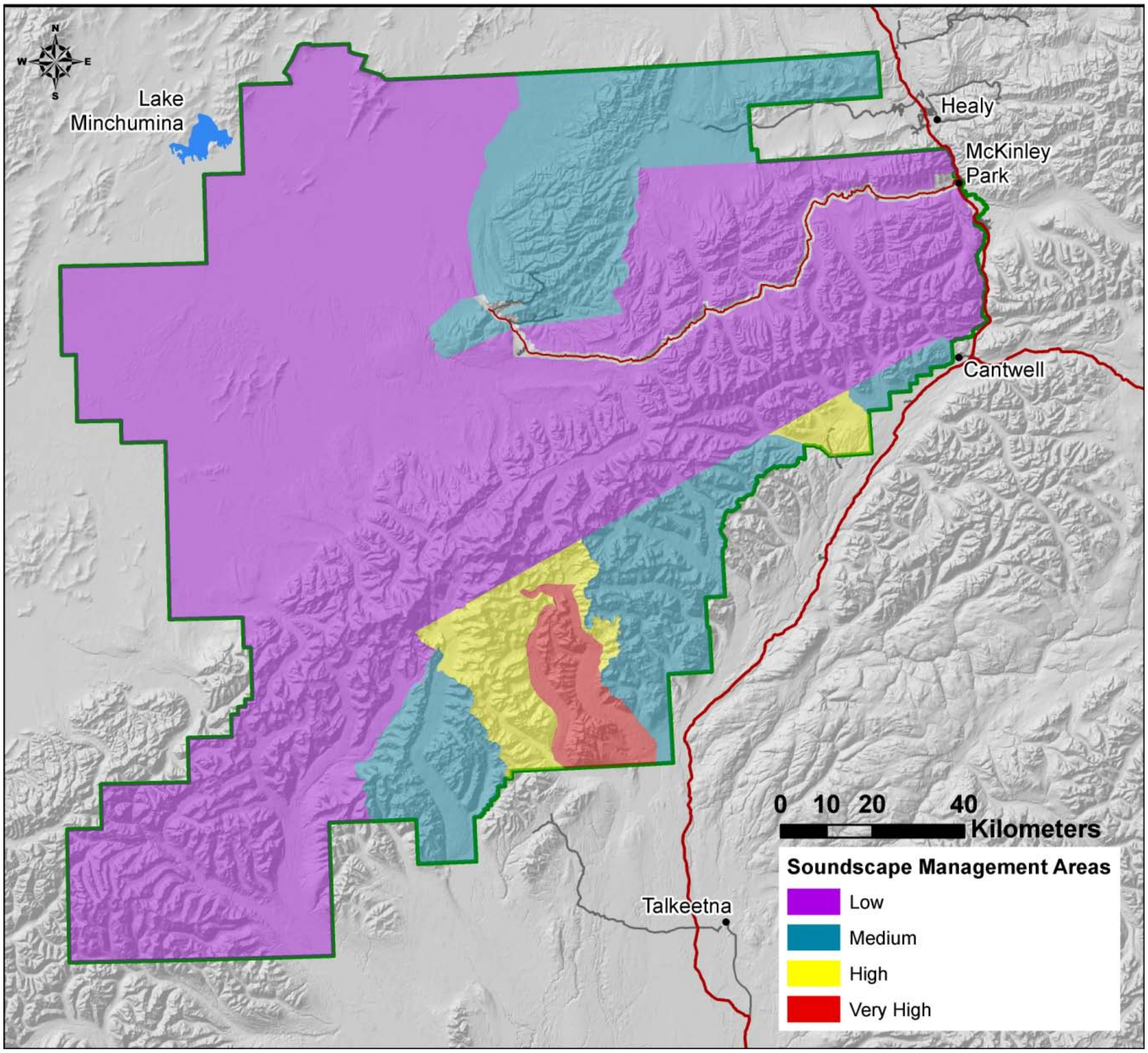


Figure 98. Map of Denali National Park and Preserve showing the four soundscape management areas (NPS 2010, Withers 2009).

Table 48. Target conditions for the four soundscape management zones in Denali National Park and Preserve (adapted from DENA 2006).

Management Area	Max. % of motorized noise per hour	Max. # of motorized noises exceeding ambient level per day	Max. motorized sound pressure level (dBA)
Very high	50%	50	60
High	25%	25	60
Medium	15%	10	40
Low	5%	1	40

Data and Methods

Soundscape research at Denali National Park and Preserve began in 2000. During this field season park staff evaluated, purchased, and tested remote sound monitoring equipment. They also developed a GIS-based atlas of aircraft landing and flight corridors, conducted aerial and ground surveys of snowmobile use, and performed audibility experiments of snowmobile noise production (Burson 2001). Three types of data are collected by the sound monitoring stations: 1) sound pressure levels in dBA every second, 2) five second sound recordings every five minutes, and 3) ten second recordings of sound events above a certain threshold (usually 55 dBA) (Withers 2006). Equipment is solar-powered and, in many cases, protected from animal interference by solar-powered electric fences (Withers 2006; Photo 28).

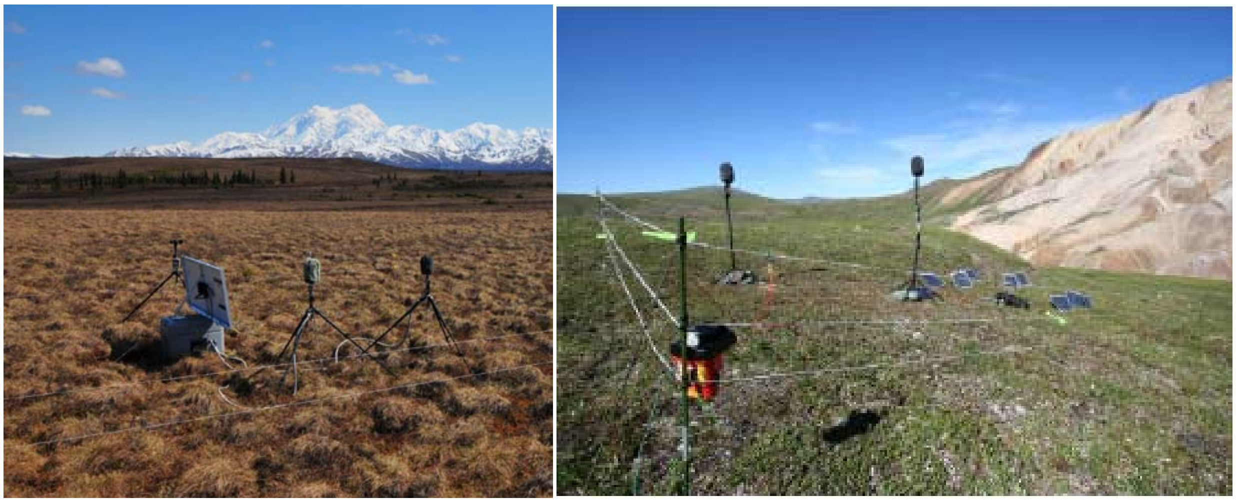


Photo 28. Sound monitoring stations and electric fence at Highpower Creek (left) and the Upper East Fork of the Toklat River (right) (NPS photos, in Withers 2009 and Hults 2005).

Through 2004, the placement of sound monitoring stations was based upon specific projects or target areas (Hults 2005). During the 2005 field season, a stratified random sampling method was developed that included the whole park and preserve, based on the Long Term Ecological Monitoring (LTEM) grid system already in place (Withers 2006). With only five monitoring stations available, researchers chose to keep several stations at a single location throughout the entire field season and to rotate the others between multiple sites. Six locations on the LTEM grid are scheduled to be sampled each year with an additional two sites chosen based on management needs (Withers 2006). A total of 60 LTEM grid sites will be sampled on a ten-year cycle (Figure 99). During the 2008 field season, stations were placed at four LTEM grid sites and at the toe of the Tokositna Glacier to monitor aircraft overflight sound levels (Withers 2009).

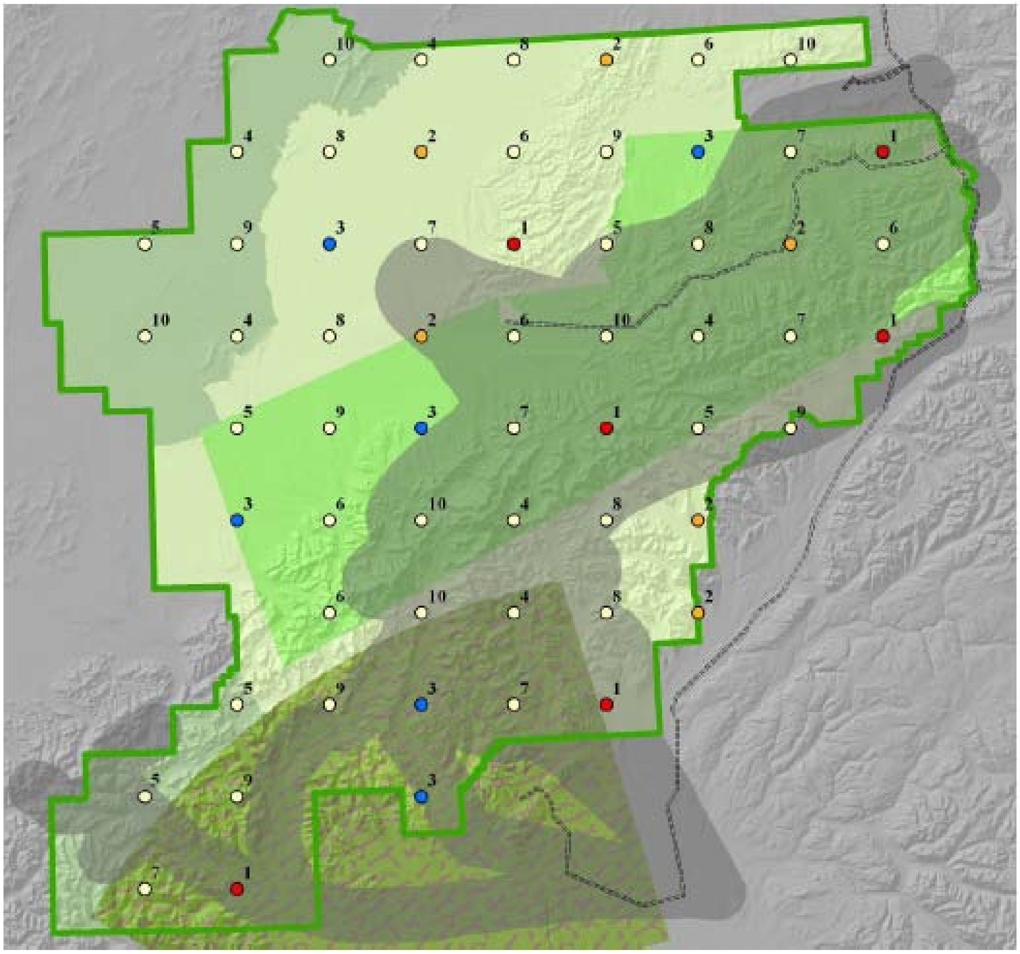


Figure 99. Soundscape monitoring locations based on the LTEM grid. Numbers indicate the study year in which each point is scheduled to be sampled. Year 1 sites were sampled in 2006. Gray shaded areas indicate common flight seeing pathways, while the camouflage shading in the south shows the Susitna Military Operating Area (Withers 2006).

The soundscape monitoring program initially encountered many problems with equipment malfunctions and animal interference. In 2004, usable data was collected for just 30% of the total time that monitoring stations were deployed (Withers 2006). Researchers took steps to better protect the equipment from animals, including electric fences and plastic sheathing for cables. As a result the proportion of usable data increased to 51.5% in 2005 and 55.6% in 2006 (Withers 2006).

The results for nine sites sampled between 2001 and 2004 are available in Hults (2004). Results for five and six separate sites sampled in 2005 and 2006 respectively can be found in Hults (2005) and Withers (2006). Data collected at five sites during the 2008 field season is available in Withers 2009 and summarized in Table 49 below.

Table 49. A summary of soundscape monitoring data collected at the five sampling sites shown in Figure 100 during 2008. Natural ambient sound level measures only natural sounds while existing ambient sound level includes natural and anthropogenic sounds (adapted from Withers 2009).

Site	Median natural ambient sound level (dBA)	Median existing ambient sound level (dBA)	% of recordings with aircraft noise	Number of aircraft per day	Max. sound pressure level of aircraft (dBA)
Highpower Creek	23.1	23.1	0.36	2.1	43.5
Toe of Kahiltna Glacier	28.8	29.1	2.25	12.3	53.8
Toe of Tokositna Glacier	41.3	41.4	5.08	28.9	51.7
Upper Wigand Creek	23.7	23.8	2.66	13.6	39.4
Upper Slippery Creek	26.3	26.5	3.89	20.9	37.4

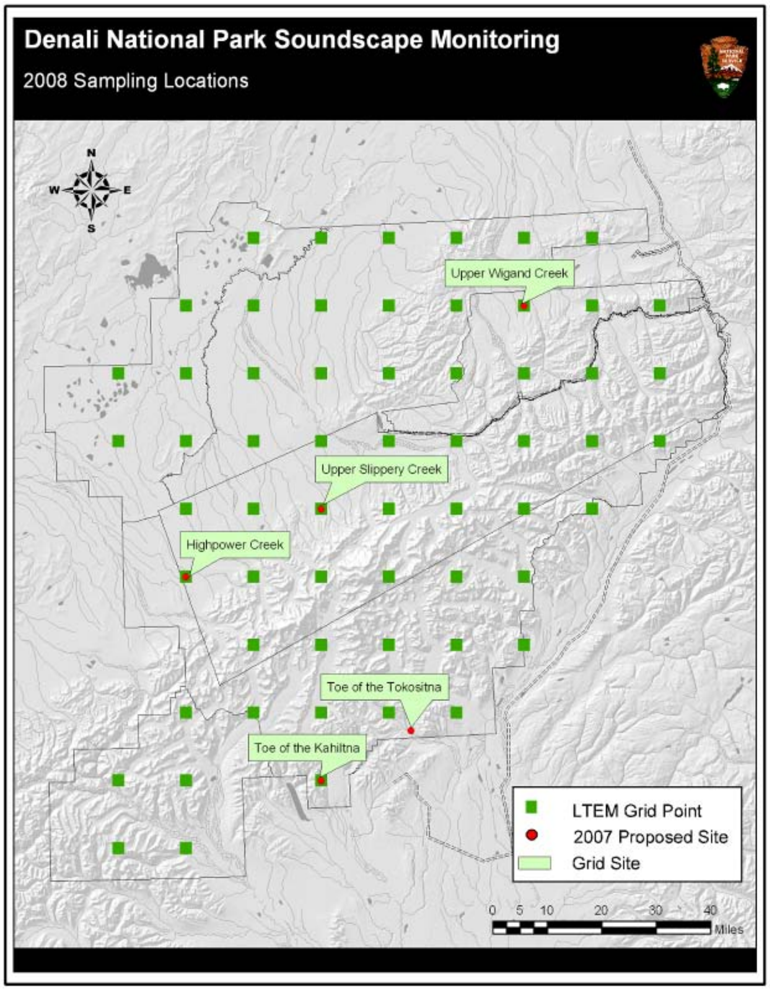


Figure 100. Locations of the five soundscape monitoring sites for 2008 (Withers 2009).

Current Condition and Trend

<u>Maximum percent of motorized noise heard per hour</u>

Figure 101 shows how frequently the standards for this measure were exceeded at soundscape monitoring sites sampled between 2005 and 2008. The highest proportions are seen in wilderness areas where the standard is lowest (5%) and flightseeing is common, peaking at 37% exceedence near Mount McKinley (Withers 2009).

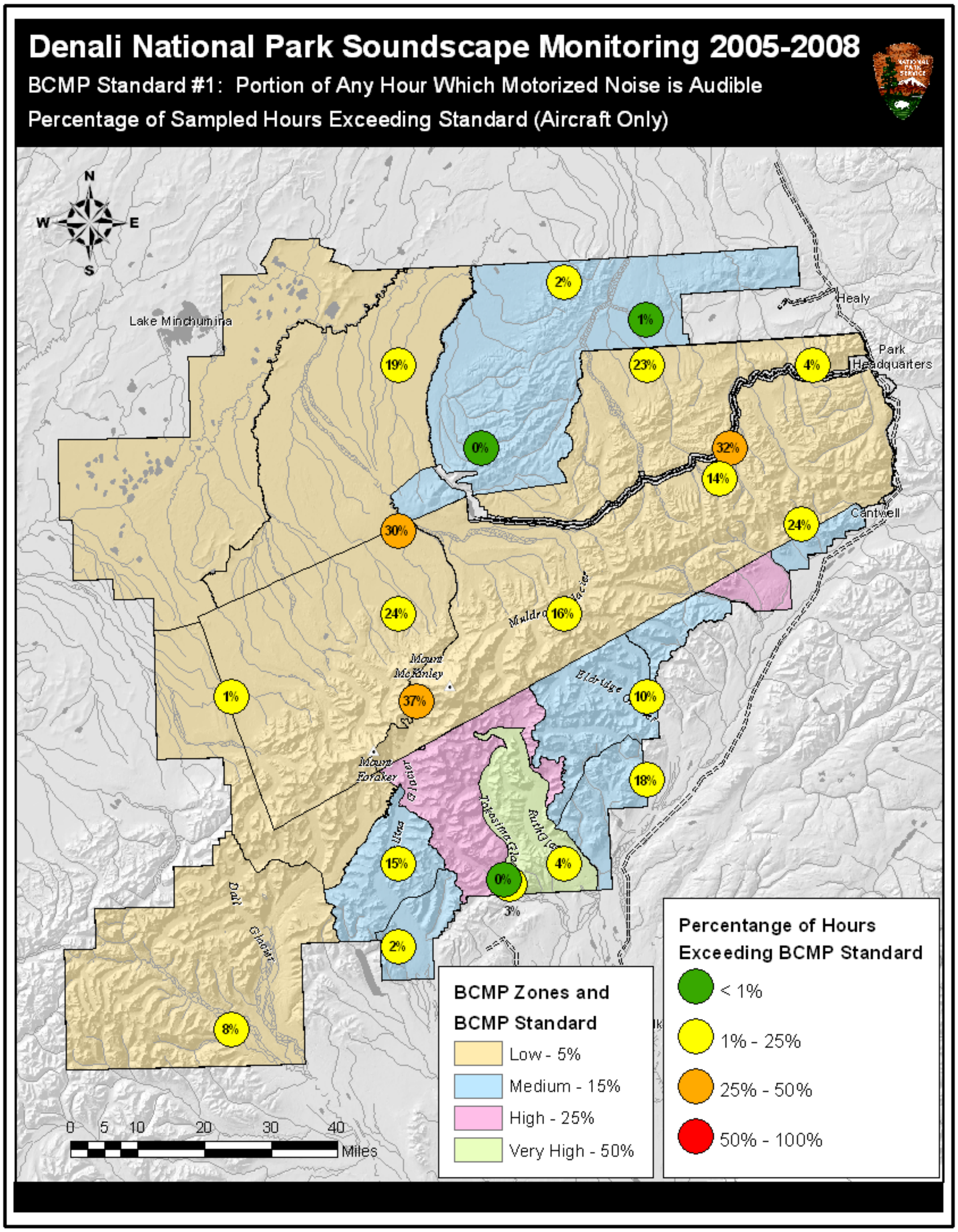


Figure 101. The percentage of time sampled when maximum percent of motorized noise heard per hour exceeded standards established in the BCMP (Withers 2009).

Maximum number of motorized noises per day that exceed natural ambient sound level

Figure 102 shows how frequently the standards for the maximum number of motorized noises per day exceeding the natural ambient sound level were exceeded at soundscape monitoring sites sampled between 2005 and 2008. Percentages were extremely high in the low level management areas, where three monitoring stations showed that the one event per day standard was exceeded 100% of the days sampled (Withers 2009).

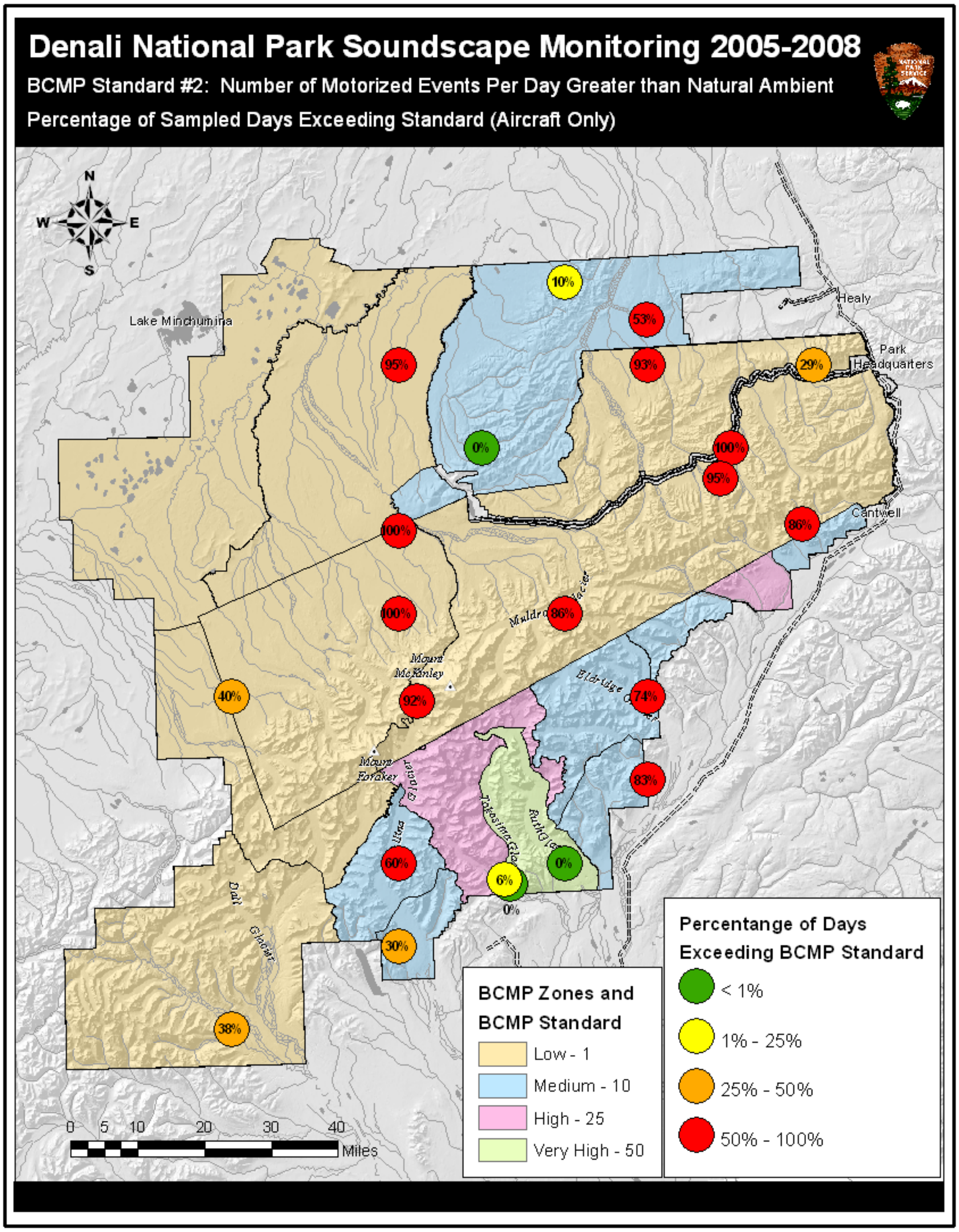


Figure 102. The percentage of days sampled when the number of motorized events per day exceeded standards established in the BCMP (Withers 2009).

<u>Maximum motorized sound pressure level (dBA)</u>
Figure 103 shows how frequently the standards for maximum sound level were exceeded (by aircraft only) at soundscape monitoring sites sampled between 2005 and 2008. Exceedence levels were highest in the low and medium management areas, where sound levels exceeded the BCMP standard more than 90% of the time at three separate stations (Withers 2009).

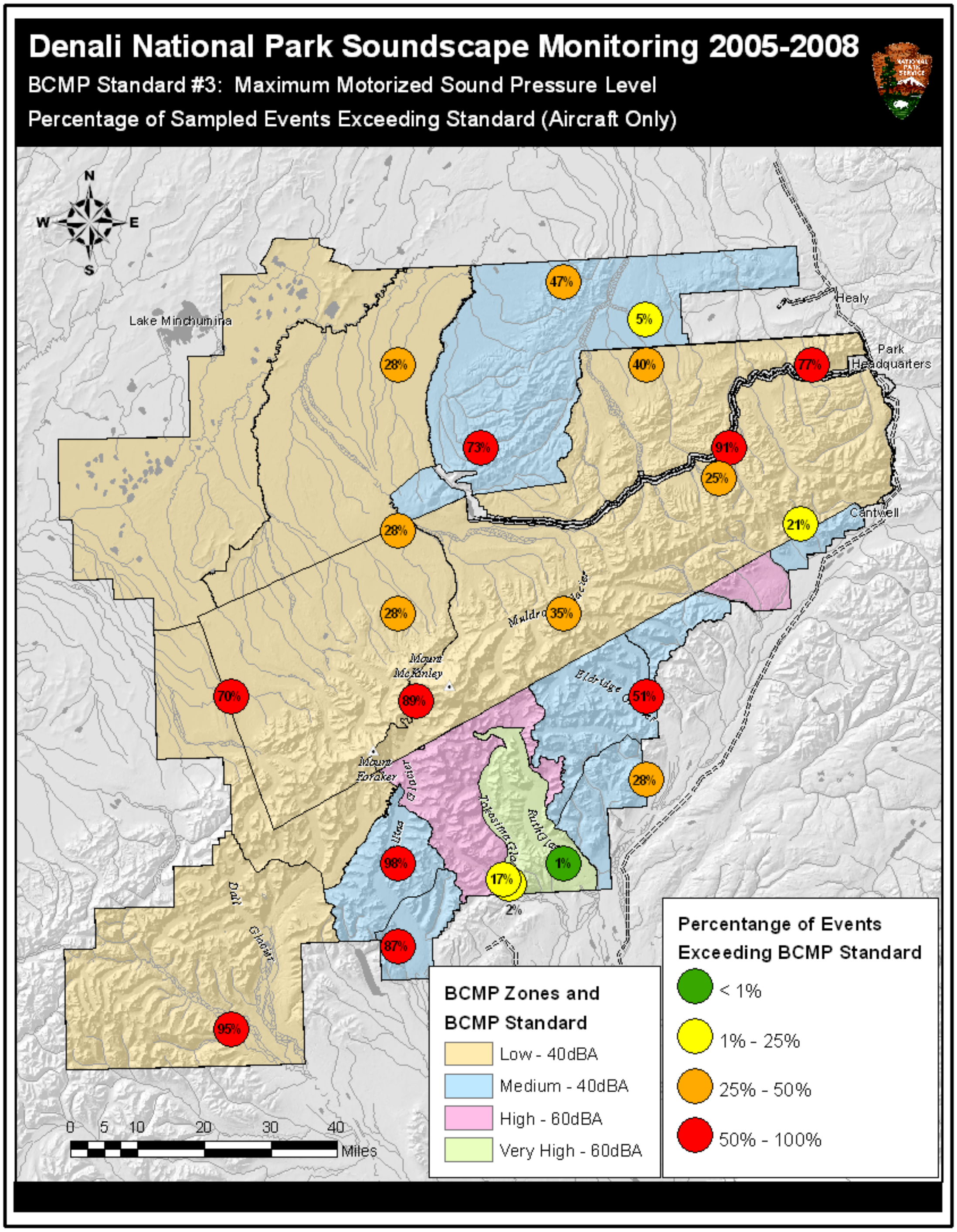


Figure 103. The percentage of days sampled when the maximum motorized sound level exceeded standards established in the BCMP (Withers 2009).

Natural ambient sound level

The natural ambient sound level (L_{nat}) is an estimate of what an acoustical environment might sound like without the contribution of anthropogenic sounds. It includes all physical and biological sounds regularly heard at a site. Methods used to calculate L_{nat} for Denali's soundscape monitoring program are described in Withers (2009). The typical L_{nat} for Denali National Park and Preserve is around 25 dBA (Hults and Burson 2006). Natural ambient sound level estimates for the five sites sampled in 2008 ranged from 23.1 dBA at Highpower Creek to 41.3 dBA at the toe of the Tokositna Glacier (Withers 2009). Natural ambient sound levels are higher at sites near rivers and sometimes glaciers where running water is audible almost continuously.

Threats and Stressor Factors

Threats to Denali's natural soundscape include motorized noise from planes and snowmobiles as well as noise from cars, trains, and buses on the borders of wilderness areas and from the park road (DENA 2009). Due to the inaccessibility of much of Denali, scenic flightseeing is a popular tourist activity, resulting in frequent aircraft overflights of the park and preserve. A portion of the southern park addition and preserve are also included in the Air Force's Susitna Military Operating Area (see Figure 99). Military overflights occur as low as 5,000 feet above ground level, but are limited to the hours between 7 a.m. and 10 p.m. (DENA 2006). A survey of overnight backcountry visitors in 2000 showed that 66% of visitors reported seeing three or more aircraft per day during their trip (DENA 2006).

A 2006 study used a Noise Model Simulation (NMSim) program to estimate the impacts of scenic overflights on the Denali soundscape (Peacock 2006). Twelve local scenic flightpaths were modeled to produce a color contour map estimating areas in the park and preserve where these flights are audible on the ground and where they exceed the 40 dBA and 60 dBA sound level standards established in the BCMP (Peacock 2006). The NMSim program estimated that these overflights are audible (>25 dBA) in 48% of the park and preserve (Figure 104; Peacock 2006).

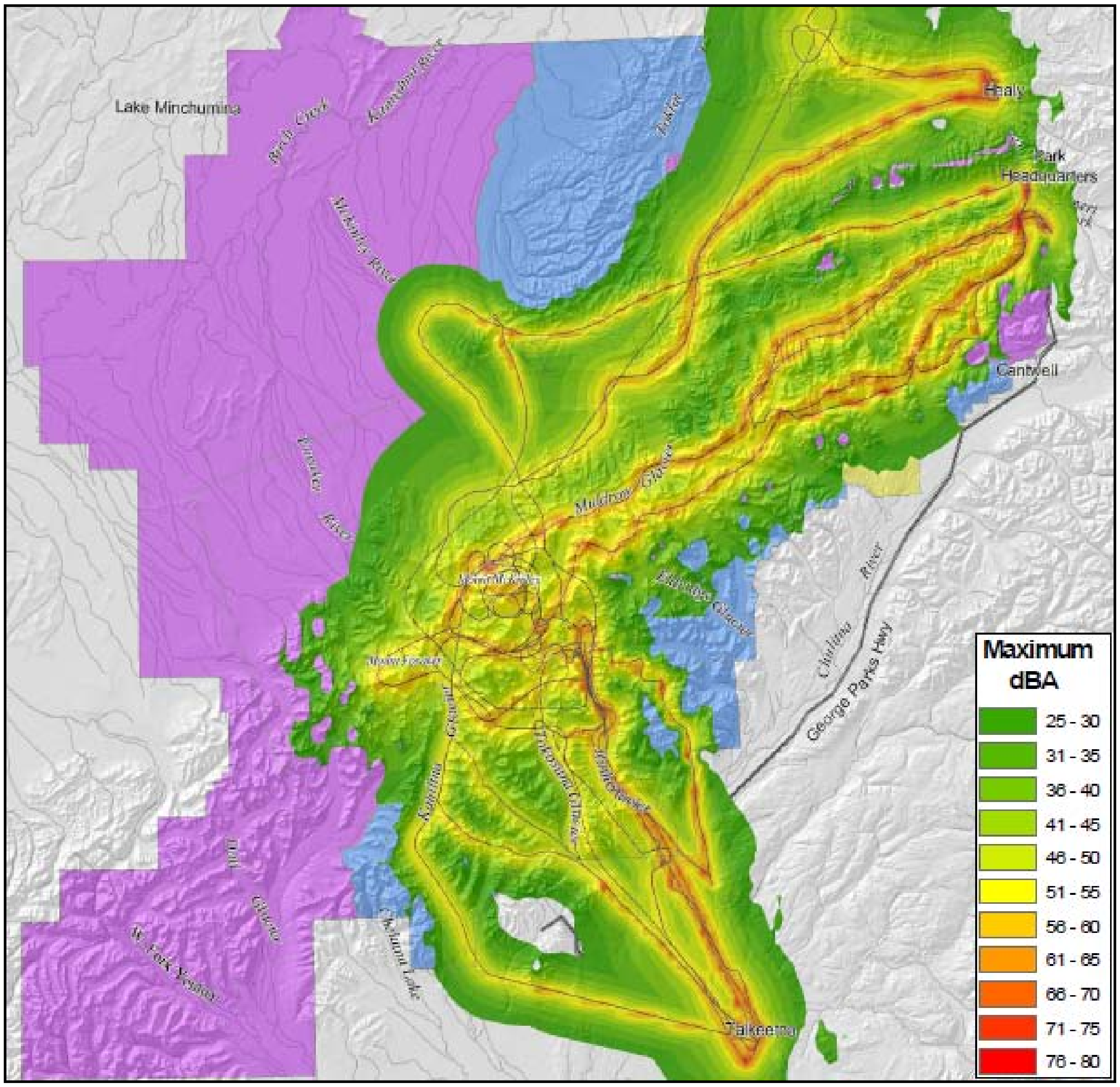


Figure 104. Estimated area within Denali where the 12 scenic overflights are audible (>25 dBA) (from Peacock 2006).

The 12 scenic overflights modeled exceeded 40 dBA and 60 dBA in 28.8% and 1.6% of the park and preserve area respectively, frequently in the low level management areas (Figure 105; Peacock 2006). The three scenic flights flown in Piper Navajo aircraft were estimated to produce the largest soundprint, with one flight exceeding the 40 dBA standard in low level management areas 29% of the time (Peacock 2006). Eight of the 12 scenic overflights were estimated to exceed the 40 dBA standard while in low level management areas, with seven of them exceeding 60 dBA, and eleven of the 12 flights were estimated to exceed the 40 dBA standard while in medium level management areas (Peacock 2006).

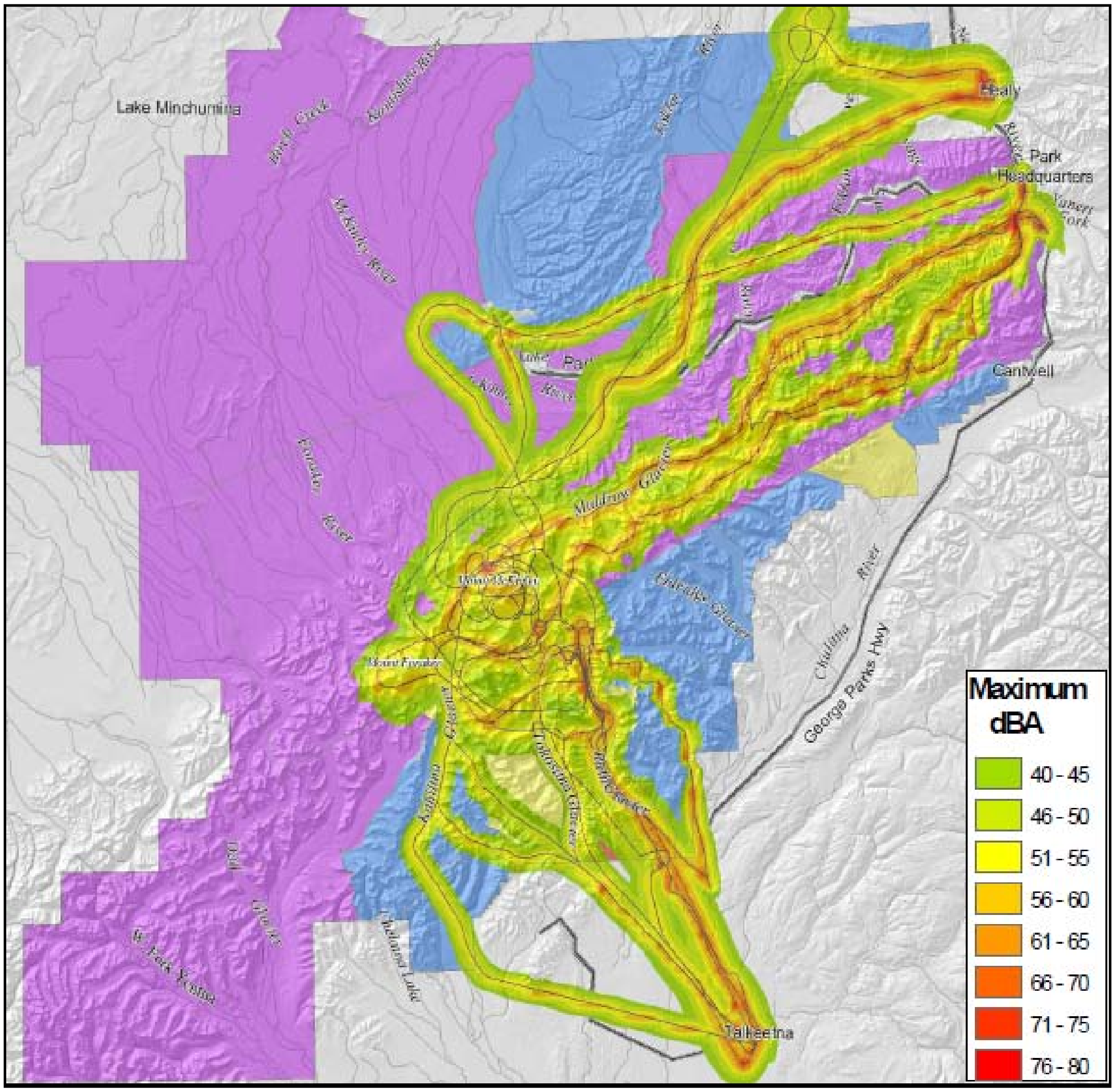


Figure 105. Areas within Denali where the 12 scenic overflights are estimated to exceed 40 dBA (from Peacock 2006).

While the number of overflights per day was never estimated to exceed the standard for motorized sounds per day in the medium, high, and very high management areas, the standard is likely exceeded regularly in the low management areas (Peacock 2006). Since some tours are flown multiple times a day and round-trip flight paths often overlap, the one motorized sound per day standard may be exceeded up to 27 times during the average summer day (Peacock 2006). The repeated circling of Mount McKinley by several flights causes the standard to be exceeded often in that area as well (Peacock 2006).

As part of the NRCA, a similar NMSim analysis was conducted for an average day of NPS administrative flights in the park and preserve. The process used in this analysis is described in detail in Appendix C and results are presented in Plate 38 and Plate 39. Analysis shows that the four selected administrative flight routes are audible (>25 dBA) in an estimated 55.7% of the park and preserve and exceed 40 dBA in an estimated 43.8% of the park and preserve area. The color contour maps generated by NMSim illustrate that NPS administrative flights in the northern part of Denali are likely exceeding the maximum motorized sound level standards established in the BCMP for low and medium management zones (Plate 39).

A formal Aircraft Overflights Advisory Council was established for the park and preserve by its 2006 BCMP (Withers and Adema 2009). The role of the advisory council is "to advise the Secretary of the Interior about voluntary measures to reduce the impacts of overflight noise on the natural soundscape and increase safety for passengers, pilots, mountaineers, and other backcountry users" (Withers and Adema 2009). In 2010, the advisory council planned to work with NPS scientists and local air touring companies "to test and evaluate the effects of actions aviators could take to reduce impact on a popular wilderness day-hiking area, and at the West Buttress climbing route on Mount McKinley" (Withers and Adema 2009).

Snowmachine use is most common in the southern park addition in areas accessible from the Parks Highway, particularly in the Broad Pass/Dunkle Hills region and the Tokositna River valley (DENA 2006). The Denali wilderness area was closed to snowmachine use in 2000 (DENA 2006).

Data Needs/Gaps

Further study is needed to evaluate the full impact of aircraft overflights. The modeling work started by Peacock (2006) did not include all scenic tours and could not account for variations in flight paths due to weather, pilot preferences, and animal sightings. More information on overflights would help identify actions that could be taken to minimize their impact. It is also important for monitoring efforts to continue so that any changes in soundscape over time can be identified.

Overall Condition

Given the results shown in Figure 101, Figure 102, and Figure 103, it appears that conditions are good in the high and very high management areas but poor in much of the low and medium management areas, which comprise a majority of the park and preserve. The exceedence levels for number of motorized noises per day are particularly high in the low and medium management areas, primarily due to scenic overflights.

Level of Confidence

The monitoring efforts of the past decade have provided Denali National Park and Preserve with one of the most extensive acoustical monitoring datasets in the National Park System (Withers 2009). However, not enough data has been gathered for a sufficient period of time to determine any trends in condition.

Sources of Expertise

The primary sources of expertise for this assessment are Withers (2006, 2009).

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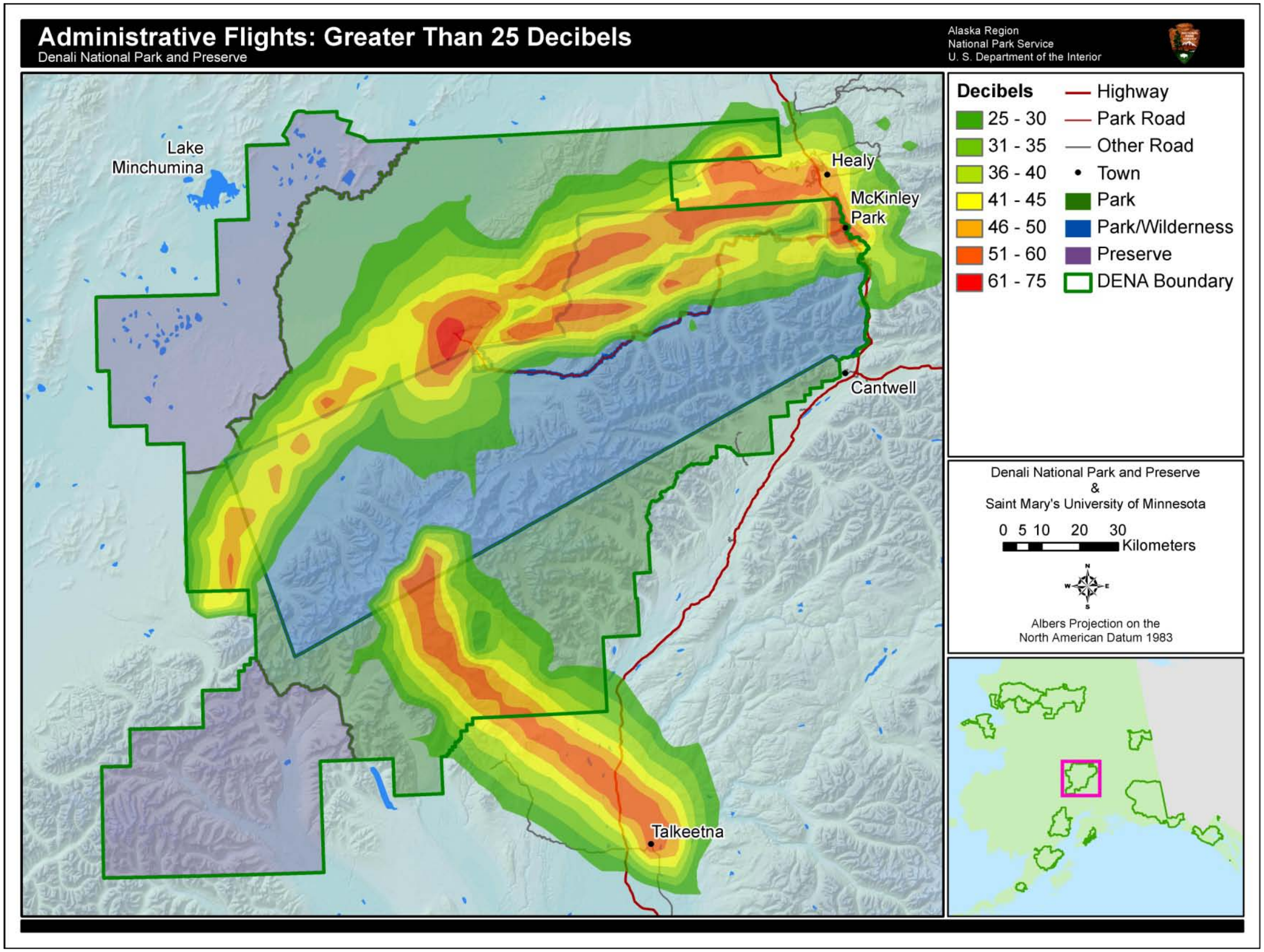


Plate 38. Administrative flights: Audible sound on the ground greater than 25 decibels (DENA 2010b, NPS 2010). This map includes only the four flights analyzed as part of the NRCA.

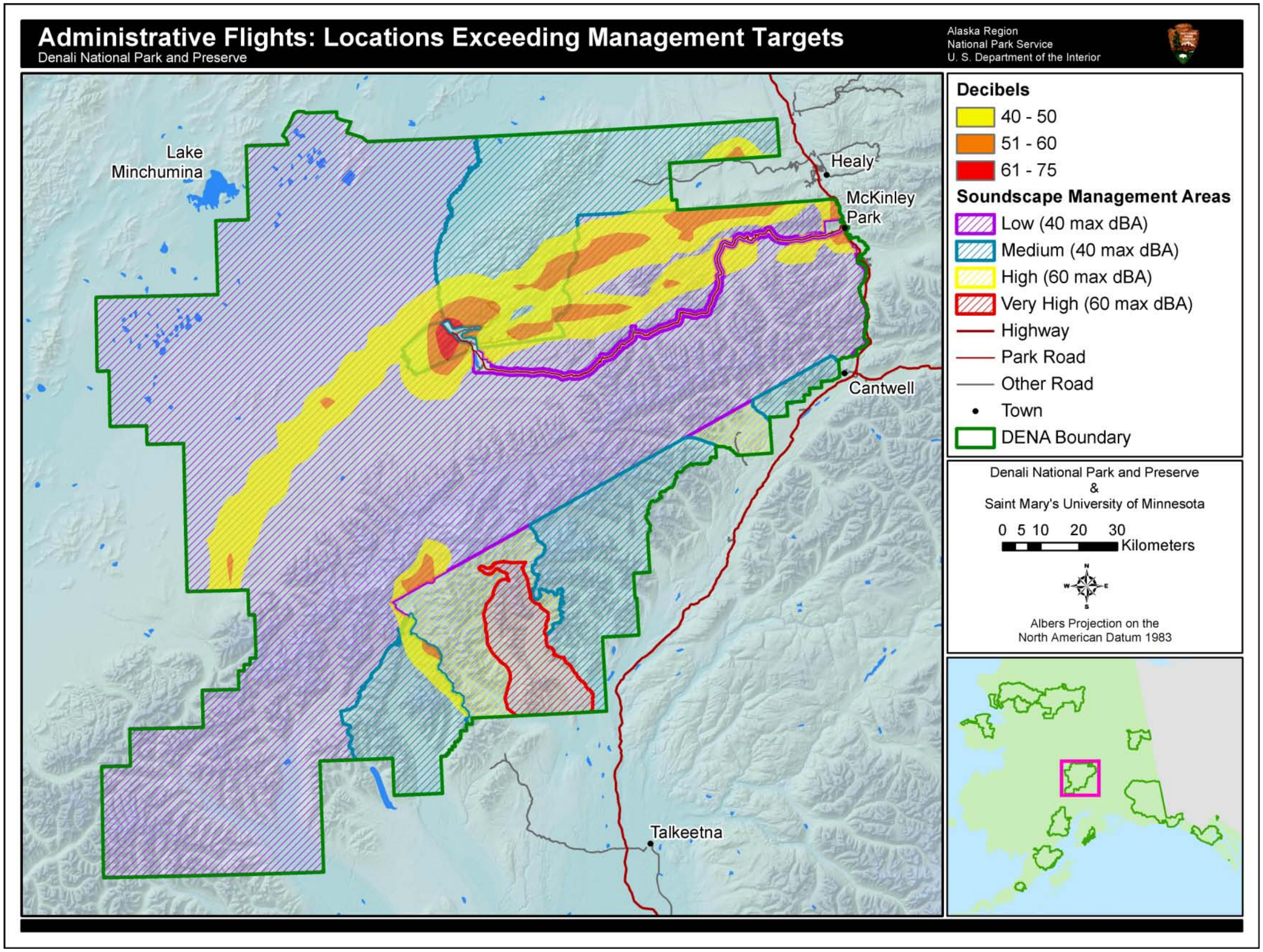


Plate 39. Administrative flights: Locations exceeding Backcountry Management Plan targets (DENA 2010b, NPS 2010). This map includes only the four flights analyzed as part of the NRCA.

Chapter 5 Discussion

5.1 Park-wide Condition

Due to its size, ecological diversity, and the remoteness of a large portion of the park and preserve, assessing the condition of Denali at a park-wide scale is problematic. It is very possible for individual resources to be in good and stable condition in one part of Denali but in moderate condition and declining in another part. There are also large remote portions of the park and preserve where certain resources (e.g., lakes, glaciers, and permafrost) are largely unstudied. However the data that are available suggest that Denali National Park and Preserve is generally in good or moderate condition with stable trends. There is little human impact in most areas of the park and preserve and it continues to function as an intact, naturally regulated ecosystem.

The condition and trend of each indicator included in the NRCA framework is summarized in Table 50. This provides the ability to view the condition of all indicators within an ecosystem category. It is important to note that the framework does not include all possible indicators and measures within an ecosystem component. The condition and trend of the selected indicators may not fully represent the condition and trend of the larger ecosystem component or the entire park. It is also important to consider that condition assessments were made with varying amounts of available data and with varying degrees of confidence. A more complete assessment of each indicator is available in chapter four.

Table 50. Summary of indicator condition and trend.

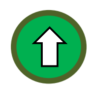
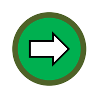
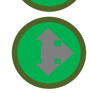
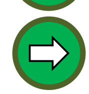
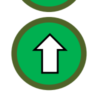
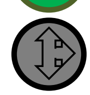
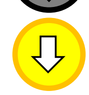
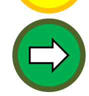
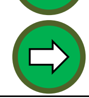
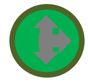
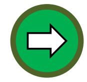
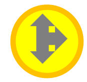
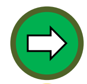
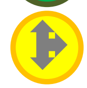
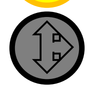
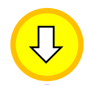
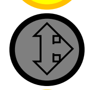
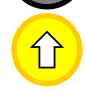
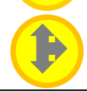
Component	Indicator	Condition
Extent and Pattern		
Landscape Pattern/Structure		
	Landcover/Soils/ Expected Vegetation	
Biological Components		
Species		
	Denali Caribou Herd	
	Dall's Sheep	
	Moose	
	Trumpeter Swans	
	Breeding Birds	
	Wolves	
	Grizzly Bears	
	Golden Eagles	

Table 50. Summary of indicator condition and trend (continued).

Component	Indicator	Condition
Biological Components		
Communities		
	Native Plant Community	
Ecological Processes		
	Fire	
Aquatic Habitat		
	Lake Ecosystem Function	
Chemical and Physical Characteristics		
Chemical Parameters		
	Air Quality	
	Ecosystem Contaminants	
	Water Quality	
Physical Parameters		
	Glacial Features	
	Permafrost	
	Paleontological Resources	
	Soundscape	

The majority of biological components are in good condition with a stable trend. Only wolves and lake ecosystem function are in moderate condition, with wolves also showing a declining trend. Wolf population numbers should be monitored closely over the next several years, especially considering there will likely be an increase in harvest pressure due to the opening of the Stampede area to sport hunting (DENA 2010).

In contrast, the majority of Denali's physical resources are in moderate condition with individual indicators trending in a variety of directions. Only air quality is considered in good condition with a stable trend. The overall condition of one physical resource (permafrost) is unknown, with two additional resources (soundscape and ecosystem contaminants) having an unknown trend. Glacial features are of the highest concern with a clearly declining trend, likely attributable to climate warming.

NPS and SMUMN GSS staff chose not to use reporting areas for this NRCA, due to the significant overlap of resources between existing legislative and management boundaries.

However some differences were noted between these traditional reporting areas for several components. For example, exotic plant species were found only in the park development zone and were not an issue in undeveloped areas of the park and preserve. It was also noted that the condition of soundscape was good in some soundscape management areas but poor in others, particularly the wilderness area, partially due to the different standards established in Denali's backcountry management plan (DENA 2006). There has also clearly been more research in the "north park" (north of the Alaska Range) than in the "south park", likely due to better accessibility from the park road in the north and its inclusion in the original Mount McKinley Park boundary.

Several threats or stressors were identified that apply to multiple resources within the park and preserve. These include airborne contaminants, scenic overflights, and climate change. Landers et al. (2008) found elevated levels of airborne contaminants in a high elevation snow samples and fish in Denali. Fish from Wonder and McLeod Lakes showed mercury concentration levels that surpassed the contaminant health thresholds for fish-eating birds, with Wonder Lake fish exceeding the contaminant threshold for fish-eating mammals as well. Unfortunately nearly all of these airborne contaminants come from outside the park, as far away as Europe and Asia, and are expected to increase with rising global population and industrialization (AK DEC 2002).

Scenic overflights threaten the soundscape of the park and preserve, affecting both wildlife and visitor experience. These overflights repeatedly exceed the "number of motorized sounds" target set by Denali's backcountry management plan, particularly in the wilderness area during the summer (Peacock 2006). Park staff are also concerned that scenic overflights may be disturbing waterfowl particularly trumpeter swans, within the park and preserve (McIntyre 2006).

Perhaps the greatest threat to nearly every resource within the park and preserve is climate change. As discussed in this assessment, Denali is predicted to become warmer and drier over the next century. Winter temperatures in interior Alaska have increased approximately 4°C (7°F) over the past few decades, while at Denali the number of snow-free days has increased and the growing season has lengthened since 1925 (DENA 2007). Temperatures are projected to increase at an average rate of about 1°F per decade, resulting in a transition from average annual temperatures below freezing (~24°F) across the park and preserve, to temperatures near or above the freezing point (~32°F) (SNAP et al. 2009). These changes will affect not only the obvious resources of permafrost and glaciers, but also vegetation, lakes and streams, chemical cycling, wildfire regime, insect and disease outbreaks, as well as wildlife distribution and habitat use (DENA 2007, Redmond and Simeral 2006).

5.2 Indicator Condition Summaries

Denali's RSS was extremely helpful in identifying reference conditions and measures for many of the indicators in this NRCA. However, establishing reference condition was still a significant challenge for assessing the condition of several indicators. The phrase "within the range of natural variation" has often been used by resource managers as a way of defining reference condition, but this idea is difficult to quantify with limited historic data or when changes in circumstance prevent current condition from mirroring historic condition. When a specific reference condition for the park was unknown, an attempt was made to include federal standards, thresholds, or data from other relevant locations in order to provide some context for interpreting results.

For many indicators, data was only available for limited areas within the park and preserve (e.g., ecosystem contaminants and breeding birds). In these cases, condition was either considered unknown (breeding birds, permafrost) or inferred from available data if it was thought by experts to be representative of the park and preserve as a whole (ecosystem contaminants, glaciers).

5.3 Data Needs

Despite the wide variety of research that has been conducted in Denali National Park and Preserve, many data needs remain. The majority of these were identified in Denali's RSS (DENA 2009) and efforts have begun to address some priority items. Inventory and monitoring protocols have been developed for glacial features (Giffen et al. 2010) and permafrost (DENA, Adema, pers. comm. 2011) and will be implemented in the near future. This will help scientists better understand both the current condition and changes occurring in these two climate-sensitive indicators. Studies are also planned to determine the effects of increased harvest pressure and predator control activities outside the park and preserve on Denali's wolf and grizzly bear populations (DENA, Meier and Owen, pers. comm. 2010).

Significant progress has been made towards completing a park-wide paleontological inventory. Given the increased importance of this resource due to discoveries over the past five years (DENA 2008), it is important for this work to continue, along with regular site monitoring for newly exposed fossils. Efforts have also begun to better understand the impacts of overflights on Denali's soundscape (Appendix C; Peacock 2006) but should be expanded to include more scenic flight paths.

Extensive research has been conducted on several wildlife species at Denali (e.g., caribou, wolves, golden eagles) that serve not only as excellent reference sources for park managers, but also for researchers across Alaska and in other areas. It is important for these studies, as well as more recently established long-term monitoring programs (native plants, breeding birds, soundscape), to continue gathering valuable data.

While water quality has been studied in certain areas of the park and preserve, particularly the Kantishna Hills, knowledge of water resources park-wide is limited. According to DENA (2009), "Essentially, there is no comprehensive database for water quality, stream discharge, lake levels, or visitor use levels… Without a baseline inventory of current conditions, understanding water resource ecosystems, threats to those ecosystems, and whether or not water resource goals are being met becomes an almost impossible task." Water quality related data needs are further discussed by The Mangi Environmental Group (2005). These needs include a better understanding of lake ecosystems within Denali, especially given the growing concern over shrinking and disappearing lakes in Alaska (CAKN 2008).

Other data needs noted in the RSS (DENA 2009) include a park-wide nonvascular plant inventory (including lichens so they can be effectively used as a measure of air quality); a park-wide bird inventory; ptarmigan and mesocarnivore/furbearer surveys; expansion of small mammal monitoring, particularly given their importance as prey species; development of a sampling design for fish and amphibians; invertebrate inventory and monitoring; and research into the effects of fire on hydrology and wildlife.

Research into the impacts of climate change on a wide variety of park resources will become increasingly important in the next several decades. Changes in climate will affect not only glaciers, permafrost, hydrology, and fire regime, but also air quality, native plants, and wildlife at all levels of the food chain. Studying these impacts within the park and preserve will help managers not only at Denali but across Alaska and perhaps in subarctic ecosystems worldwide.

During the NRCA scoping session, a number of potential projects were identified that would contribute knowledge and understanding to specific ecosystem components. Six of these were selected for inclusion in the initial NRCA as discussed in chapter three. Additional projects could not be completed due to time and budget limitations. The projects that were discussed but not addressed include:

- **Snow on/ Snow off Timing**: There is interest in reviewing data for snow on, snow off timing over the past several years. Denali resource staff are expecting to see changes in this timing; especially related to spring melt. Data sources could include acoustic snow depth hourly readings, MODIS imagery, park headquarters records, May 1^{st} snow course survey readings, and data from SNOTEL sites.

- **Salmon distribution and winter upwellings:** Prepare an updated map of anecdotal salmon survey data and cross reference with the ADF&G data to create a prototype map of salmon distribution in Denali. This may or may not incorporate data on winter open water and upwellings and could document locations for future research activity on anadromous fish.

- **Bear Human Information Mnanagement System (BHIMS) database clean-up:** This project focuses on organizing all current and historic records in the Denali BHMIS database. This might be something that can be taken care of without a large database organization or redesign effort. Data from BHIMS would be used in future NRCA reports to discuss stressors on the bear population.

- **Stream Functional Morphology**: Map potential impairment sites and symbolize by type (survey sites at the Toklat river crossing; other road crossings; in-holdings; bridges; high priority mine sites for restoration with and without plans for restoration). An initial mapping of potential sites could be done by an outside analyst, and DENA staff could identify areas of concern and follow up with site visits to identify threats.

- **GIS Layer of Florence Collins' Aeolian Deposit Map**: Florence Collins mapped the distribution of aeolian deposits across the Yukon range in the 1970s. This is a formal, numbered USGS cartographic product and it would be good to digitize it into a spatial layer. The basemap was USGS 1:63,360 scale topographic maps. Printed copies can be ordered from the USGS and probably the map center at University Alaska Fairbanks.

- **Mineral activity map**: The purpose of this project would be to compile all mineral activity in the park over time into one spatial layer. The historic human footprint of these activities in Denali would be very useful for interpreting other data. For example, it would be good to know if there was mining activity around a stream used in a research study or where structures, roads, and associated infrastructure were historically located.

- **Geohazard Analysis**: Look at seismic activity and faults, mass movement and correlate with the geology of slopes from a hazards point of view. One product could be a map of all landslide locations.

- **Spatial Representation of Backcountry Use**: The Park is interested in analyzing back country access and use for each of the units identified in the Backcountry Management Plan with the objective of determining which areas are the most popular. This project could be combined with an initiative to capture social trails in the back country for better management.

- **Lightscape**: This project would start with documentation of light point sources throughout the park and preserve. Denali maintenance staff will have information on exterior lights, light bulbs, buildings, miles of roads which could contribute to an understanding of point sources.

- **Wolf Den Database Update**: The wolf den data is currently in dBase IV format and complete through 1993. It needs to be updated. There are probably up to 30 locations to add to the 100 sites already in the database. Denali resource staff have the data required for this update and could also provide the detail required to create a spatial layer from this database.

In addition to the NRCA, SMUMN GSS has also created a database summarizing the contents of Denali research files from 1907 to present for the park and preserve. This project included scanning and digitizing a wide variety of reports and spatial data spanning several decades. The database will provide greater accessibility to research file data and information for park staff and third-party researchers plus it will inform future NRCAs.

5.4 Conclusion

Since its establishment in 1917, Denali National Park and Preserve has earned renown for its “devotion to science, learning, and preservation of its natural and cultural heritage” (DENA 2011). It is known around the world for its amazing scenery and wildlife. The park and preserve, with its largely unspoiled wilderness, represents one of the world’s last great frontiers (DENA 2011).

Denali, however, faces some significant challenges in the coming decades including climate change (lake drying, permafrost degradation, habitat modification, fire regime changes), exotic and invasive species encroachment, predator control, human pressure (tourism, sport and subsistence harvest). In addition, there are still some significant gaps in existing data for specific ecosystem components, including permafrost, water quality, salmon, and small mammals. NPS resource managers need to continue baseline inventory and comprehensive monitoring projects in order to develop and implement management strategies in a timely and effective manner, so that these challenges do not result in the degradation of this incredible natural resource.

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Appendices

Appendix A. Subsistence map series

The following maps are a presentation of known subsistence activity in and around the park and preserve, including trapping, hunting, fishing, and plant collection for subsistence communities near Denali. All spatial datasets were provided by Denali National Park and Preserve staff or accessed through the NPS Permanent GIS Dataset with the exception of the Kantishna subsistence use area, which was estimated based on conversations with Denali staff. The subsistence community use areas in the NPS Permanent GIS Dataset were derived from research and interviews of subsistence users conducted by the Alaska Department of Fish and Game and the NPS in the early 1980s and published in a series of technical papers (Stickney 1981, Stokes 1985). The areas of trapping activity were derived from work completed in the late 1970s. Precise locations of subsistence activity may have changed since these studies were completed and therefore should be considered only as estimates.

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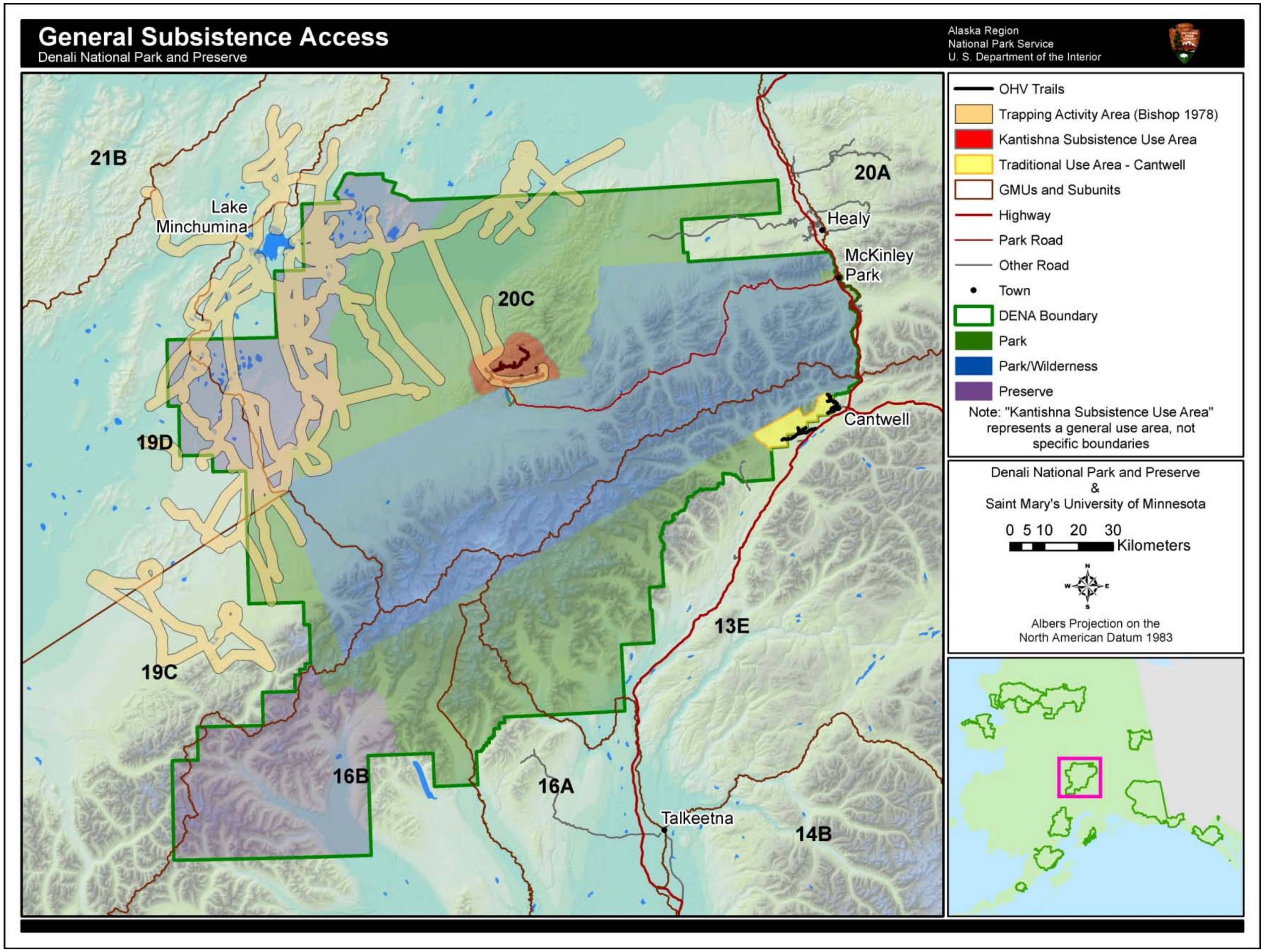

Plate A-1. General subsistence access routes and areas of the park and preserve (DENA 2009, NPS 2010).

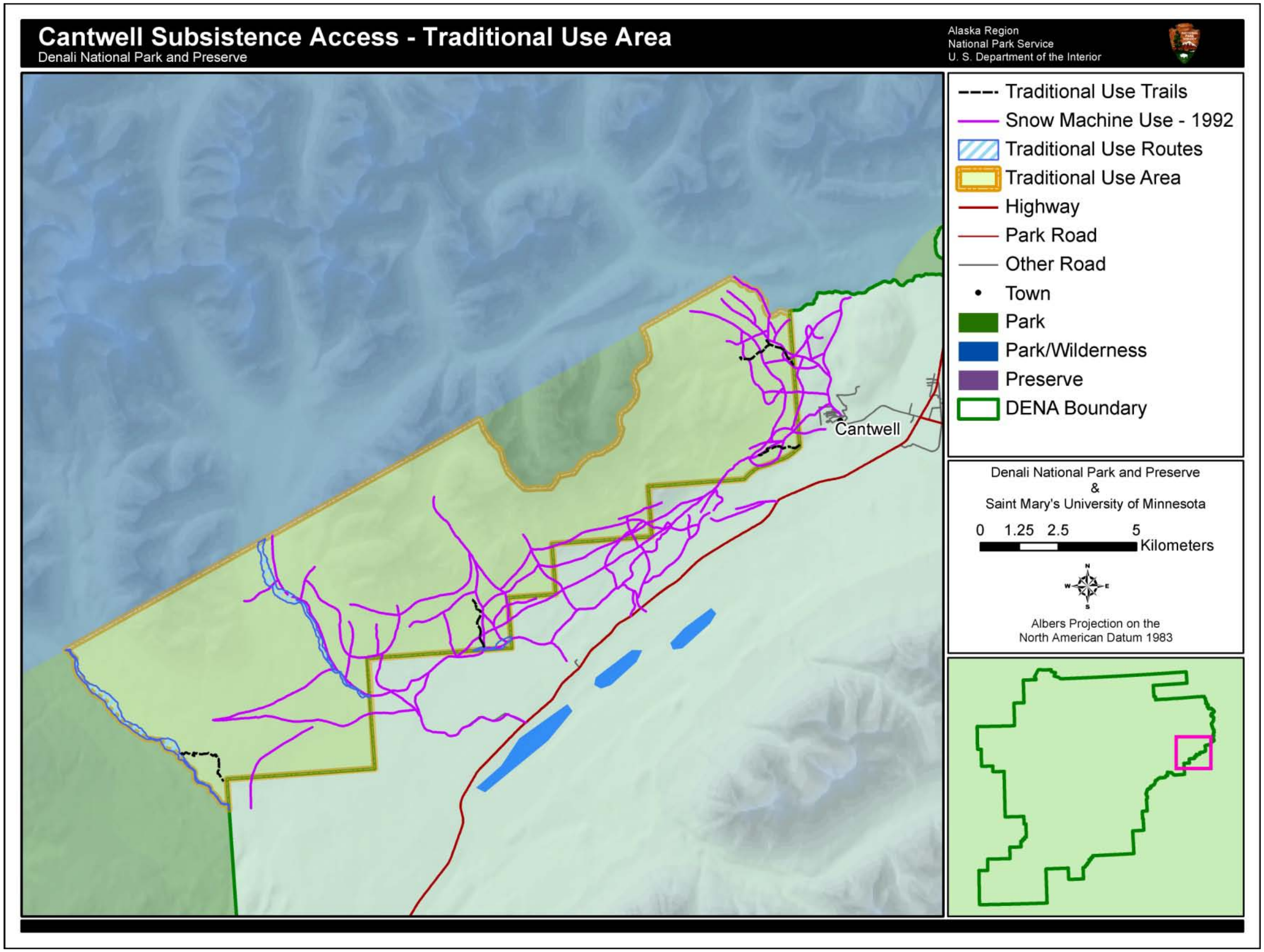

Plate A-2. Subsistence access to the Cantwell traditional use area (DENA 2010, NPS 2010).

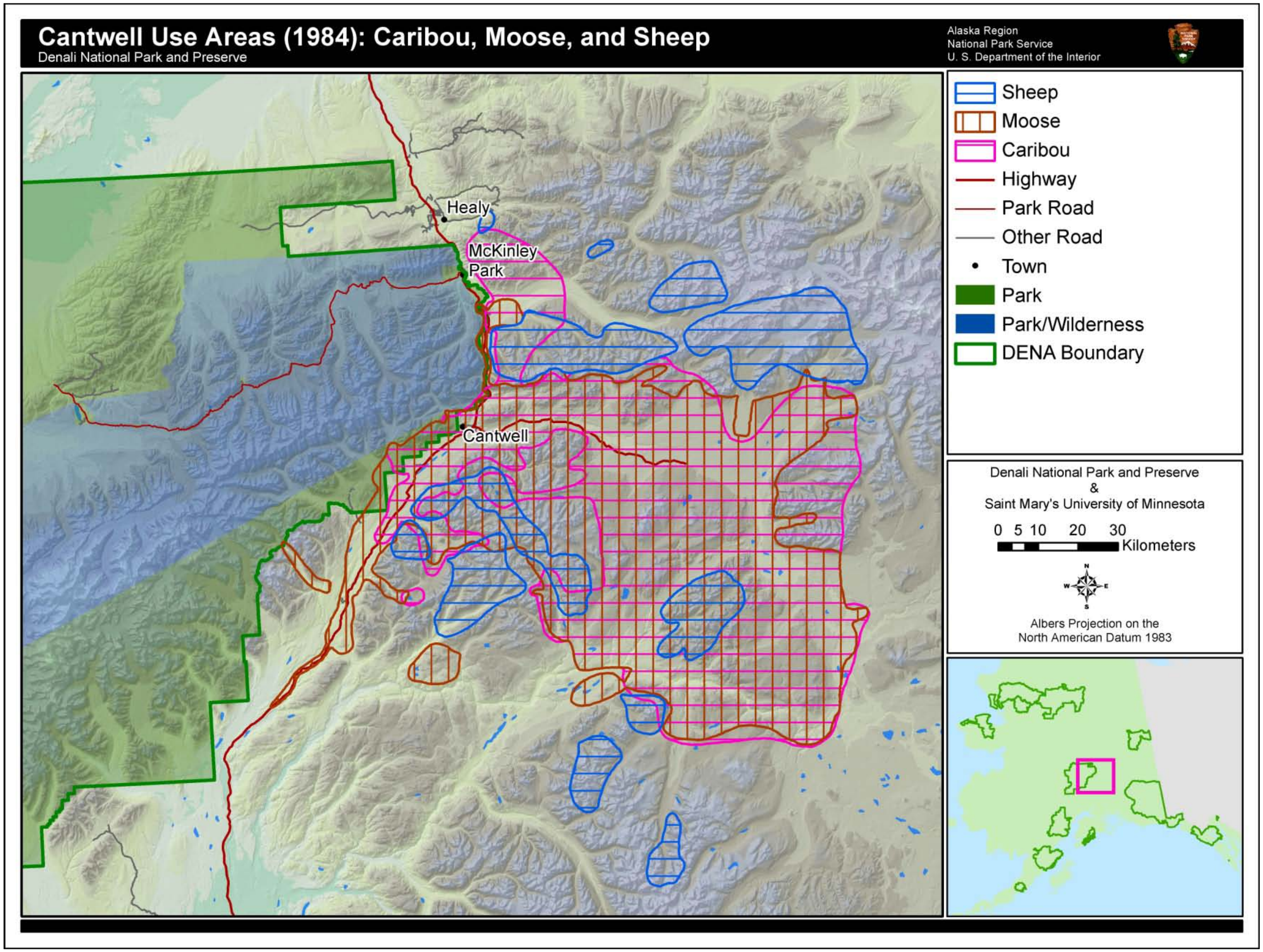

Plate A-3. Cantwell subsistence use areas for caribou, moose, and sheep hunting (NPS 2010).

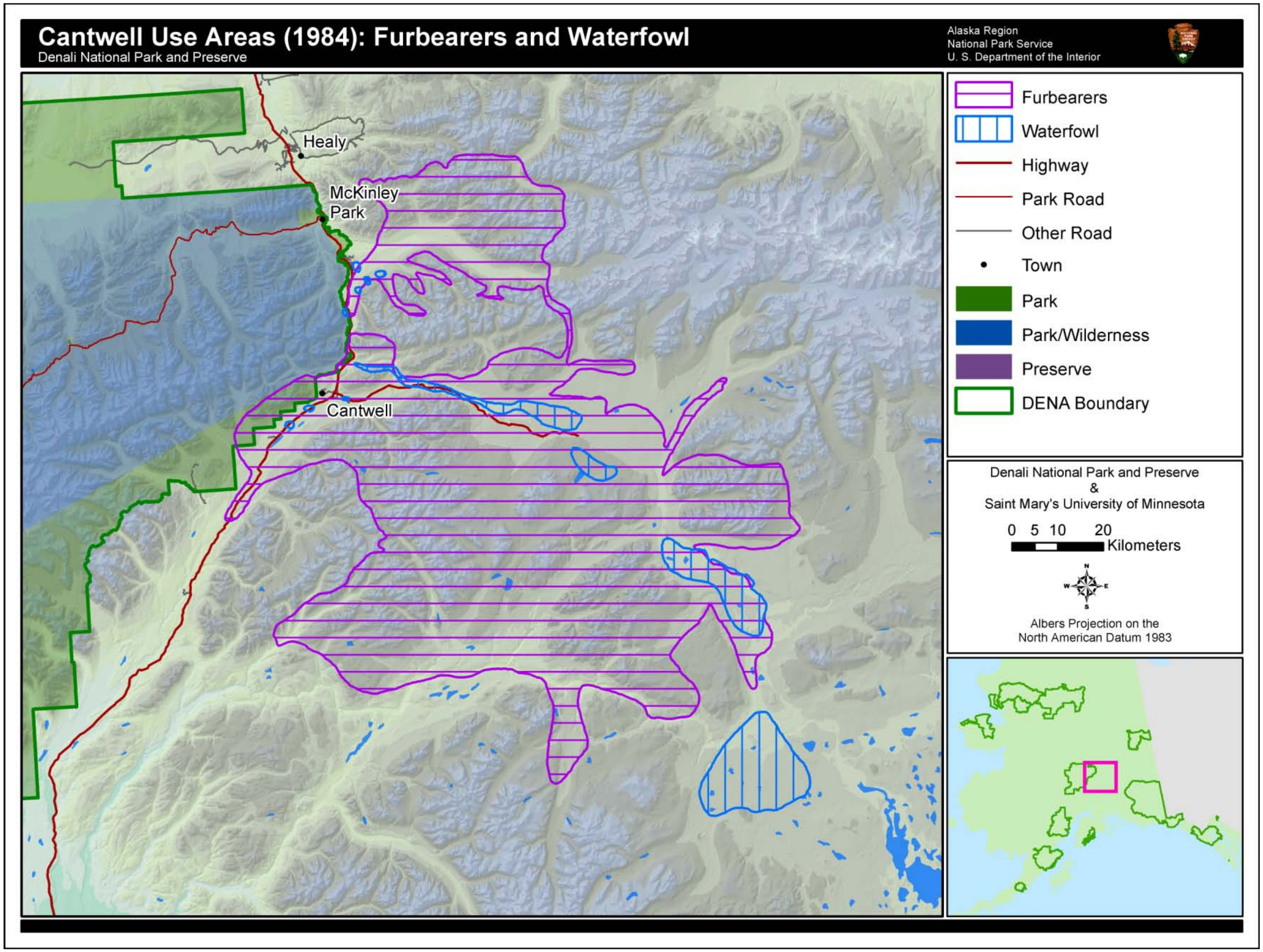

Plate A-4. Cantwell subsistence use areas for furbearers and waterfowl harvest (NPS 2010).

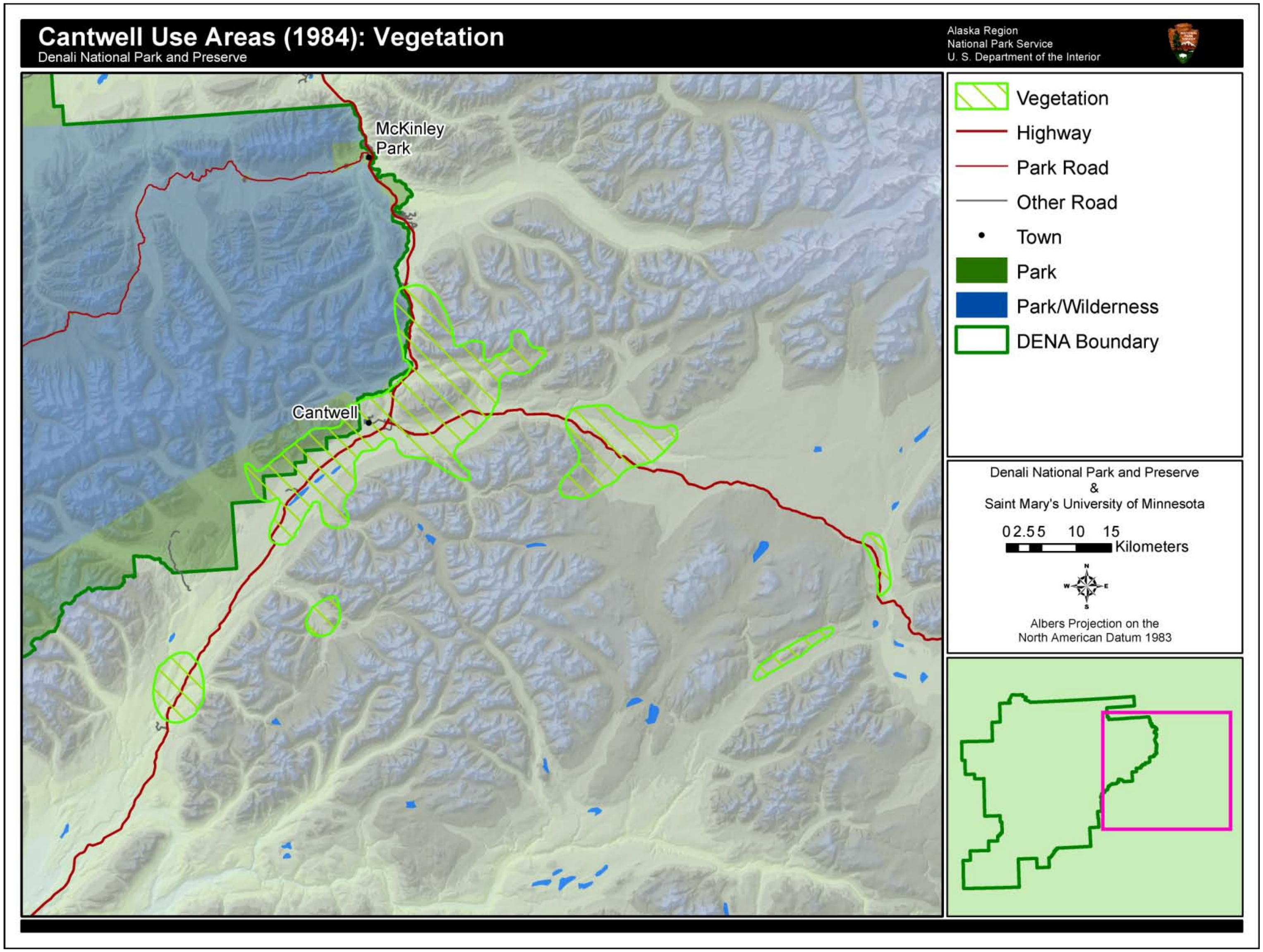

Plate A-5. Cantwell subsistence use areas for vegetation harvest (NPS 2010).

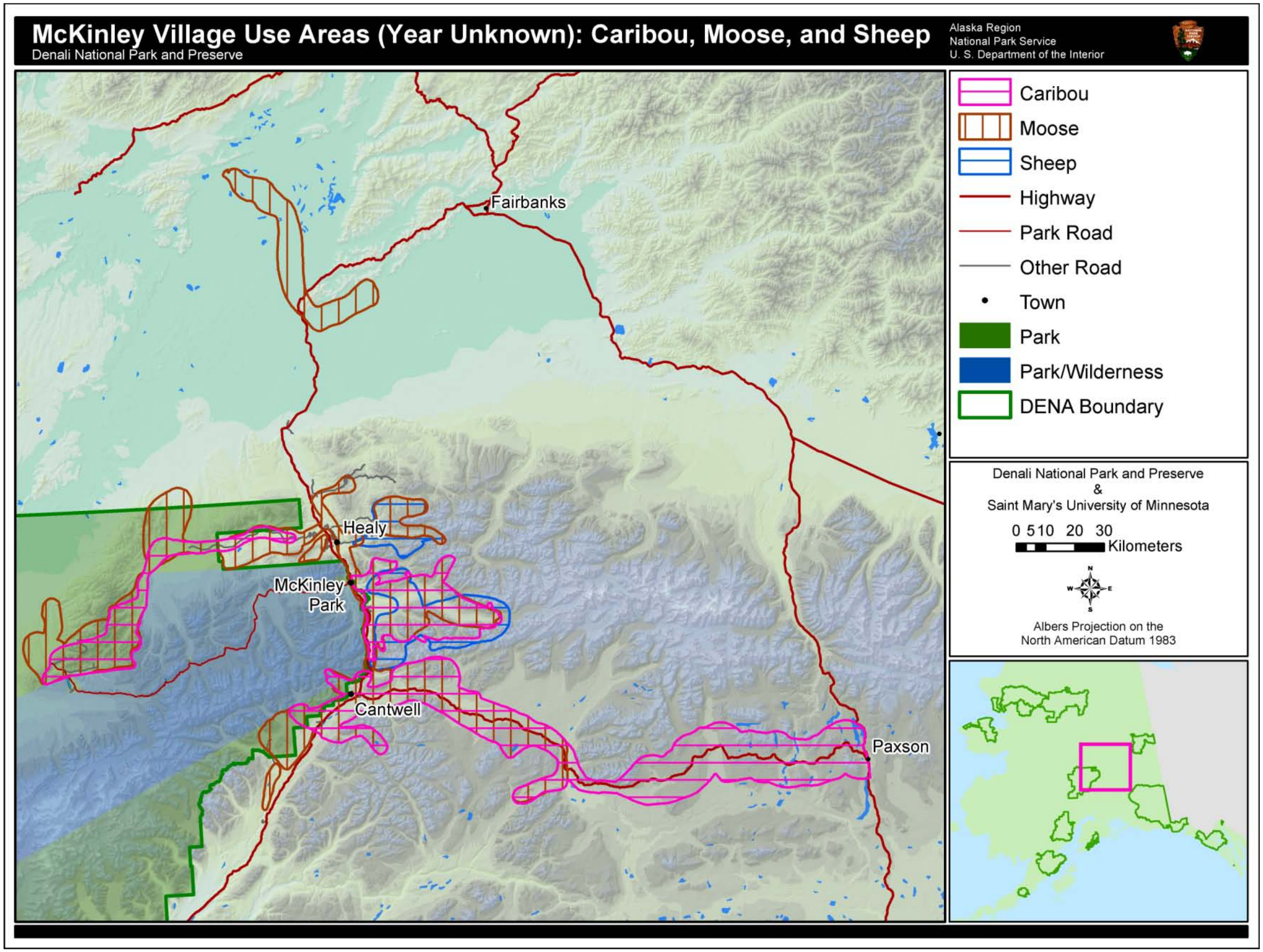

Plate A-6. McKinley Village subsistence use areas for caribou, moose, and sheep hunting (NPS 2010).

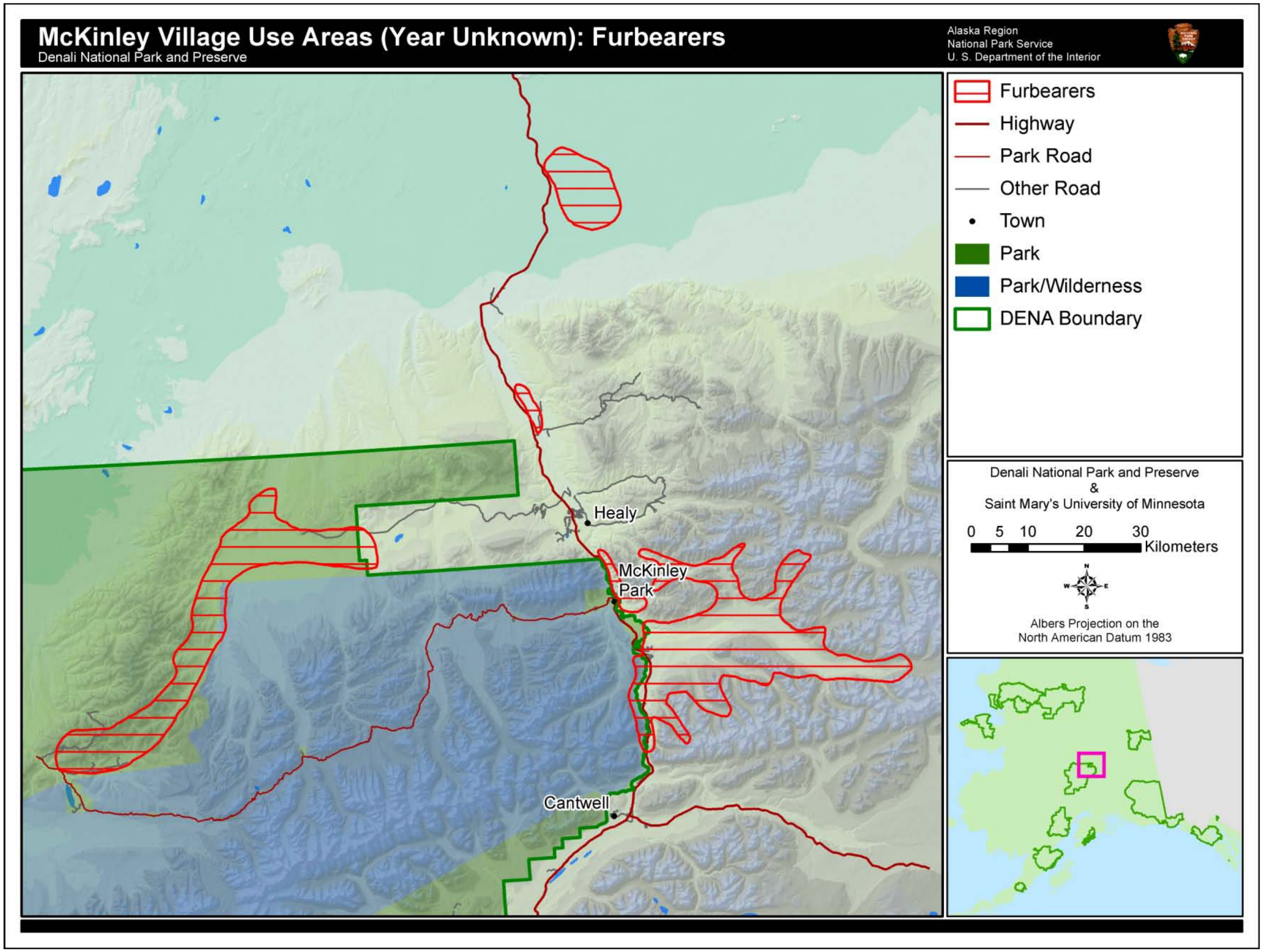

Plate A-7. McKinley Village subsistence use areas for furbearer harvest (NPS 2010).

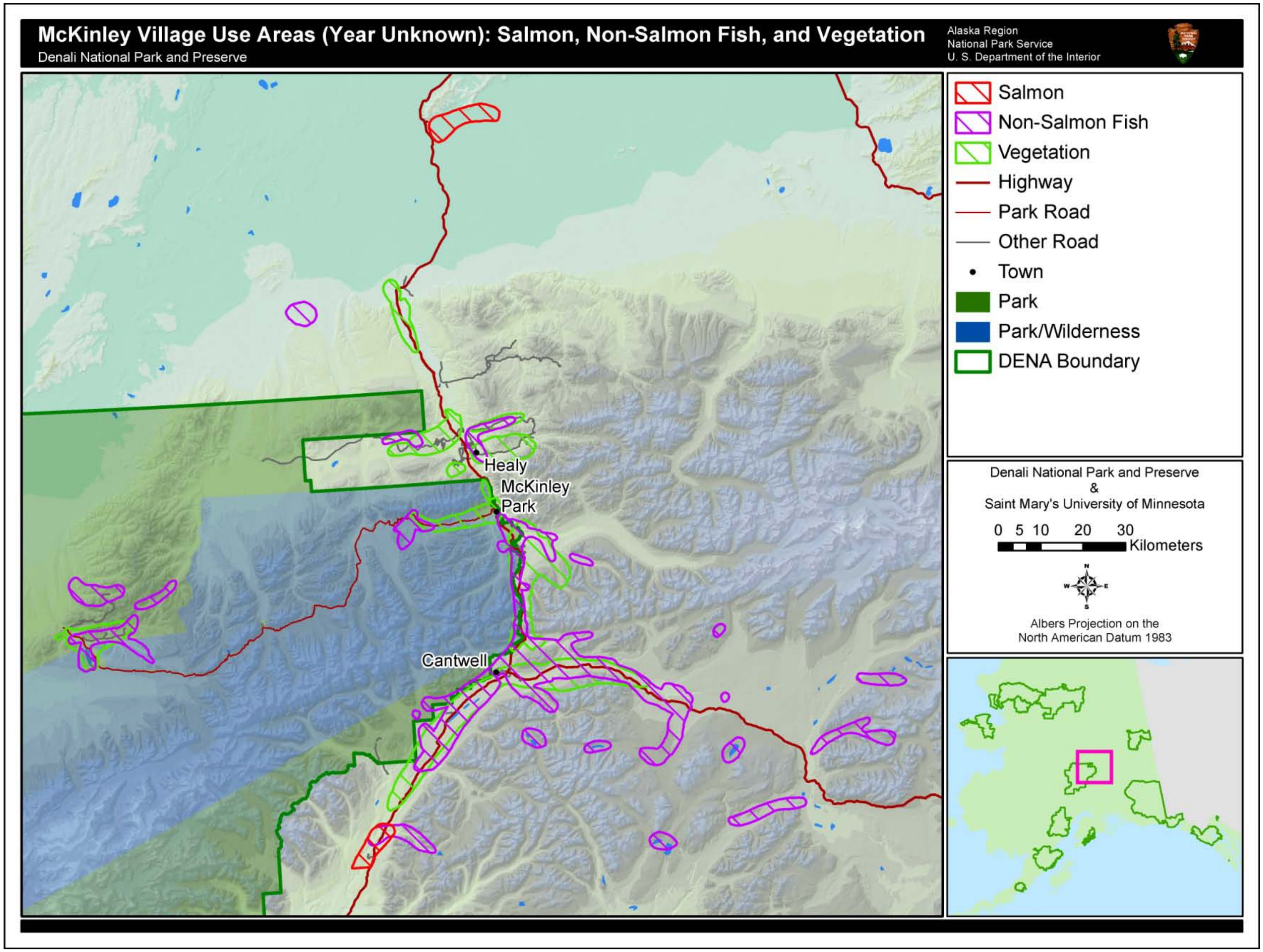

Plate A-8. McKinley Village subsistence use areas for fish and vegetation harvest (NPS 2010).

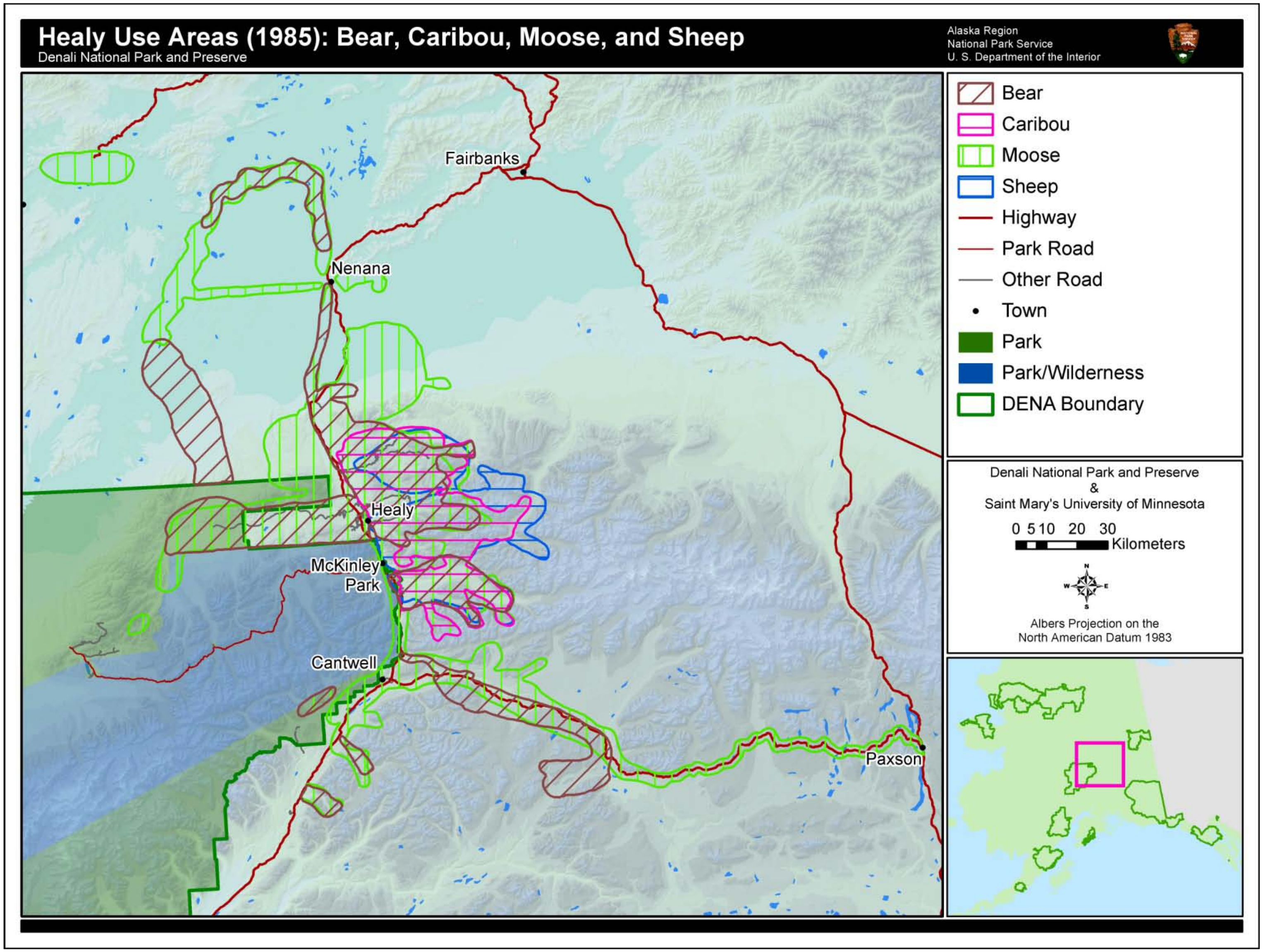

Plate A-9. Healy subsistence use areas for bear, caribou, moose, and sheep hunting (NPS 2010).

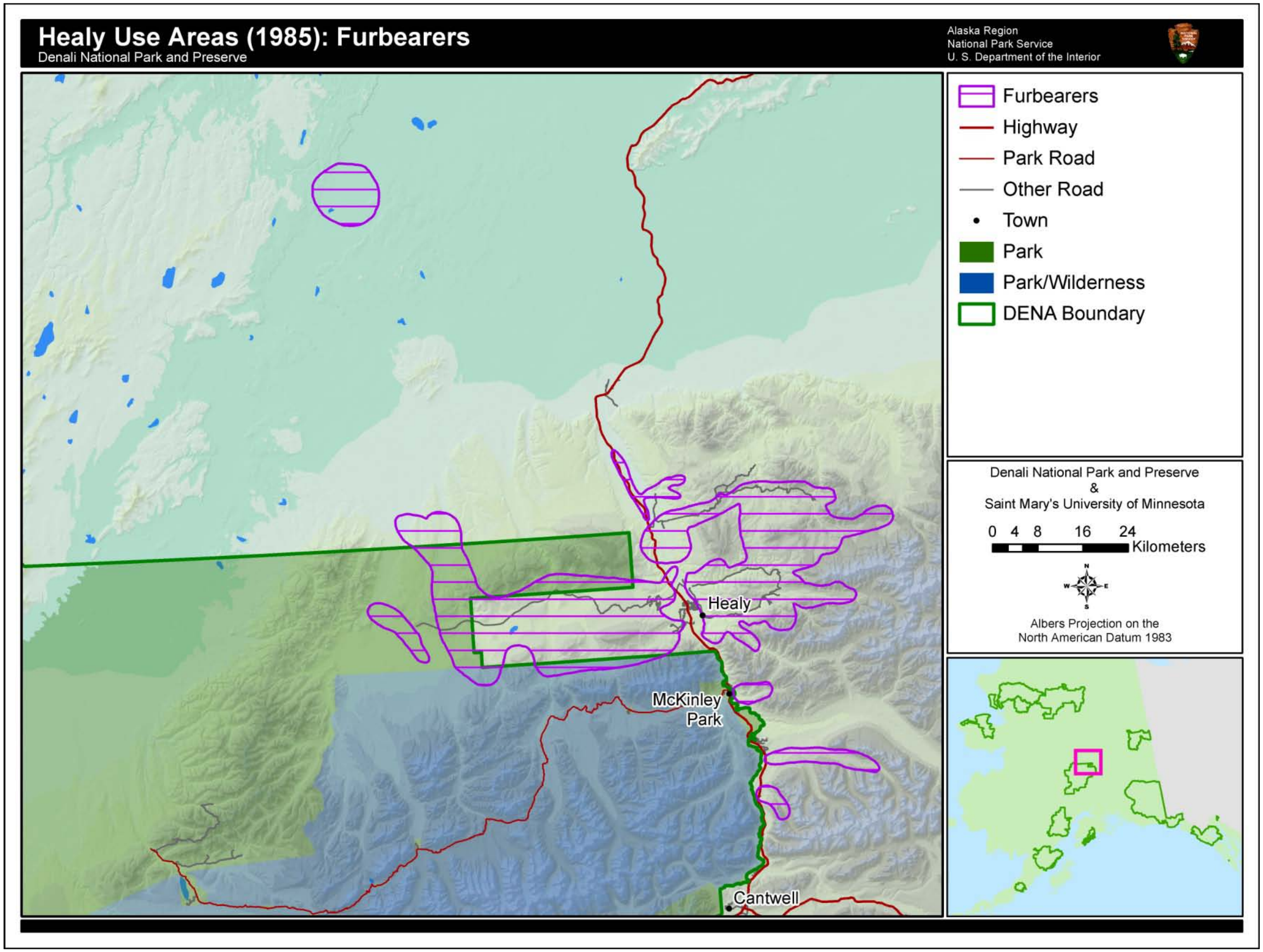

Plate A-10. Healy subsistence use areas for furbearer harvest (NPS 2010).

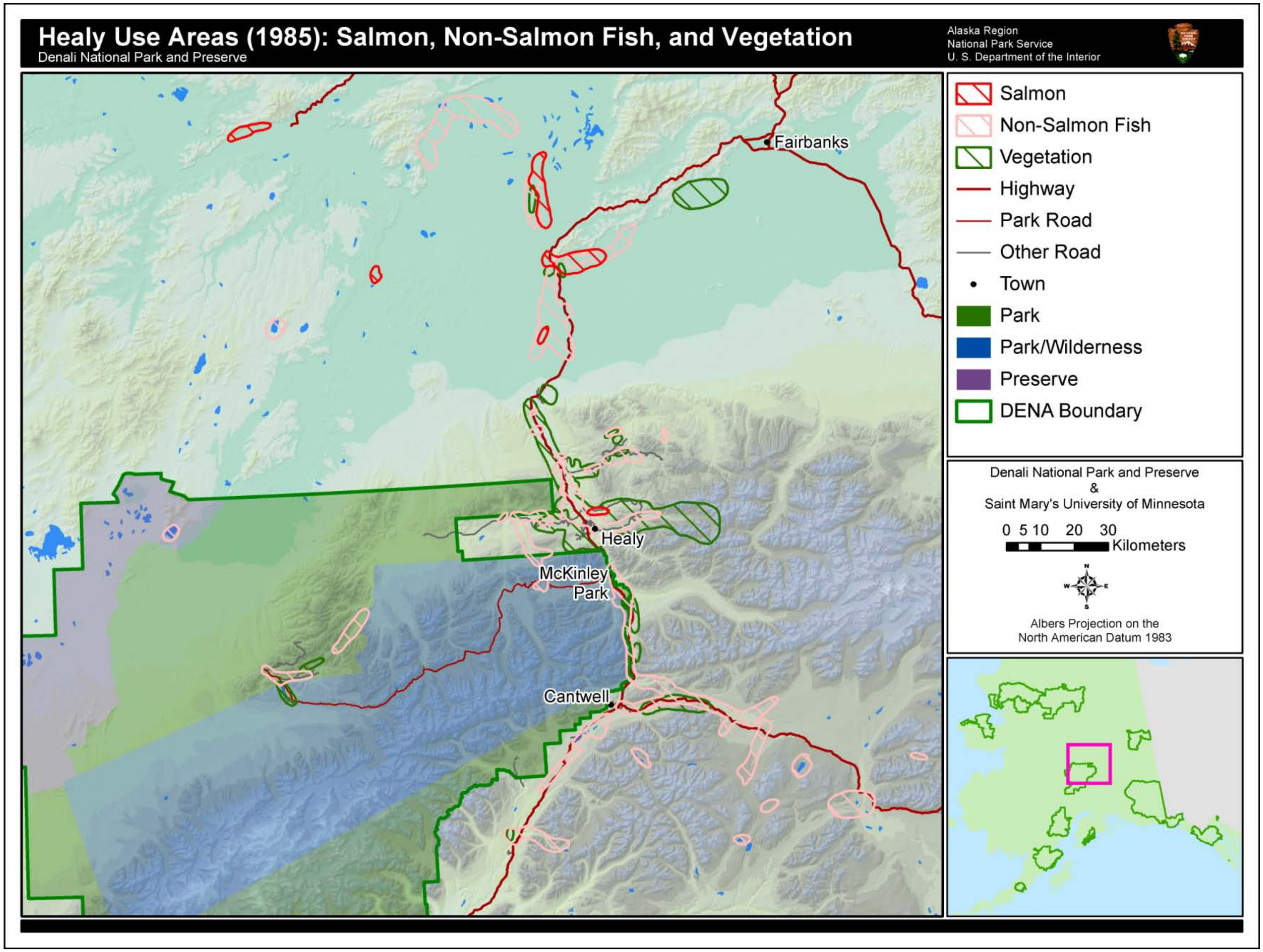

Plate A-11. Healy subsistence use areas for fish and vegetation harvest (NPS 2010).

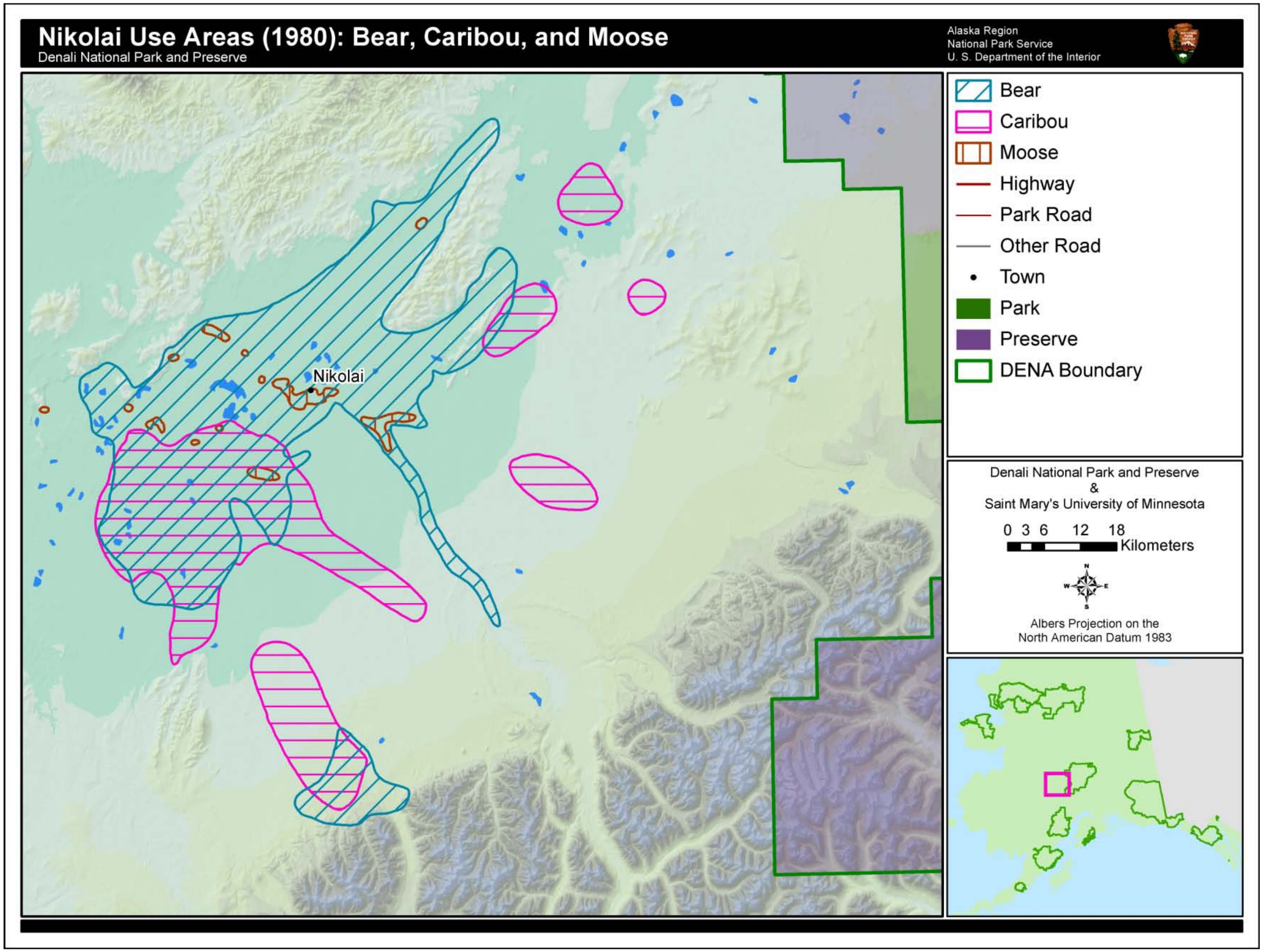

Plate A-12. Nikolai community use areas for bear, caribou, and moose hunting (NPS 2010).

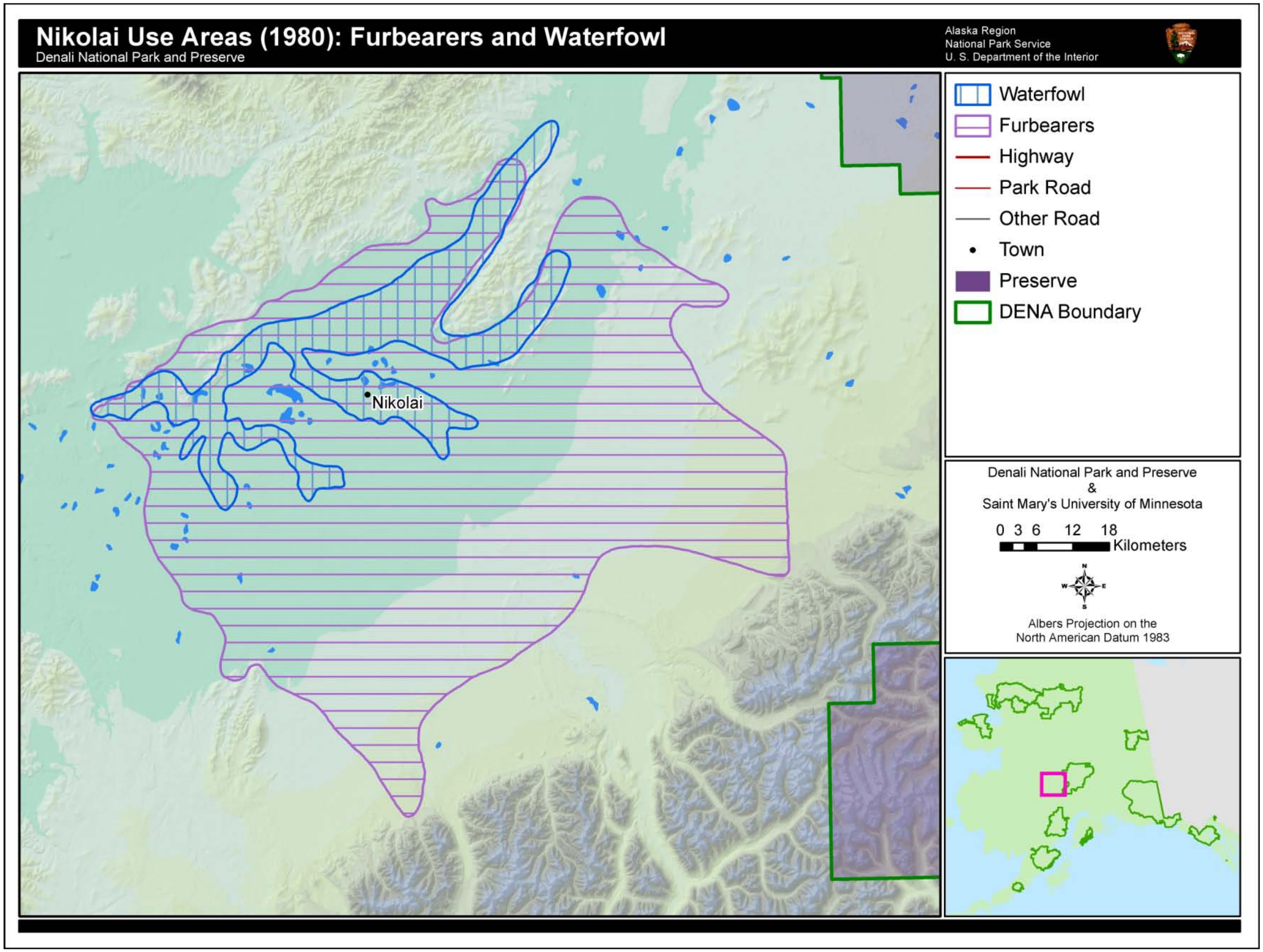

Plate A-13. Nikolai subsistence use areas for waterfowl and furbearer harvest (NPS 2010).

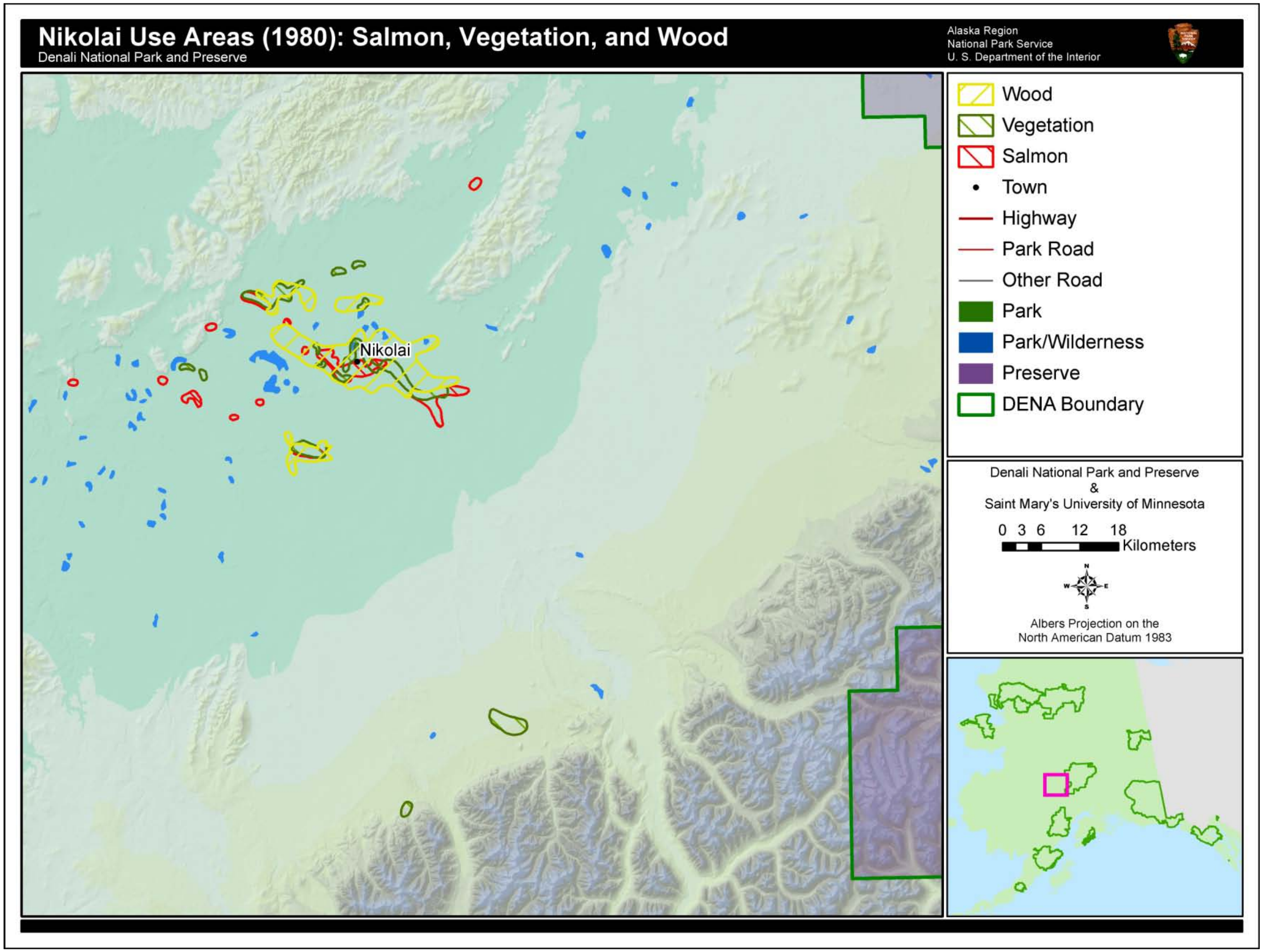

Plate A-14. Nikolai subsistence use areas for salmon, wood, and vegetation harvest (NPS 2010).

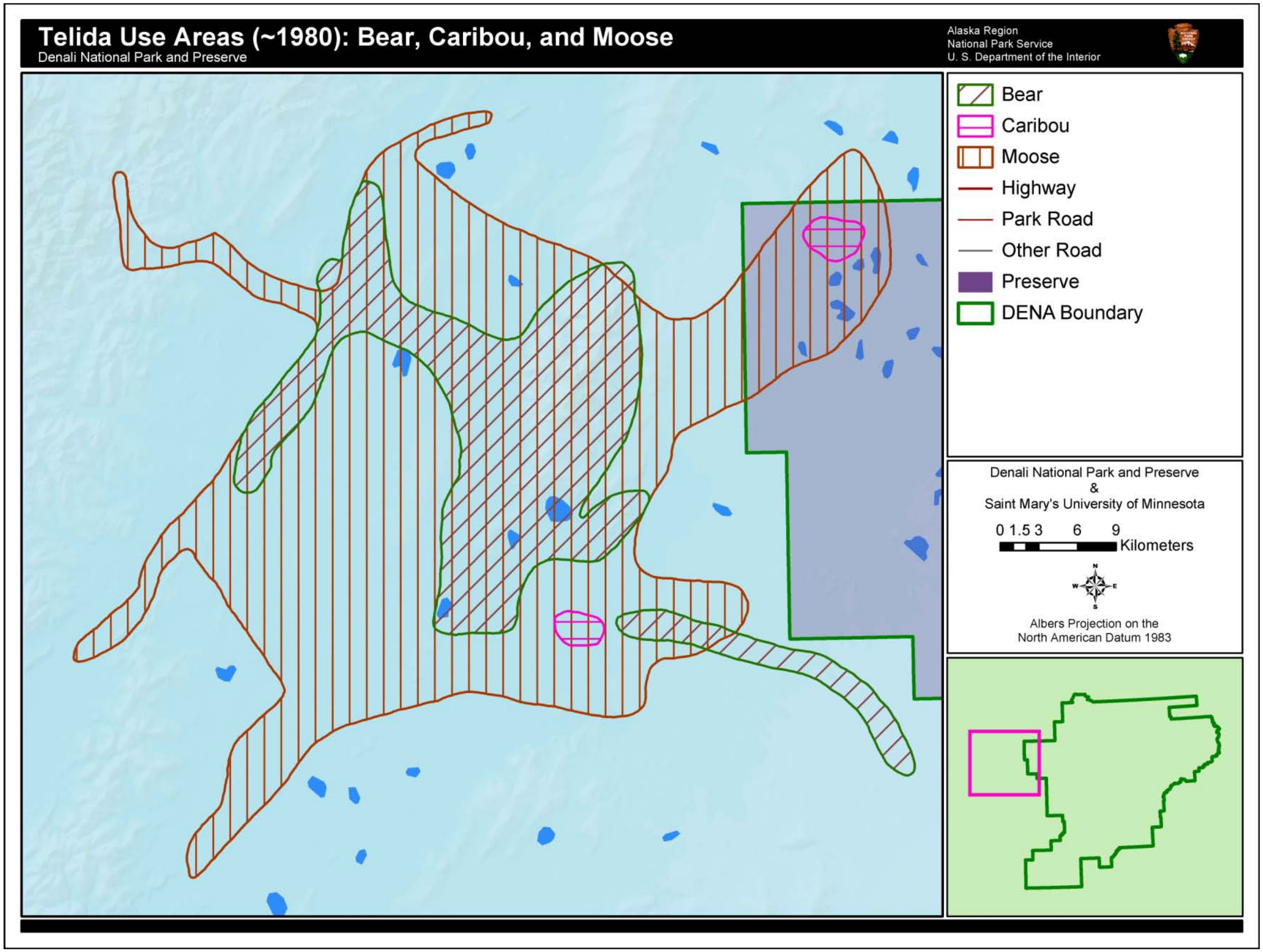

Plate A-15. Telida subsistence use areas for bear, caribou, and moose hunting (NPS 2010).

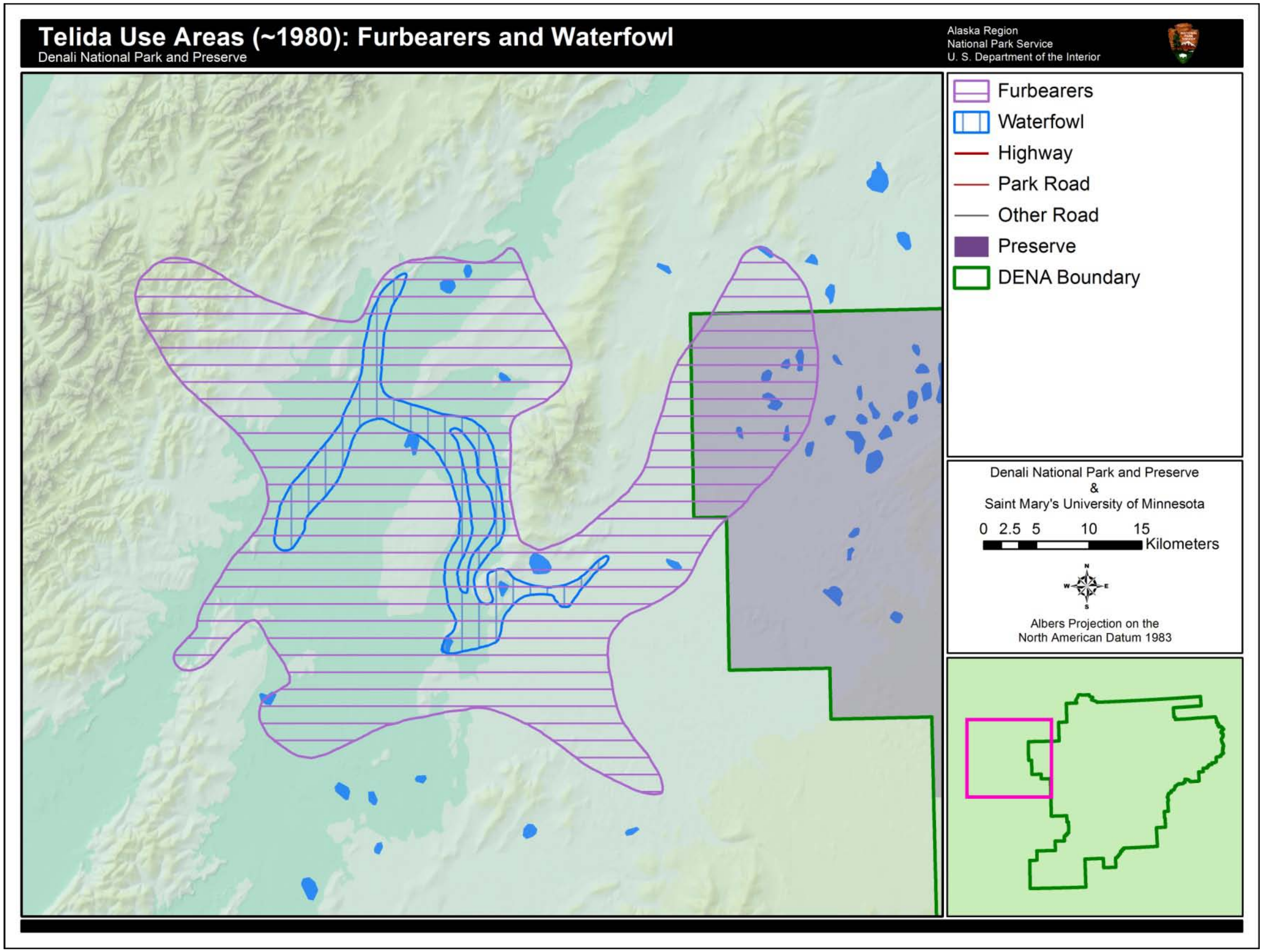

Plate A-16. Telida subsistence use areas for furbearer and waterfowl harvest (NPS 2010).

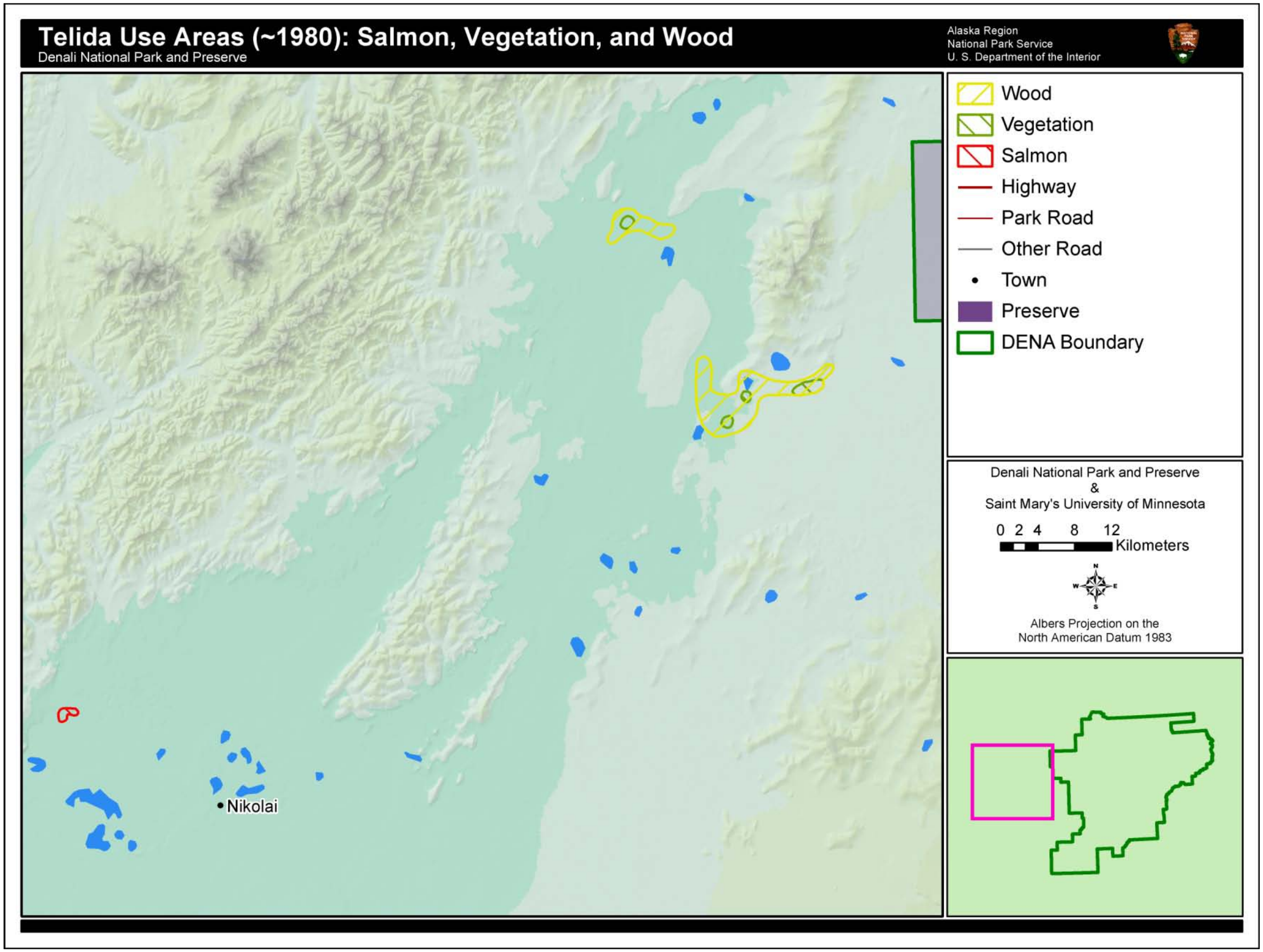

Plate A-17. Telida subsistence use areas for salmon, vegetation, and wood harvest (NPS 2010).

Appendix B. Kantishna water quality analysis

Denali resource staff selected five studies from the early 1980s and one from the mid 1990s for the focus of this project. These studies are described below, followed by two tables summarizing which streams and variables are covered by each study (Table B-4 and Table B- 5). Plate B-1 depicts the water sampling locations from all of these studies and areas identified as disturbed by mining activity within the Kantishna Hills. Sampling methods in all 1980s studies are nearly identical and are therefore directly comparable. The NPS also provided recent data from several streams gathered by the USGS for comparison.

Meyer and Kavanagh 1983:

In 1982, Scott Meyer and Ross Kavanagh studied the fish resources of Kantishna streams and the potential effects of mining activity. Their report includes aquatic habitat descriptions for 27 streams, including several small tributaries not covered in any other studies. Meyer and Kavanagh observed five different fish species in Kantishna streams during their research: Arctic grayling (*Thymallus arcticus*), slimy sculpin (*Cottus cognatus*), Chinook salmon (*Oncorhynchus tshawytscha*), chum salmon (*Oncorhynchus keta*), and the first ever report of round whitefish (*Prosopium cylindraceum*). Three additional species - coho salmon (*Oncorhynchus kisutch)*, northern pike (*Esox lucius*), and inconnu (*Stenodus leucichthys*) - were found in the lower Bearpaw River or Moose Creek by the ADF&G in the mid-1970s but were not observed in 1982. Notable findings are listed in Table B- 1.

Table B-1. Notable fish observations by Meyer and Kavanagh 1983.

Species	Location	Notes
Chinook Salmon	Bearpaw River, below Glacier Creek	Adults observed during an aerial survey
Chum Salmon	Moose Creek, near Kantishna and in the North Fork	Small number of adults
Round Whitefish	Moose Creek and its North Fork	Adults, presumably swimming upstream to spawn in Sept.

Arctic grayling were generally more abundant in streams undisturbed by mining. The potential effects of mining on fish health were shown by comparing grayling size and abundance in unmined Eldorado Creek above and below its confluence with Slate Creek which was mined (Table B-2). Grayling were generally larger and more frequent above Slate Creek's mining influence than below or in Slate Creek itself.

Table B-2. Arctic grayling sampling results on Eldorado Creek (unmined) above and below Slate Creek (mined) and on Slate Creek (Meyer and Kavanagh 1983).

Stream	# of fish	Fish/km	Fork length (mm)		Weight (g)	
			Mean	Range	Mean	Range
Eldorado above Slate	20	33.3	272	185-365	239	68-555
Eldorado below Slate	21	4.6	253	108-352	202	34-475
Slate Creek	4	2.4	207	174-252	106	57-174

The full report includes species occurrence, abundance, and habitat disturbance by stream, as well as detailed information on grayling sampling results.

West and Deschu 1984:

During 1983, Robin West and Nancy Deschu gathered data on heavy metal concentrations in Kantishna streams and their possible effects on Arctic grayling populations. Their results showed that metal concentrations in water were often higher downstream of mining activity, with arsenic and mercury of the most concern due to their high toxicity (Table B-3). Iron and manganese concentrations were also high but were of lesser concern due to their lower toxicity. Metal concentrations in several mined streams regularly exceeded EPA water quality criteria. In addition, West and Deschu found that metal concentrations were generally higher in grayling from mined streams than in those from unmined streams. Histopathological analysis of sampled grayling also showed more change or damage in the gill tissues of fish from mined streams.

Table B-3. Total heavy metal concentrations (mg/L) for two Kantishna streams, above and below mining activity, in 1983 (West and Deschu 1984).

Stream	Arsenic	Mercury	Iron	Manganese	Lead
Eldorado - above	0.0026	<0.0002	<0.004	<0.0025	<0.0007
- below	2.645	0.0032	28.9	0.385	0.175
Friday - above	0.0044	<0.0002	0.073	0.0105	0.0007
- below	0.785	0.0035	40.5	6.215	0.845

Deschu 1985a (arsenic):

During 1983 and 1984, Nancy Deschu collected water quality data, sediment samples, and slimy sculpin (*Cottus cognatus*) from two mined and two unmined streams in the Kantishna Hills. Her objective was to study the effects of placer mining on arsenic levels in stream water, sediment, and fish. Sculpin were chosen for study because unlike Arctic grayling, the other common fish species in Kantishna streams, sculpin do not migrate and spend most of their lives on stream bottoms, feeding on bottom organisms and potentially ingesting sediment. While arsenic occurs naturally in the earth's crust, it is a major concern to environmental scientists because of its high toxicity.

Deschu found that total arsenic concentrations in water were highest below mining activity. Turbidity, settleable solids, and other metal concentrations also increased below mining activity on the two mined streams. Arsenic levels in sediment were actually higher in the headwaters than in lower portions of three of the four streams, demonstrating "the important role the underlying geologic structure plays in determining metal concentrations in stream water" (Deschu 1985a). Arsenic concentrations in sculpin livers were found to be directly correlated to sediment arsenic levels. The mean length and width of sculpin were lower in mined streams than in unmined streams. However researchers could not determine if this was due to higher turbidity or elevated arsenic levels. Deschu concluded that mining activity elevates arsenic levels in water and fish, although concentrations were below the EPA criteria for freshwater aquatic life at that time.

Deschu 1985b (turbidity):

In this report, Nancy Deschu focuses on turbidity and settleable solids in mined and unmined Kantishna streams. Data from 1979 through 1984 is analyzed, although the majority of data is from 1984. She determined that turbidity and settleable solids conditions had "deteriorated dramatically" between 1980 and 1984, coinciding with an increase in heavy mining activity upstream. While natural background turbidity levels for Kantishna streams averaged 1-2

Nephelometric Turbidity Units (NTU), mined streams often exceeded 100 NTU with several sites reporting turbidities above 1000 NTU. The highest recorded turbidity was 6200 NTU during mining activity on Glen Creek in 1984. Deschu determined that mining wastewater can affect streams as far as 33 km downstream from any activity. However she also found that natural background levels of turbidity and settleable solids are often recovered within a year of cessation of mining activity.

Deschu and Kavanagh 1986:
Nancy Deschu and Ross Kavanagh reported on general water quality data collected in 1983 from 20 Kantishna streams, both mined and unmined. Detailed descriptions for each stream include water temperature, discharge, pH, alkalinity, hardness, turbidity, settleable solids, conductivity, fish observations, and reports of any mining activity. Deschu and Kavanagh found that an increase in mining activity from 1982 to 1983 lead to a decrease in the water quality of Kantishna streams. Turbidity, settleable solids, and metal concentrations all increased below mining activity and appeared to impact fish populations in these areas. High iron concentrations actually caused orange discoloration in some streambeds. Mining-related roadbuilding further contributed to increased turbidity and settleable solids.

Edwards and Tranel 1998:
From 1994 to 1996, Pamela Edwards and Michael Tranel collected water quality data for streams and rivers throughout Denali National Park and Preserve. One of their objectives was to "determine present condition and level of recovery since 1985 in streams in the Kantishna Hills that were placer mined" (Edwards and Tranel 1998). Data was collected for nine of the streams that had been studied in the early 1980s. They found that turbidity and suspended sediments were extremely low in all streams and were similar in mined and undisturbed areas. Sulfate, calcium, and magnesium ion concentrations were generally higher in mined streams, although researchers could not determine if this was due to mining history or natural geological differences. Although metal concentrations were not analyzed, Edwards and Tranel believed that high pH levels in Kantishna streams suggested that dissolved metal concentrations were not high.

Recent developments:
The CAKN flowing waters monitoring program has included Moose Creek at the park road bridge as one of its regular sampling sites. In 2007 and 2008, Moose Creek produced the highest number of macroinvertebrate taxa of all streams sampled in the park and preserve, with 29 and 33 taxa respectively (Simmons 2009 and 2010). Juvenile Chinook salmon were captured at the Moose Creek Bridge in 2007, marking a 40 km expansion of their known range in the drainage.

In 2008, Tim Brabets of the USGS began a comprehensive analysis of water quality in previously mined Kantishna streams (DENA 2010a). A closer look is being taken at Slate Creek, which is currently classified as an "impaired waterway" by the Clean Water Act (CWA). Restoration efforts have taken place on several streams, including Glen, Slate, and Caribou Creeks, and are planned for lower Moose Creek in the near future (DENA 2010a and b). Caribou Creek was removed from the CWA impaired waterways list in 2010 (DENA, Adema, pers. comm. 2011).

Table B-4. Kantishna streams covered by seven different studies. Streams in bold are discussed in this text and locations are shown on Plate B-1.

Stream Name	Meyer and Kavanagh 1983	West and Deschu 1984	Deschu 1985a	Deschu 1985b	Deschu and Kavanagh 1986	Edwards and Tranel 1998	USGS 2010
Bearpaw River	X			X	X		
Beauty (Bearpaw tributary)				X			
Canyon (Clearwater tributary)				X	X		
Caribou	X	X	X	X	X	X	X
Clearwater Fork	X	X		X	X		
Crevice (Caribou tributary)	X						
Eldorado	X	X		X	X		X
Eureka	X			X	X	X	X
Flat (Glacier tributary)	X				X		
Friday	X	X		X	X	X	X
Glacier	X	X	X	X	X	X	
Glen	X	X		X	X	X	X
Jumbo	X			X	X	X	
Lake (Moose tributary)	X						
Last Chance (Caribou tributary)	X						
Moonlight		X	X	X	X		
Moose	X	X		X	X	X	X
Myrtle		X	X	X	X		
Rainy	X			X	X	X	
Reinhart (Eldorado tributary)	X						
Rock	X			X	X	X	X
Slate	X	X		X	X		X
Spruce	X	X		X	X		
Stampede	X	X		X	X		
Stony (Clearwater tributary)				X	X		
Twentytwo Gulch (Glacier tributary)	X						
Willow	X			X	X		
Yellow (Glacier tributary)				X			

Table B-5. Variables sampled in each study. Edwards and Tranel 1998 is not included in this table, as actual data was not available from their research.

Variable	Meyer and Kavanagh 1983	West and Deschu 1984	Deschu 1985a	Deschu 1985b	Deschu and Kavanagh 1986	USGS 2010
Water temperature	X	X	X		X	X
pH	X	X	X		X	X
Hardness		X	X		X	
Alkalinity	X	X	X		X	X
Turbidity	X	X	X	X	X	X
Settleable Solids		X	X	X	X	X
Discharge	X	X	X	X	X	X
Metal concentrations		X	X			x
Conductivity	X		X		X	X
Dissolved Oxygen			X			X
Grayling physical characteristics	X	X			X	
Grayling metal concentrations		X				
Slimy sculpin			X			

Individual stream descriptions:

To better understand the history and condition of Kantishna area streams, many of the creeks are described here individually. The majority of these streams were disturbed by mining and all streams recently sampled by the USGS (2010) are included. Two tables summarizing dissolved metal concentrations over time and 1982 grayling sampling in several of these creeks can be found at the end of this report (Table B-18 and Table B-19), along with several graphs showing changes in dissolved metal concentrations in selected streams over time (Figure B-3 through Figure B-8). Overall, turbidity has decreased in all placer-mined streams since mining activity ceased in the mid-1980s (Figure B-1). pH has increased slightly in most streams since mining stopped (Figure B-2), perhaps reflecting the highly mineralized geology of the area.

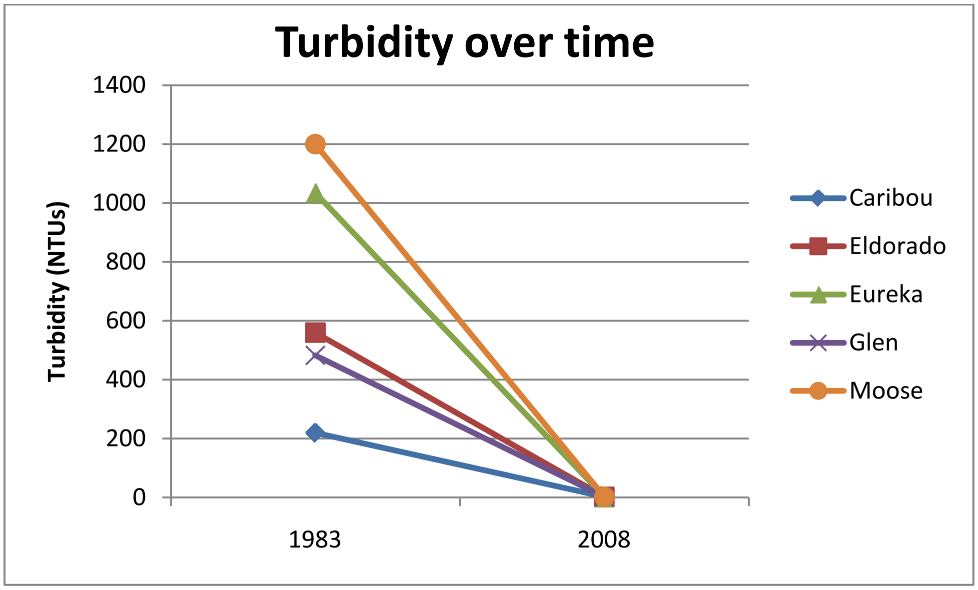

Figure B-1. Changes in turbidity for selected Kantishna streams since mining ceased in the mid-1980s. All included 1983 measurements were taken below mining activity. The most dramatic change occurred on Friday Creek (not shown here due to scale), where turbidity decreased from 2,900 NTUs to just 2.4 NTUs over the same time period.

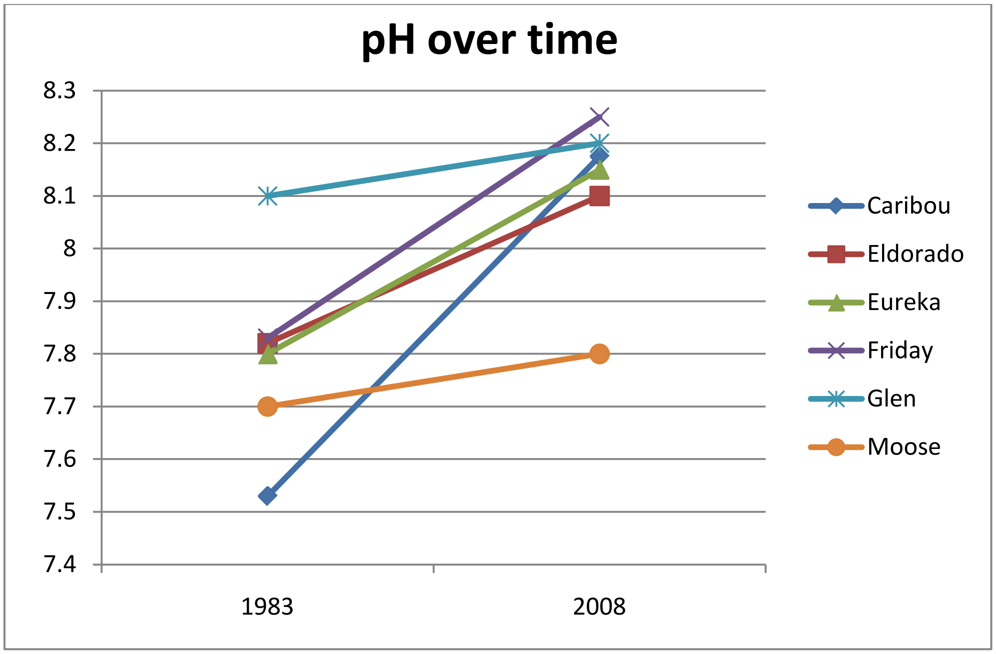

Figure B-2. Changes in pH for selected Kantishna streams since mining ceased in the mid-1980s. All included 1983 measurements were taken below mining activity. pH also increased on Slate Creek from 5.51 to 6.95 (not shown due to scale).

Caribou Creek

Caribou Creek rises on the western side of the highest peaks in the Kantishna Hills (Meyer and Kavanagh 1983). It was mined from 1905 to 1985 and has the most extensive placer-mining related damage of any stream in the Kantishna Hills (DENA 2010b, Mangi Environmental Group 2005). In the early 1980s, large tailing piles were still present from intensive mining in the early 1940s (Deschu 1985a). These symmetrical piles separated the stream "into braided channels of fairly uniform width and depth" for nearly 6.4 km of the creek (Meyer and Kavanagh 1983). The tailing piles and the entire floodplain were reportedly "nearly devoid of vegetation" in 1982, even though mining had not occurred since 1945 (Meyer and Kavanagh 1983).

 

Photo B-1. Aerial photo of Caribou Creek (left), showing tailing piles and lack of vegetation (NPS photo, in DENA 2010a). Tailing piles can also be seen on the left in an aerial photo of Caribou Creek from 2007 (NPS photo, in Norris 2008).

During 1982, two small suction dredge operations worked on Caribou Creek for approximately one month (Deschu and Kavanagh 1986). Mining intensified in 1983, with three placer mining operations involving heavy equipment operating throughout that summer and again in 1984 (Deschu and Kavanagh 1986, Deschu 1985a). Deschu (1985a) found that turbidity, settleable solids, conductivity, and arsenic and iron concentrations in water were all higher below mining activity than in the headwaters, while pH, alkalinity, and hardness decreased below mining. Dissolved oxygen levels were high throughout the creek, but were lower below mining activity (Deschu 1985a). Arsenic in stream sediment was actually higher at the headwaters and midstream than at the stream mouth, suggesting a natural geological source (Deschu 1985a). Deschu and Kavanagh (1986) reported that total iron, total zinc, and total and dissolved mercury below mining “were found in concentrations that are of concern.”

Turbidity and settled solids were a particular concern, given Caribou Creek’s importance as fish habitat. The creek was a known salmon spawning area in the 1970s and 80s and grayling were also believed to spawn there (Meyer and Kavanagh 1983). Meyer and Kavanagh (1983) reported that Miller (1981) collected 67 juvenile salmon in the lower 1.6 km of the creek in July of 1981. Salmon spawning and rearing habitat appeared best in the lower 6 km where pools and slow runs comprised approximately 50% of the stream, with Miller (1981) reporting some pools up to 3.5 m deep (Meyer and Kavanagh 1983). The largest grayling (635 g) caught in Kantishna streams by Meyer and Kavanagh (1983) was in Caribou Creek. However, Deschu and Kavanagh (1986) noted that many of the deep slow pools, particularly next to cliffs, “are filling in with settled solids.” Deschu (1985b) observed settled solids up to one foot thick in many areas of the creek, with some solids in wide, shallow areas of the lower reaches forming an “armor layer” that would make it extremely difficult for stream waters to re-suspend and transport the sediments further downstream.

While there is no evidence of placer mining on any of Caribou Creek’s tributaries, an antimony lode mine operated near the mouth of Last Chance Creek from 1969-1974 (Meyer and Kavanagh

1983). West and Deschu (1984) found higher concentrations of antimony above mining on Caribou Creek than below, indicating a likely natural geological source.

USGS water sampling shows that dissolved metal concentrations have decreased in Caribou Creek since mining activity ceased (Table B-18,). Restoration efforts took place on upper Caribou Creek in 2010, including recontouring of the stream and tailing piles, construction of bank reinforcement structures, and revegetation. This restoration contributed to the removal of Caribou Creek from the CWA "impaired waterways" list in 2010 (DENA, Adema, pers. comm. 2011).

Table B-6. Physical and chemical characteristics of Caribou Creek over time, above and below areas of mining activity. All samples were taken between June and September (From Meyers and Kavanagh 1983, Deschu 1985a, and USGS 2010).

	1982	July 1983		July 1984		2008		2009	
		above	below	above	below	above	below	above	below
Water temp (°C)	5-10	7.92	7.53	7.74	7.63	4.4	7.6	7	11.5
Discharge (cfs)*	9-46	0.43(cms)	1.61	0.29 (cms)	1.56	11.3	77.25	5.1	35.5
Turbidity (NTU)	0.27-0.48	0.5	220	0.63	162	<2	<2	<2	<2
pH	7.89-7.91	7.92	7.53	7.74	7.63	8.2	8.175	8.15	8.15
Alkalinity (mg/L)	69-87	68	80	110	89	115	90	124.5	86.5

* Note that discharge measurements from 1983 and 1984 are in cubic meters per second (cms) rather than cubic feet per second (cfs).

Eldorado Creek

Eldorado Creek has its source in the open Tundra southwest of Kantishna and Moose Creek (Meyer and Kavanagh 1983). Its upper reaches, above the confluence with Slate Creek, were relatively undisturbed and still contained "productive aquatic habitat" in 1982 (Meyer and Kavanagh 1983). Invertebrate and vegetation densities were high in this area (Deschu and Kavanagh 1986) and Arctic grayling were abundant, suggesting a major spawning area somewhere between the headwaters and the mouth of Slate Creek (Meyer and Kavanagh 1983). Placer mining on Eldorado Creek was sporadic since before 1916 and occurred primarily near its mouth on Moose Creek (Meyer and Kavanagh 1983). During 1982, mining along Eldorado Creek where it enters the Moose Creek valley resulted in repeated cutting and moving of the stream channel, including the construction of a series of settling ponds just before it enters Moose Creek. A steep artificial cascade at the creek's mouth in 1982 also appeared to be preventing upstream fish passage (Meyer and Kavanagh 1983). Although no mining occurred on the Eldorado in 1983, mining continued on its Slate Creek tributary (Deschu and Kavanagh 1986).

Deschu and Kavanagh (1986) found that heavy metals were a significant concern on lower Eldorado Creek "as several different metals are present at concentrations of concern", likely as a result of mining on Slate Creek. Luckily the natural "hardness" of the stream is also high, which can counteract some of these metals' toxic effects (Deschu and Kavanagh 1986). They also observed accumulated sediments from past mining along the streambanks of lower Eldorado Creek. Mark Oswood of the University of Alaska Fairbanks reported that aquatic vegetation and insect biomass in the Eldorado were much lower below the Slate Creek confluence (Deschu and

Kavanagh 1986). Surprisingly, no slimy sculpin were observed anywhere in Eldorado Creek by Meyer and Kavanagh (1983). It was the only Kantishna stream where grayling were abundant but sculpin were not found (Meyer and Kavanagh 1983).

Two unnatural sulfide seeps on the east bank approximately two kilometers upstream from the mouth of Eldorado Creek were a major concern during the early 1980s. According to Deschu and Kavanagh (1986), a strong hydrogen sulfide odor was present at both seeps in 1983 and rocks downstream showed red-orange iron stains or precipitates. The downstream seep appeared to be an old water-filled mining test pit along the road. Water sampled at this site had an alkalinity of 692 mg/L with a conductivity of 2500 micromhos/cm and a total iron concentration of 2.61 mg/L (Deschu and Kavanagh 1986). The upstream seep was apparently an attempted road cut next to the established road. Alkalinity at this site was the highest recorded in the Kantishna Hills at 1005 mg/L (Deschu and Kavanagh 1986). Conductivity measured 2000 micromhos/cm and total iron concentration was 5.6 mg/L. Deschu and Kavanagh (1986) reported "what appeared to be iron deposits" on willows overhanging the road cut. The combination of a high iron concentration and a low pH of 6.37 indicated the presence of exposed pyrite (FeS_2). A rock sample from the road cut showed "high concentrations of *Thiobacillus ferrooxidans*, a bacterium which gains its energy from oxidizing iron and sulfur… they are, in essence, releasing heavy metals into the stream" (Deschu and Kavanagh 1986). Fish sampling by Meyer and Kavanagh (1983) above and below the sulfur seeps yielded similar results, suggesting that fish are not affected by their influence on the water chemistry of the creek.

Mark Oswood and Kathleen Wedemeyer have studied the effects of heavy metals from mining on aquatic ecosystems, particularly macroinvertebrates, in Eldorado and Slate Creeks, along with the ecosystem's potential for recovery once mining has ceased. Their findings are discussed in Wedemeyer 1987 and Oswood et al. 1990.

Most dissolved metal concentrations have decreased in Eldorado Creek since mining ceased, with the exception of iron (Table B-18, Figure B-8). This could be due to the unnatural sulfide seeps or a natural geologic source in the watershed. Alkalinity has also increased since mining stopped (Table B-7).

Table B-7. Physical and chemical characteristics of Eldorado Creek over time. 1983 samples were taken just above and below the confluence with Slate Creek while 2008 sampling occurred near the creek's mouth (from Meyer and Kavanagh 1983, Deschu and Kavanagh 1986, and USGS 2010).

		1983		
Parameter	**1982**	**above**	**below**	**2008**
Water temp (°C)	3-8	4-5.5	6-12.5	4.5-6
Discharge (cfs)	8-25	1.9-2.7	4.6-6.6	9-19
Turbidity (NTU)	0.66-2.4	0.35-0.5	6.2-560	<2
pH	7.67-7.95	7.67	7.82	8-8.2
Alkalinity (mg/L)	72-116	92.2-96.5	65.2-88	136-156

<u>Eureka Creek</u>
Eureka Creek is a small tributary of Moose Creek just northeast of the town of Kantishna (Meyer and Kavanagh 1983). It was one of the first Kantishna streams where gold was discovered in

1904 (Mangi Environmental Group 2005). Placer mining began in 1906, although there was little activity between 1945 and 1961 (Meyer and Kavanagh 1983). At least two mining operations were active in 1982, and by the end of that summer Meyer and Kavanagh (1983) reported that "approximately 88% of the aquatic and riparian habitat along the length of the stream had been altered in the course of placer mining." Disturbance included channelization, relocation, and straightening of the channel, road and settling pond construction, and vegetation clearing. Mining also occurred in 1983 and 1984, with substantial road-building activity and stream rechannelization in 1983 (Deschu and Kavanagh 1986).

Photo B-2. This 1985 aerial photo shows placer mining activity at the mouth of Eureka Creek. The park road is visible in the foreground (NPS photo, in Norris 2008).

Meyer and Kavanagh (1983) reported that aquatic habitat above mining activity on Eureka Creek "appears pristine, but the lack of water and suitable pools make this section of stream unsuitable for supporting many fish." However, high turbidity and settleable solids, primarily from road building, were a major concern in 1983. Turbidity on Eureka Creek was 3.8 NTU with no disturbance, 13 NTU after rain, 610 NTU after rain during mining activity, and 1460 NTU after rain during road work (Deschu and Kavanagh 1986). These high turbidity levels were "an ecological stress to what may remain of the Eureka Creek grayling population" and also to fish populations in Moose Creek (Deschu and Kavanagh 1986).

Restoration efforts began on lower Eureka Creek in the late 1990s. Over 20 tons of mining debris were removed, 500 feet of floodplain and stream channel were reconstructed, and stream banks were revegetated (Mangi Environmental Group 2005). This work is described in Karle and Griffiths 1999.

Table B-8. Physical and chemical characteristics of Eureka Creek over time. All samples were taken between June and September. 1983, 2008, and 2009 samples were taken near the stream's mouth (From Meyer and Kavanagh 1983, Deschu and Kavanagh 1986, and USGS 2010).

Parameter	1982	1983	2008	2009
Water temp (°C)	4.5-13	8-14	5.6-6.1	10-13.8
Discharge (cfs)	5-27	---	7.7-17	2.8-4.3
Turbidity (NTU)	0.21-290	3.8-1460	<2	<2-6.5
pH	7.72-8.13	7.5-8.1	8-8.3	8.1-8.3
Alkalinity (mg/L)	69-109	59.1-142	87-128	111-158

Friday Creek

Friday Creek is a relatively short stream that enters Moose Creek about two kilometers north of the town of Kantishna (Meyer and Kavanagh 1983). It was one of the first Kantishna streams where gold was discovered in 1904 (Mangi Environmental Group 2005). Mining began there in 1905 but with little activity between 1945 and 1969 (Meyer and Kavanagh 1983). Extensive placer mining occurred on Friday Creek in 1982 and 1983, causing "heavy water quality impacts" (Deschu and Kavanagh 1986), but was limited in 1984 to a few days at the beginning of the season (Deschu 1985b). By the end of 1982, Meyer and Kavanagh (1983) reported that 44% of the total stream length had been considerably altered by mining activity. They found that the lower portion of the creek was "of little or no value for supporting aquatic invertebrate or fish populations because of consistently high turbidity and heavy reworking of the channel" (Meyer and Kavanagh 1983). No fish were observed in Friday Creek during 1982 and according to Meyer and Kavanagh (1983), "None of the miners, local area residents, or NPS personnel talked to had ever observed or heard of fish being present in Friday Creek."

Photo B-3. Photo from 1984 showing placer mining on upper Friday Creek (NPS photo, in Norris 2008).

Photo B-4. Placer mining on upper Friday Creek in 1984 (NPS photo, in Norris 2008).

Deschu and Kavanagh (1986) found that high settlable solids, turbidity, and metal concentrations, along with changes in the streambed and discharge were all major concerns for Friday Creek in the early 1980s. Settleable solids and turbidity were 13 mL/L/hr and 2900 NTU respectively during mining but just <0.1 mL/L/hr and 33NTU when there was no mining activity occurring (Deschu and Kavanagh 1986). Metal concentrations were "consistently and substantially (10 to 1000 times) higher" below mining than above it (Deschu and Kavanagh 1986). West and Deschu (1984) reported that Friday Creek, during mining activity, exceeded more water quality criteria "more frequently than any other sampled stream" in both 1982 and 1983.

Silver-lead ore mining also occurred near Friday Creek at the Red Top Mine. Clean-up of this site took place in 1993 with reclamation efforts beginning in 1999. This work is described in Karle 1999.

Most dissolved metal concentrations have decreased in Friday Creek since mining ceased, with the exception of arsenic (Table B-18, Figure B-6), suggesting a natural geologic source of that element in the Friday Creek watershed.

Table B-9. Physical and chemical characteristics of Friday Creek over time. All samples were taken between June and September (From Meyer and Kavanagh 1983, Deschu and Kavanagh 1986, and USGS 2010).

Parameter	1982	1983	2008	2009
Water temp (°C)	5-10	9-10	5-5.5	8.4-11.1
Discharge (cfs)	---	0.1-0.6	1.3-3.1	0.1-0.3
Turbidity (NTU)	60-3000	33-2900	<2-3.7	<2
pH	7.83-7.86	7.78-7.89	8.1-8.4	8.3
Alkalinity (mg/L)	134-277	45-120	120-154	142-177

Glen Creek

Glen Creek rises in the Kantishna Hills as two forks and flows south into Moose Creek (Meyer and Kavanagh 1983). Mining began in 1906 with considerable placer mining activity starting in 1961 (Deschu and Kavanagh 1986). One or two operations were active on Glen Creek each year from 1982 to 1984 (Deschu 1985b, Deschu and Kavanagh 1986). In 1982, Meyer and Kavanagh (1983) reported an artificial waterfall on Glen Creek that was blocking upstream fish passage. They also observed that nearly the entire length of the stream below the convergence of its two forks had been altered by placer mining, resulting in "complete loss of the original channel and all riparian vegetation on the valley floor" (Meyer and Kavanagh 1983). A mining access road also ran in the stream channel for over 2 km in a narrow section of the valley. Meyer and Kavanagh (1983) observed "numerous sand and silt bars, uncharacteristic of Kantishna Hills streams" in the lower 1.5 km and "a large bed of sediment up to 0.3 m thick" just above the road crossing near the mouth of Glen Creek. According to Deschu (1985b), "intensive mining over many years in low volume Glenn Creek presents little potential for recovery of the benthic habitat to its natural state."

Glen Creek's water quality was consistently reported as poor during the early 1980s. Turbidity measurements taken between 2 and 5.5 km below active mining regularly measured between 700 and 6200 NTU (Deschu 1985b). Antimony, arsenic, mercury, and lead concentrations were much higher below mining activity than above it (Deschu and Kavanagh 1986). Meyer and Kavanagh (1983) believed that Glen Creek likely supported large populations of Arctic grayling and slimy sculpin at one time, but no grayling were captured or observed there in 1983, probably because of an increase in mining between 1982 and 1983 (Deschu and Kavanagh 1986).

Restoration efforts began on lower Glen Creek in the early 1990s. Several stream restoration techniques were tested and, as a result, Glen Creek was referred to as "the flagship for NPS floodplain restoration techniques for 10 years" (Mangi Environmental Group 2005). These efforts are described in Karle and Densmore 1994 and Karle et al. 1996. A second restoration operation was conducted in the summer of 2009 and included the removal of mining debris, excavation of contaminated soils, revegetation of disturbed areas, and leveling of tailing piles (Photo B-5; DENA 2010b).

Photo B-5. Photos from Glen Creek restoration work in 2009: removing abandoned mining debris (left) and tailing piles to be leveled (right) (NPS photos, in DENA 2010b).

Table B-10. Total metal concentrations (µg/L) in Glen Creek above and below mining activity in 1983 (from West and Deschu 1984).

	Antimony	Arsenic	Manganese	Mercury	Iron	Lead
Above mining	26.5	9.7	17	0.4	32.5	0.1
Below mining	58.1	71.6	576	0.6	16000	31

Table B-11. Physical and chemical characteristics of Glen Creek over time. All samples were taken between June and September. 1983 samples were taken near the creek mouth while 2008-09 samples were taken further upstream, just below the confluence of the East and West forks (From Meyer and Kavanagh 1983, Deschu and Kavanagh 1986, and USGS 2010).

Parameter	1982	1983	2008	2009
Water temp (°C)	8-15.5	9.5-12	3.5-11	8-11
Discharge (cfs)	8-10	8.2-23	6.5-19	2.4-5.5
Turbidity (NTU)	1-18,000	290-800	<2	<2
pH	7.65-8.16	7.97-8.24	8-8.4	7.5-8.1
Alkalinity (mg/L)	74-89	106-114	85-116	107-113

<u>Moose Creek</u>
Moose Creek rises as two forks on the southern end of the Kantishna Hills. The South Fork, often called the main stem, originates north of the Eielson visitor center and runs roughly parallel to the park road and through the town of Kantishna, eventually joining the Bearpaw River.

Deschu (1985b) noted naturally eroding, undercut stream banks in the headwaters near Mt. Galen that contribute significantly to stream turbidity and settleable solids, particularly after rain. The North Fork contains “some of the most productive aquatic habitat in the Kantishna Hills” (Meyer and Kavanagh 1983). Its largest branch starts at a small lake, described in 1982 as approximately 12 ha in size and likely at least six meters deep, which appeared adequate for grayling and whitefish overwintering (Meyer and Kavanagh 1983). There were also numerous beaver ponds in the headwaters and dense strips of willow and other shrubs bordering nearly the entire length of the North Fork (Meyer and Kavanagh 1983).

Arctic grayling were abundant in the North Fork in the early 1980s, suggesting it was a major spawning area (Meyer and Kavanagh 1983). Grayling were also believed to spawn in the South Fork. Meyer and Kavanagh (1983) observed round whitefish in lower Moose Creek and the North Fork during the fall of 1982, presumably swimming upstream to spawn. This was the first record of the species in the Kantishna Hills. Small numbers of chum salmon were also found in lower Moose Creek and a single adult was observed near the mouth of Spruce Creek in the North Fork (Meyer and Kavangh 1983). Coho salmon were caught by the ADF&G three km above the mouth of Moose Creek in September of 2005, but none were observed by Meyer and Kavanagh (1983) in 1982.

While mining on many of Moose Creek’s tributaries was extensive, mining activity on Moose Creek itself was limited to areas below the North Fork confluence, primarily around Kantishna (Photo B-6). Researchers have collected water and fish samples at many locations along Moose Creek to explore the impacts of mining on downstream areas. As a result it is somewhat difficult to compare findings between studies. Some historical data and more recent results are included in Table B-12 below.

Photo B-6. This aerial photo of Moose Creek at Kantishna in 1983 shows the large-scale placer mining that was occurring. Eldorado Creek can be seen entering on the left and Eureka Creek on the right (NPS photo, in Norris 2008).

Table B-12. Physical and chemical characteristics of Moose Creek over time. 1982and 2008 samples were all taken above the vicinity of Kantishna while 1983 results are from the Moose Creek bridge (Meyer and Kavanagh 1983, Deschu and Kavanagh 1986, and USGS 2010).

Parameter	1982	1983	2008
Water temp (°C)	4-15	7-14	4.7-11.5
Discharge (cfs)	125-231	68-920	145-289
Turbidity (NTU)	0.38-3075	0.9-1200	<2-2.5
pH	6.93-7.85	7.36-8.12	7.5-8.1
Alkalinity (mg/L)	51-60	36.6-82.9	49-85

Recent studies suggest that Moose Creek is a healthy stream despite years of mining influence. Most dissolved metal concentrations have decreased since mining ceased with the exception of manganese (Table B-18, Figure B-5), suggesting a natural source of that mineral somewhere in the Moose Creek watershed. In 2007, juvenile Chinook salmon were captured at Moose Creek Bridge, marking a “substantial expansion” (40 km) of their range in the drainage (Simmons 2009). In both 2007 and 2008, water samples from Moose Creek Bridge produced the highest macroinvertebrate taxa richness of any stream sampled in the park (Simmons 2009 and 2010).

Restoration is planned for Moose Creek in the town of Kantishna area in the near future (DENA 2010a).

Smaller tributaries of upper Moose Creek that experienced varying levels of mining include Rainy, Spruce, and Willow Creeks. Most placer mining on Rainy Creek occurred after 1979, with some activity in 1982 and late in 1983 (Deschu and Kavanagh 1986, Deschu 1985b). In 1982, Meyer and Kavanagh (1983) observed two settling ponds about one km above the creek's mouth, approximately 15 m wide and one meter deep. The ponds contained a layer of sediment up to 0.5 m thick, but they were the deepest pools in the stream and grayling were seen there in June. For most of July in 1982, the lower 0.5 km of Rainy Creek was dry or nearly dry "even though enough water to support fish flowed continuously above the settling ponds" (Meyer and Kavanagh 1983). Deschu and Kavanagh (1986) also observed "unnatural accumulations of sediment in the stream" below mining, as well as evidence of overland runoff and vegetation damage.

Spruce Creek has seen sporadic mining over the years with most activity occurring after 1974 (Deschu and Kavanagh 1986). In 1982, mining disturbance included a pit dug in the floodplain next to the creek approximately 15 m wide, six m deep, and 200 m long, and an access road running "alongside and in Spruce Creek" from its mouth to this mined area about 3.5 km upstream (Meyer and Kavanagh 1983). While only one mine was active for just two weeks in 1983, researchers found an iron seep about 0.7 km upstream from the mouth, "apparently from an unnatural cut into the eastern bank" (Deschu and Kavanagh 1986). They also noticed organic input to the stream from bank destruction, contributing to higher turbidity levels below mining even when mining was not occurring (Deschu and Kavanagh 1986). West and Deschu (1984) found slightly higher concentrations of arsenic and copper upstream of mining, suggesting a natural geological source for these minerals, although no metals were found at levels of concern. Meyer and Kavanagh (1983) noted that grayling in lower Spruce Creek were smaller than the average for other Kantishna streams.

Willow Creek has no history of actual placer mining, but three test pits were dug there in 1983 (Deschu and Kavanagh 1986). Meyer and Kavanagh (1983) believed that the creek still contained productive aquatic habitat, although in 1982 several beaver dams and ponds just upstream of its mouth appeared to be preventing fish passage. The largest of these ponds was estimated at 100 m long and over two meters deep. A water sample taken from Willow Creek in 1982 showed the lowest turbidity of any stream in the Kantishna Hills at 0.03 NTU (Meyer and Kavanagh 1983).

<u>Slate Creek</u>

Slate Creek is a tributary of Eldorado Creek rising in the southwest Kantishna Hills (Meyer and Kavanagh 1983). There is no record of placer mining on Slate Creek, but an antimony lode mine operated intermittently from 1910 to 1983 (DENA 2010b). Even above mining activity, Slate Creek's pH values were lower than other Kantishna streams with a range of 6.58-6.73, probably due to "exposed sulfides that are oxidizing and leaching into the system as sulfuric acid" (Deschu and Kavanagh 1986). Major concerns about Slate Creek's water quality in the early 1980s included low pH, settleable solids and turbidity, and high heavy metal concentrations. The NPS found arsenic, cadmium, iron, and mercury concentrations that exceeded several state and federal water quality standards (Meyer and Kavanagh 1983). According to Deschu and

Kavanagh (1986), “From a human health standpoint, the high heavy metal concentrations in Slate Creek are something which must be considered in backcountry visitor-use management.” Researchers also noticed orange iron staining in the streambed and lower algal growth below the mine (West and Deschu 1984, Deschu and Kavanagh 1986).

Meyer and Kavanagh (1983) noted that, “a rough road runs in and alongside Slate Creek from the mouth up to the antimony mine near the headwaters.” Fish habitat is of poor quality as a result of the streambed being used as a road and only a few grayling were found there in 1982 (Meyer and Kavanagh 1983). No fish were observed in Slate Creek during 1983, likely because mining resumed that year after a break in 1982 (Deschu and Kavanagh 1986).

Slate Creek is currently listed as a CWA “impaired waterway”. In recent years, Tom Trainor of the University of Alaska Fairbanks has been researching the presence and transport of heavy metals in Slate Creek. Sampling in 2007 showed that antimony and arsenic concentrations were still elevated near tailing piles at the abandoned mine (DENA 2010a). As of 2009, the old antimony mine site still contained “exposed mine walls that are leaching acidic minerals” (Photo B-7) and 245 meters of tailing piles (DENA 2010b). Table B-13 shows that the concentrations of most other dissolved metals have decreased since mining ceased. Although limestone buffering methods began in 1998 to counteract the acidic inputs from the mine site, a recent measurement in the stream near the old mine produced a pH reading of 2.8 (DENA 2010b). Restoration plans for the summer of 2010 included capping mineralized outcrops, backfilling an open pit, leveling tailing piles, and relocating and re-enforcing the stream channel (DENA 2010b).

Photo B-7. The exposed mine wall near Slate Creek (left, NPS photo, in DENA 2010b), and a stream restoration project along the creek (right, NPS photo, in Thornberry-Ehrlich 2010).

Table B-13. Dissolved metal concentrations (µg/L) in Slate Creek. 1983 samples were taken at a settling pond constructed by miners. 2008 values are the mean of three samples taken between June and September (from West and Deschu 1984 and USGS 2010). Also see Figure B-4 and Figure B-7.

Year	Antimony	Arsenic	Manganese	Iron
1983	937	54	484	1170
2008	140.7	5.3	115	967

Table B-14. Physical and chemical characteristics of Slate Creek over time. Mining was occurring only during the 1983 sampling period; samples that year were taken from a dredge pond and a settling pond at the mine (From Meyer and Kavanagh 1983, Deschu and Kavanagh 1983, Deschu and Kavanagh 1986, and USGS 2010).

Parameter	1982	1983	2008	2009
Water temp (°C)	7.5-9.5	9-13	4.8-5.5	4.8-10
Discharge (cfs)	5	---	0.6-1.1	0.4-2
Turbidity (NTU)	1.6-3.3	73-88	<2	2.1-14
pH	7.15	5.37-5.65	6.7-7.2	6.6-7.2
Alkalinity (mg/L)	69-71	88-115	64-92	81

Stampede Creek

Stampede Creek is a tributary of the Clearwater Fork on the eastern side of the Kantishna Hills (Meyer and Kavanagh 1983). Placer mining here was limited, occurring between 1905 and 1949, but antimony lode mining occurred sporadically from 1916 to 1936 and "fairly continuously" from 1936 to 1970 (Deschu and Kavanagh 1986). By 1941, the Stampede mine was the largest antimony producer in Alaska (Meyer and Kavanagh 1983, from Bundtzen 1978). The mine closed in 1970, but tailing piles remained in the early 1980s and wastewater was still leaching into the stream (Deschu and Kavanagh 1986). Although turbidity and settleable solids were no longer a concern, heavy metal concentrations were still a potential problem for aquatic life (Table B-15; Deschu and Kavanagh 1986). Aquatic vegetation and fish were both rare below the mine site (West and Deschu 1984, Deschu and Kavanagh 1986). However it was not clear if this was due to the leaching of heavy metals or just a natural condition (Meyer and Kavanagh 1983).

Hardness measurements from Stampede Creek were some of the highest in the Kantishna Hills, ranging from 269-488 mg/L (Deschu and Kavanagh 1986). Hardness decreased further downstream, suggesting the high values were due to a natural geologic source rather than any mining influence (Deschu and Kavanagh 1986). The upper reaches of Stampede Creek were largely undisturbed, and "the streambanks support abundant willows that shade the stream and occasionally make walking in the stream difficult" (Meyer and Kavanagh 1983).

Photo B-8. This photo of the abandoned Stampede mine was taken in May of 1987 (NPS photo, in Norris 2008).

Table B-15. Total metal concentrations (µg/L) in Stampede Creek, above and below the old antimony lode mine, in 1983 (from West and Deschu 1984).

	Antimony	Arsenic	Manganese	Iron
Above Mine	9.8	0.2	12	4
Below Mine	334.5	2.4	42	271.5

Table B-16. Physical and chemical characteristics of Stampede Creek in the early 1980s (From Meyer and Kavanagh 1983 and Deschu and Kavanagh 1986).

Year	Water Temp (°C)	Discharge (cfs)	Turbidity (NTU)	pH	Alkalinity (mg/L)
1982	4.5-11.5	---	---	7.61-8.09	121-139
1983	3.5-12.5	0.8-11.3	1.2-4	7.58-7.87	112-176

Unmined "Control" Creeks – Jumbo, Moonlight, Myrtle, and Rock

Unmined streams that have been regularly used for comparison to mined streams include Jumbo Creek in the Moose Creek drainage, Rock Creek in the Bearpaw drainage, and Moonlight and Myrtle Creeks in the Clearwater Fork drainage. Moonlight and Myrtle Creeks are in the eastern Kantishna Hills, unlike most of the mined streams which are in the western Kantishna Hills, but are used as control streams because the geology at their headwaters is similar to that of most mined streams in the western hills (Deschu 1985). For example, Moonlight Creek had high zinc and cadmium concentrations in 1983, suggesting a natural source in its highly mineralized headwaters (West and Deschu 1984).

While no placer mining ever occurred on Myrtle Creek, there is evidence of pick and shovel mining on an upper section of its West Fork, likely from the early 1900s (Deschu and Kavanagh 1986). A small mineralized seep in the area is believed to be from this early mining activity (Deschu and Kavanagh 1986). Grayling habitat was abundant in Myrtle Creek in 1983, "particularly on the east fork and in the canyons below the confluence of both forks. Pools reaching depths of 1.5 m were observed" (Deschu and Kavanagh 1986). Grayling, slimy sculpin, and aquatic invertebrates were particularly abundant on the East Fork. Deschu and Kavanagh (1986) also found a natural mineralized seep on the north bank of the confluence of the East & West Forks. They observed a caribou there several times, suggesting the seep may be used by wildlife as a mineral lick. On Moonlight Creek, streambank and aquatic vegetation were both sparse and few pools were observed, resulting in a relatively small grayling population (Deschu and Kavanagh 1986).

The location of Jumbo Creek, which enters Moose Creek from the south just below the confluence of its North and South Forks seem to make it a convenient control creek. However, Jumbo Creek originates in the tundra rather than in mineralized hills like most Kantishna streams, which influences its water chemistry (Deschu and Kavanagh 1986). Grayling and aquatic invertebrates were both abundant in Jumbo Creek's undisturbed aquatic habitat (Deschu and Kavanagh 1986) and it was presumed to be a major grayling spawning area (Meyer and Kavanagh 1983). During a reconnaissance hike in June of 1982, "literally hundreds of grayling were observed in the lower 1.3 km" (Meyer and Kavanagh 1983).

Rock Creek, which enters the upper Bearpaw River above Caribou Creek, has recently been used by the USGS as a control stream (Table B-17). Both its location and source in the highly mineralized western Kantishna Hills make it comparable to previously mined streams in the Moose and Bearpaw drainages.

Table B-17. Physical and chemical characteristics of Rock Creek over time. 1982 samples were taken at multiple sites along the creek, while only a single water sample was taken approximately 5 km upstream in 1983. Recent results were taken from a single site sampled multiple times each season (From Meyer and Kavanagh 1983, Deschu and Kavanagh 1986, and USGS 2010).

Parameter	1982	1983	2008	2009
Water temp (°C)	7-10.5	---	2.9-6.4	9.6-11.5
Discharge (cfs)	74	---	31-66	15-27
Turbidity (NTU)	0.38-1.5	3.7	<2	<2
pH	---	7.44	8-8.2	8-8.2
Alkalinity (mg/L)	---	39.1	70-92	81-98

Table B-18. Dissolved metal concentrations (µg/L) for several Kantishna streams in 1983 during high and low mining activity and in 2008-09. Concentrations from unmined Rock Creek in 2008 are included for comparison (from West and Deschu 1984 and USGS 2010). Also see Figures B-3 – B-8.

Stream	Antimony	Manganese	Arsenic	Iron
Caribou - high	7.3	14	2.4	130
- low	7.3	<4	1.9	24
- 2008-09	2.28	8.45	0.71	71.75
Eldorado - high	805	95	37.1	<4
- low	335	98	18.7	66
- 2008	39.97	39.83	1.63	81
Friday - high	3.7	36	0.2	<4
- low	1	6	1.4	129
- 2008-09	1.21	0.65	2.64	6.5
Moose - 1983	9.7	<4	1.8	76
- 2008-09	3.35	9.62	0.78	43.2
Rock – 2008-09	0.67	3.57	0.18	13.67

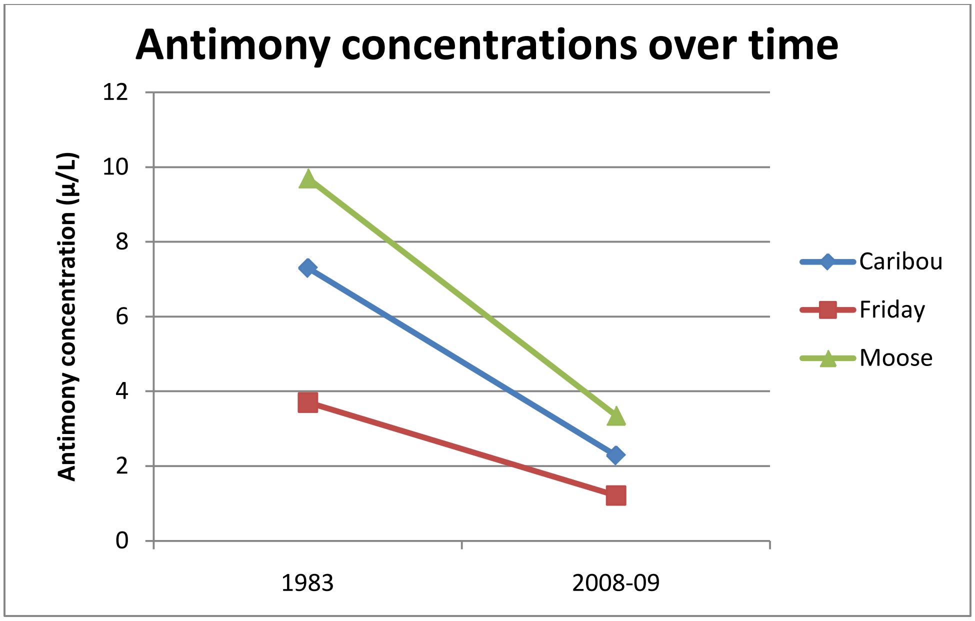

Figure B-3. Changes in antimony concentration in Caribou, Friday, and Moose Creeks since mining ceased.

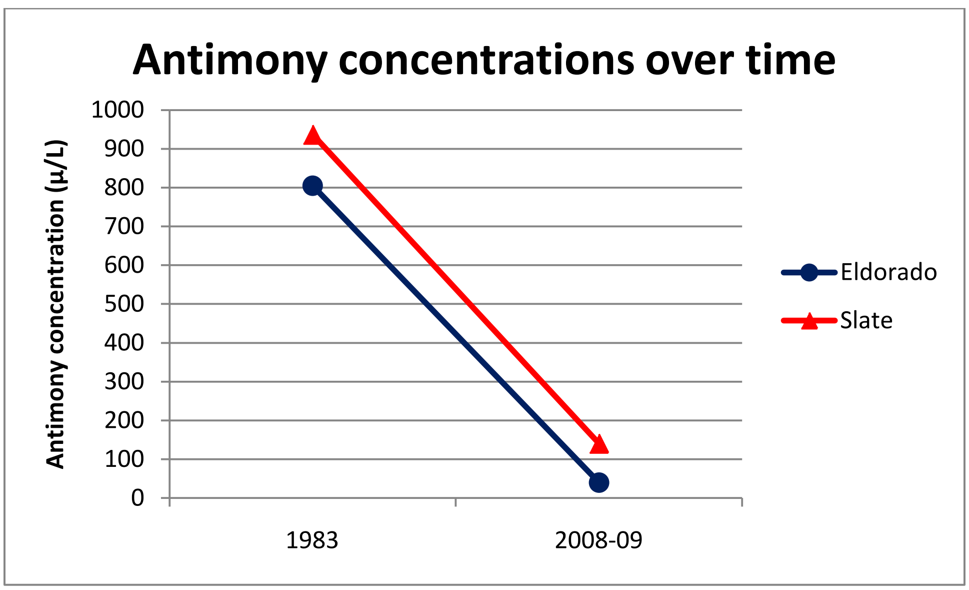

Figure B-4. Changes in antimony concentration in Eldorado and Slate Creeks since mining ceased.

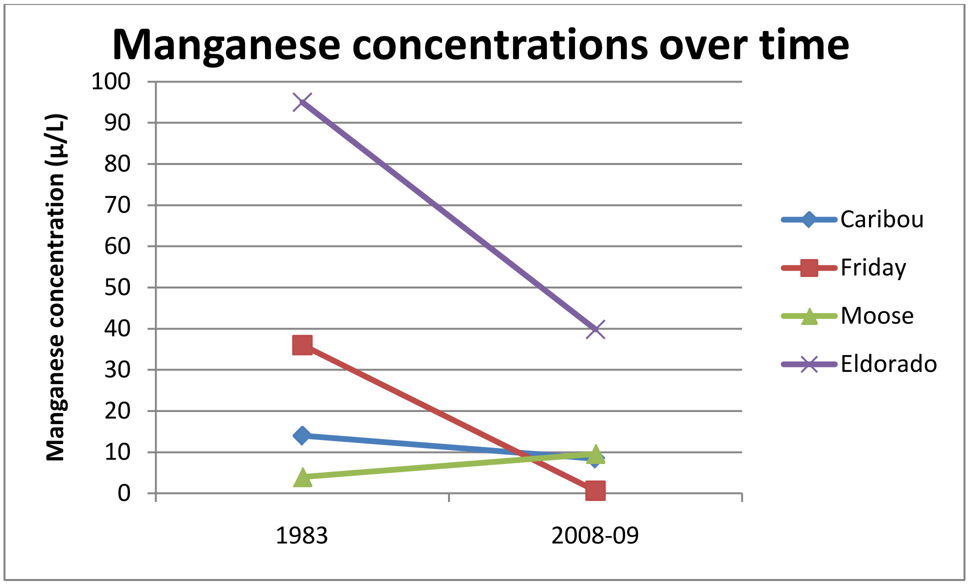

Figure B-5. Changes in manganese concentrations for selected streams since mining ceased. Manganese concentrations also decreased in Slate Creek from 484 µg/L to 115 µg/L (not shown here due to scale).

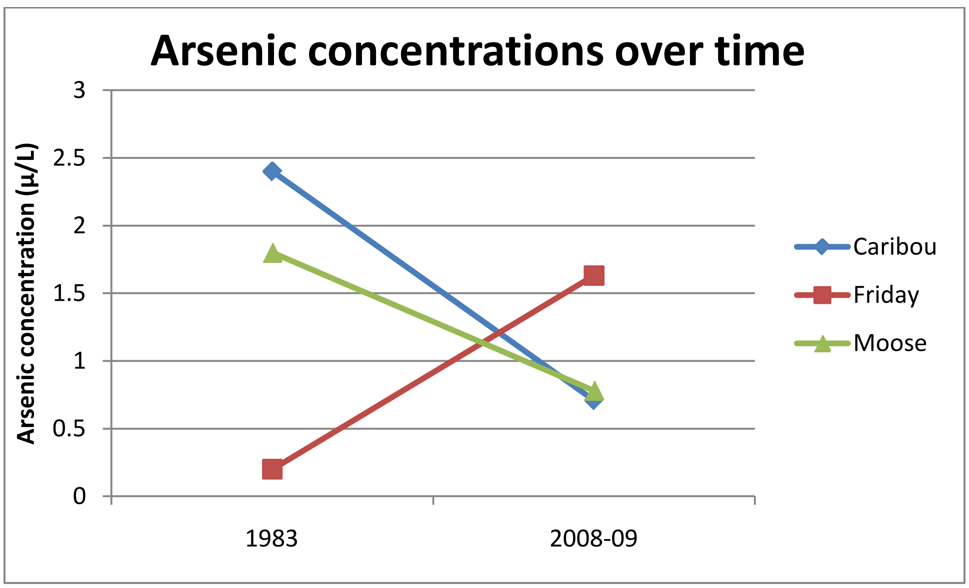

Figure B-6. Changes in arsenic concentrations for Caribou, Friday, and Moose Creeks since mining ceased.

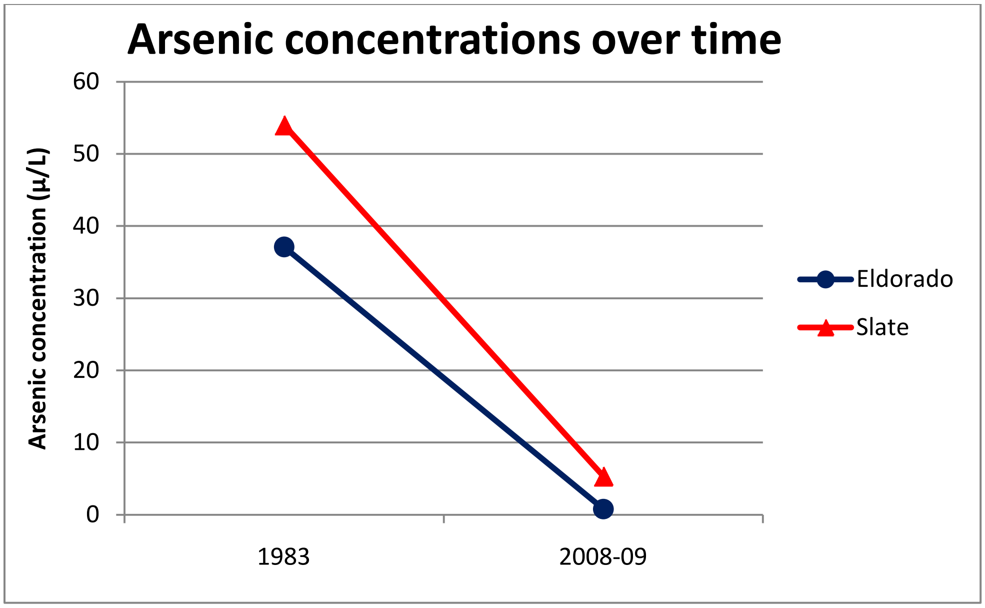

Figure B-7. Changes in arsenic concentrations for Eldorado and Slate Creeks since mining ceased.

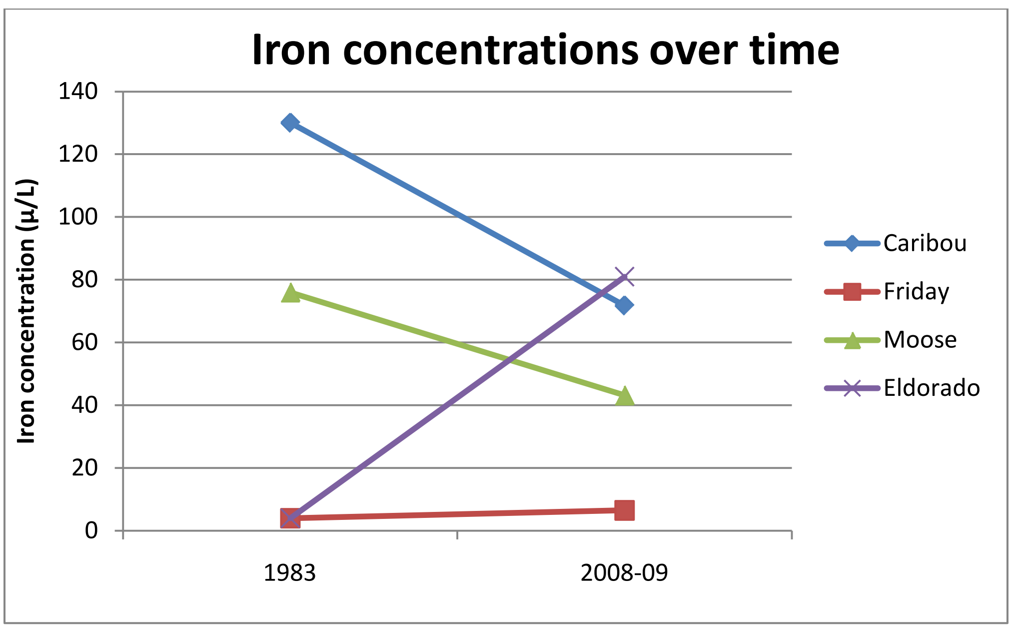

Figure B-8. Changes in iron concentrations for selected streams since mining ceased. Iron concentrations also decreased in Slate Creek from 1179 µ/L to 967 µ/L (not shown here due to scale).

Table B-19. Results of Arctic grayling sampling for selected Kantishna streams in 1982. Jumbo Creek is an unmined control stream. No grayling were caught in Friday and Stampede Creeks (From Meyer and Kavanagh 1983).

Stream	# Caught	Distance sampled (km)	Fish/km	Fork Length (mm)		Weight (g)	
				Mean	Range	Mean	Range
Caribou	1	3.6	0.3	296	---	---	---
Eldorado	41	5.5	7.5	257	108-365	220	34-555
Eureka	3	2.4	1.3	164	148-174	---	---
Glen	2	5.2	0.4	237	194-279	240	---
Jumbo	25	1.4	17.9	300	248-345	319	192-476
Moose Creek (including North Fork)	41	4.1	10	225	78-349	177.5	6-419
Slate	4	1.7	2.4	207	174-252	106	57-174

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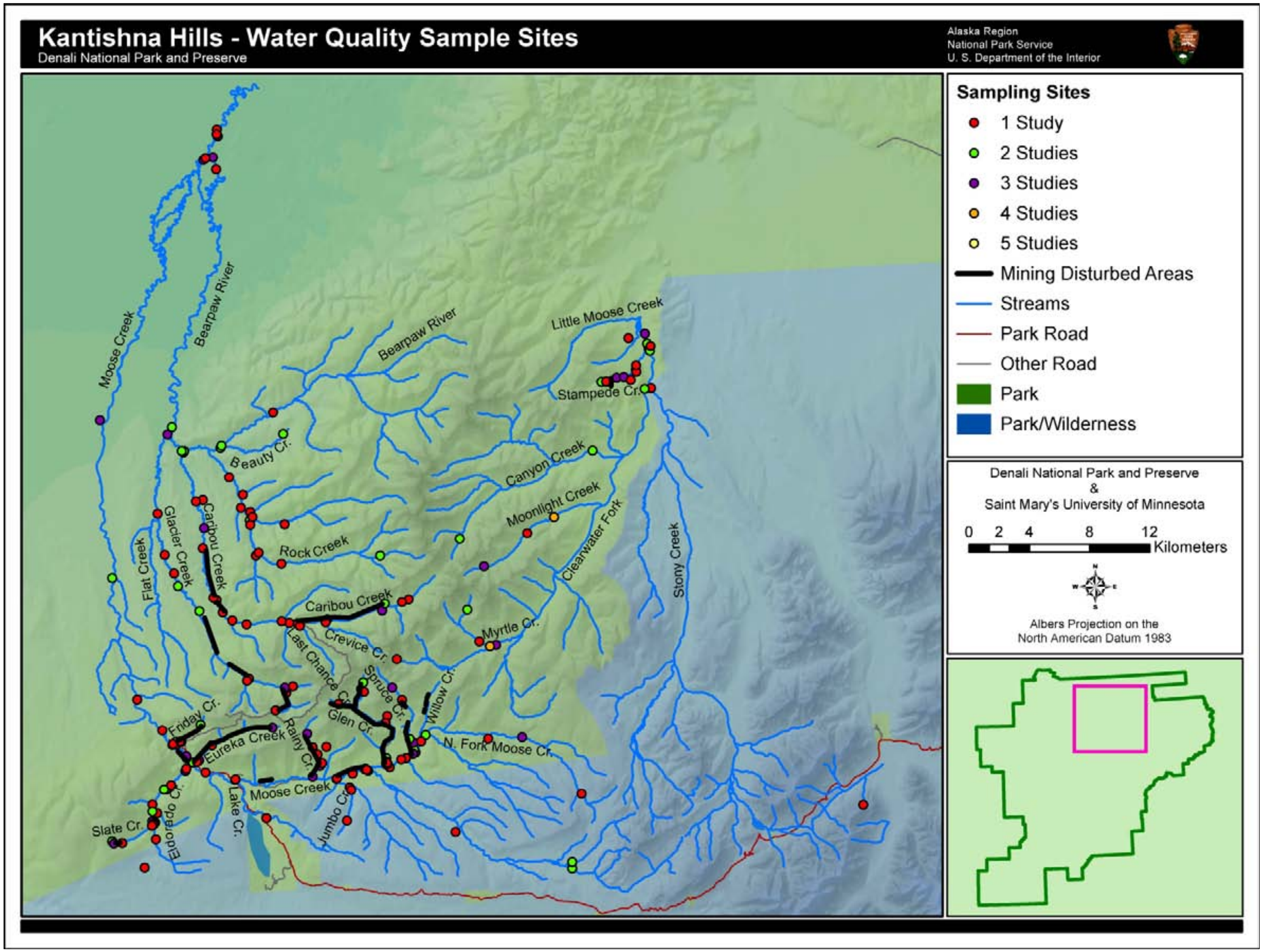

Plate B-1. Water quality sampling locations and areas disturbed by mining activity in the Kantishna Hills, Denali National Park and Preserve.

Appendix C. Modeling the impact of administrative flights on Denali's soundscape

Background

Park managers use aircraft for many purposes in Denali National Park and Preserve. These include wildlife surveys, wildfire monitoring, and reaching or transporting equipment to other scientific study sites. As part of the NRCA process, NPS staff asked SMUMN GSS to model the impact these administrative flights have on the park and preserve's soundscape. With data provided by the NPS, SMUMN GSS was able to identify major activity corridors and areas of the park where aircraft noise is audible (>25 dBA). This report describes the methods used by SMUMN GSS analysts to model selected administrative flights in the northern portion of Denali.

Methodology

<u>Flight Data</u>

Administrative aircraft were supplied with GPS receivers to gather data for each flight from January 2009 to September 2010 (Figure C-1). This analysis focused on the months of May 2010 to September 2010, as these months are generally the busiest flight season for Denali staff. The point data for four administrative aircraft were exported and provided to SMUMN GSS for processing.

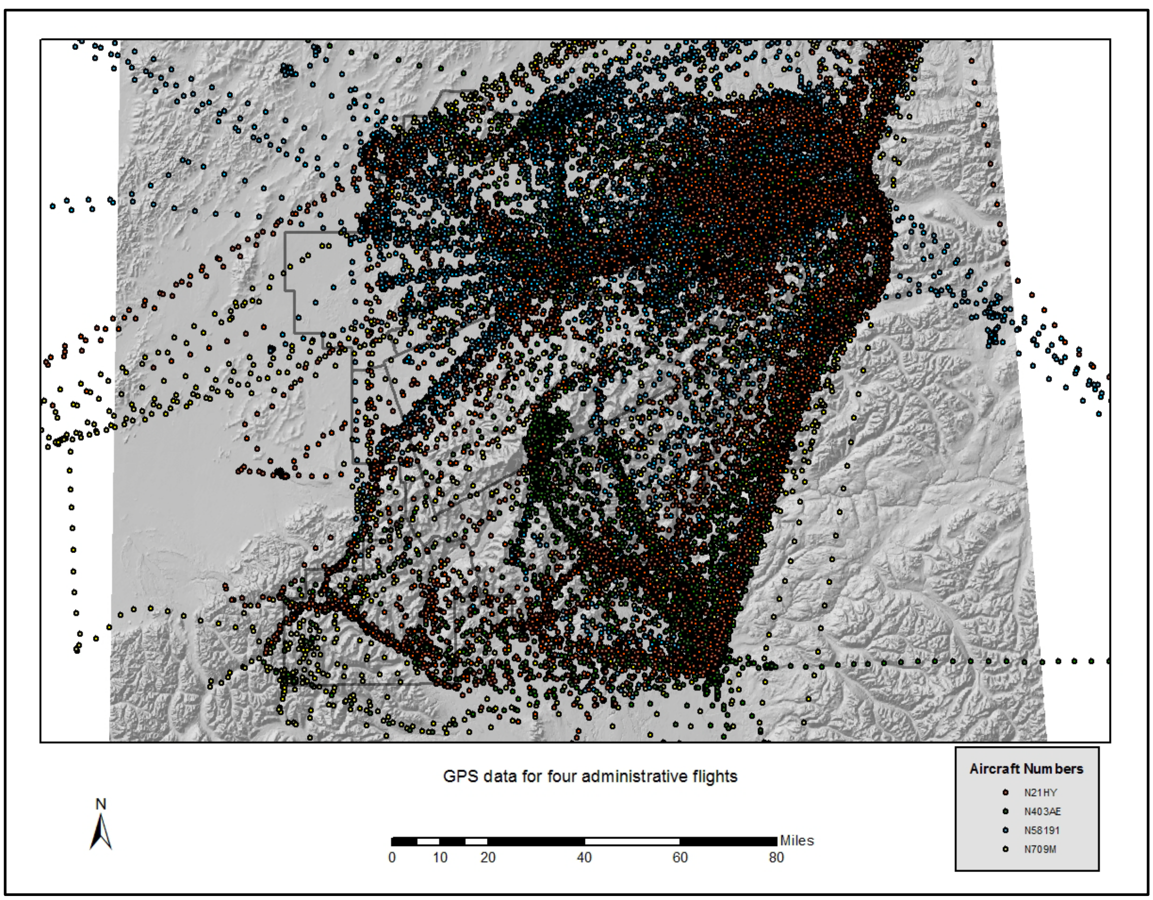

Figure C-1. Flight data from selected NPS administrative aircraft.

The aircraft types included: N403AE a Eurocopter helicopter, N709M an FBA-2C2 single engine fixed wing, N21HY an Aviat Husky A-1B single engine fixed wing, and N58191 a Hughes 369D helicopter.

Kernel Analysis:

Point data from the GPS were processed using a kernel density analysis to identify main traffic corridors and four flights were selected for modeling. With kernel analysis, feature density is calculated in a neighborhood around each point. A smooth curved surface is created with the greater values at locations with a higher density of points. The different settings within the interface were explored to achieve the best and most logical output (Figure C-2).

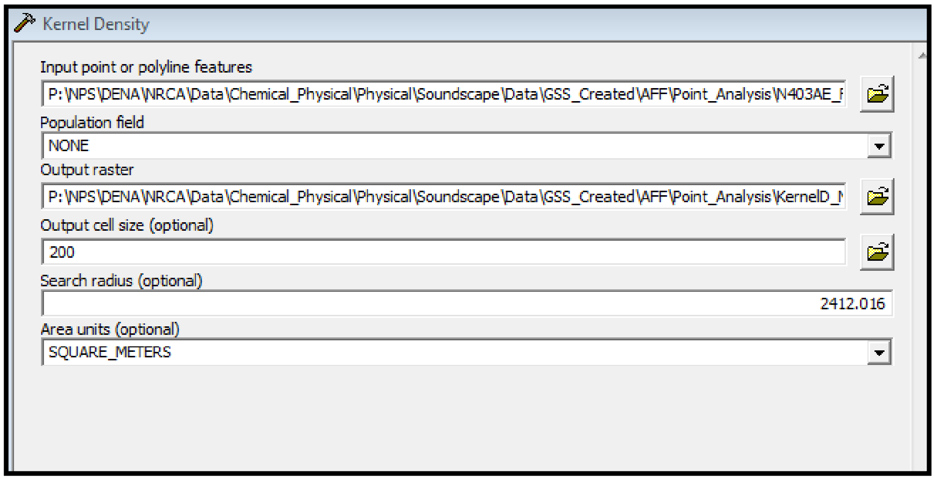

Figure C-2. ESRI kernel density interface.

There is no population field used because each point should have equal value or weight in the analysis. Testing of the output cell size showed that larger values produced coarser raster outputs (Figure C-3) and smaller values generated large file sizes. The compromise value was found to be 200 square meters. The point datasets were projected from decimal degrees to WGS83 UTM Zone 5 projection with the linear units measured in meters. Search radii from .5 to 5 miles were examined with varied results (Figure C-4). With the dataset unit of measure being meters, the mile values were input as meter values for the search radius, thus 1.5 miles was input as 2414.016 meters.

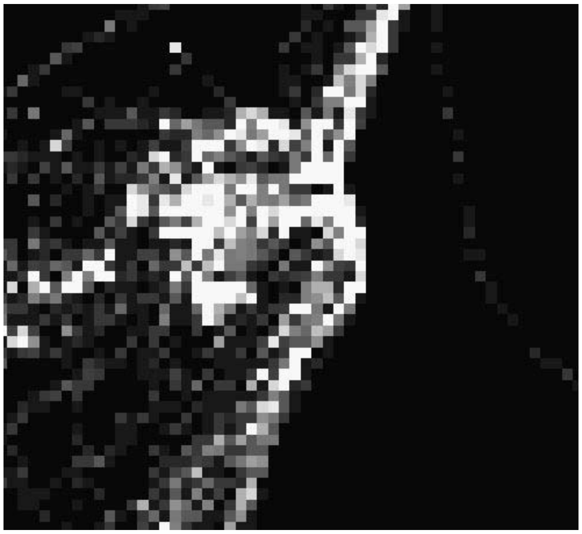

Figure C-3. Large cell size value.

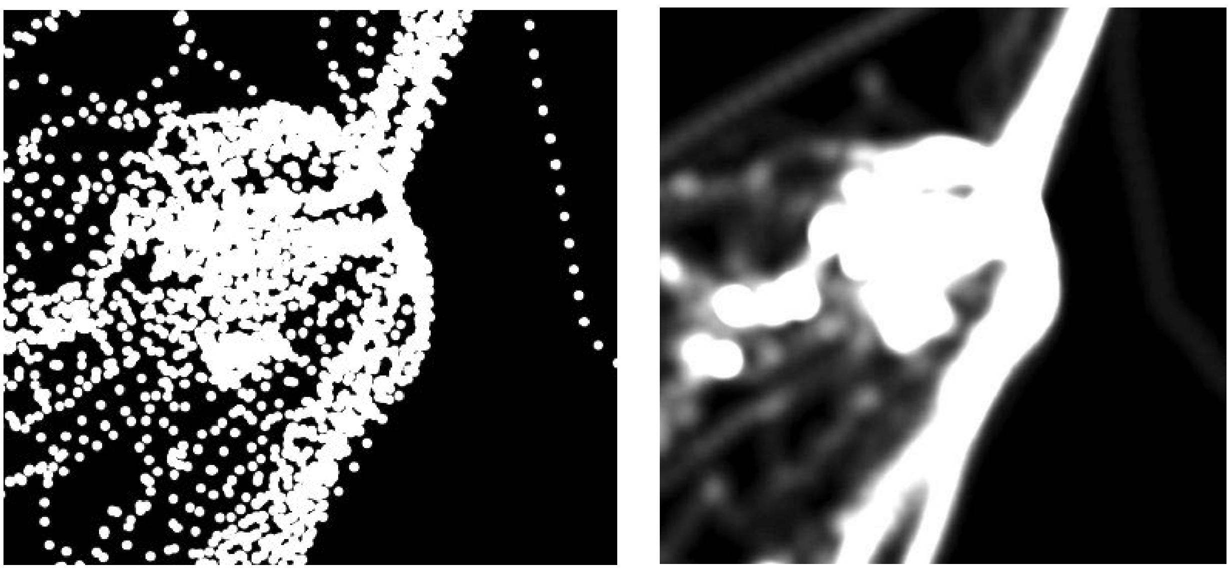

Figure C-4. 1.5 mile (2414.016 meters) 5 mile (8046.72 meters)

As Figure C-4 shows, a 1.5 mile radius value created a readable GRID where most individual tracks and main flight corridors were well defined. The 5 mile radius blended the tracks into one mass which did not distinguish flight corridors. The 1.5 mile radius kernel density analysis was run on each of the four aircraft in this study. Upon visual inspection of the kernel density result for each aircraft, the highest traffic flight corridor was determined and one flight track for the aircraft was selected from the corridor. This process resulted in one flight trajectory for each aircraft.

<u>Sound level modeling:</u>
Noise Modeling Simulation (NMSim) is a software program created by Wyle Laboratories to model sound levels. The end result of the program is a quality ESRI GRID model of maximum sound levels. Before running the modeling program, GPS tracks had to be converted into

NMSim compliant trajectory files (Figure C-5). The trajectory file contains information about the noise source's location in 3D space. It does not contain any information about the source itself. Data in the trajectory file includes X and Y locations, elevation, and heading (collected by the GPS during each flight) as well as climb angle, velocity, time, engine power, and roll (calculated by the SMUMN GSS analyst).

```
Flight track trajectory variable description:
time - time in seconds from reference time
Xpos - x coordinate (UTM)
Ypos - y coordinate (UTM)
UTM Zone 5
Zpos - z coordinate in meters MSL
heading - aircraft compass bearing in degrees
climbANG - aircraft climb angle in degrees
vel - aircraft velocity in knots
power - % engine power
roll - bank angle (right wing down), degees
FLIGHT xxx
TEMP. 55
Humid. 58
```

time(s)	Xpos	Ypos	Zpos	heading	climbANG	Vel	power	rol
0.000	701755.914	7073698.030	544.982	44.000	2.657	0.000	95.000	0.000
206.250	701931.608	7077898.573	740.054	357.000	1.513	107.000	95.000	0.000
412.500	698170.777	7083434.342	916.838	310.000	1.124	119.000	95.000	0.000
618.750	691649.503	7083576.311	1044.854	261.000	0.874	107.000	95.000	0.000
825.000	685210.122	7081536.643	1147.877	258.000	0.520	105.000	95.000	0.000
1031.250	678346.841	7079888.592	1211.885	260.000	0.168	107.000	95.000	0.000
1237.500	671958.652	7078482.895	1231.087	258.000	-0.058	109.000	95.000	0.000
1443.750	665247.835	7076560.090	1224.077	256.000	0.079	107.000	95.000	0.000
1650.000	659125.515	7074592.517	1232.916	251.000	0.377	99.000	95.000	0.000
1856.250	653014.058	7072269.572	1275.893	251.000	0.650	107.000	95.000	0.000
2062.500	646776.811	7070354.824	1349.959	261.000	-0.065	111.000	95.000	0.000
2268.750	640037.433	7068463.959	1342.034	252.000	-0.305	117.000	95.000	0.000
2475.000	633371.164	7065854.751	1303.934	247.000	-0.427	113.000	95.000	0.000
2681.250	626866.068	7062686.633	1249.985	246.000	0.477	115.000	95.000	0.000
2887.500	620279.397	7060042.463	1309.116	245.000	-1.398	117.000	95.000	0.000
3093.750	613764.962	7056489.513	1128.065	256.000	-1.523	119.000	95.000	0.000
3300.000	606569.063	7055068.537	932.993	251.000	-1.355	119.000	95.000	0.000
3506.250	600027.494	7051622.040	758.038	238.000	-2.877	124.000	95.000	0.000
3712.500	599453.252	7047746.306	561.137	258.000	-14.886	43.000	95.000	0.000
3918.750	599559.257	7047537.785	498.958	84.000	0.000	0.000	95.000	0.000
4125.000	599559.257	7047537.785	497.129	172.000	10.668	2.000	95.000	0.000
4331.250	597757.630	7047894.405	843.077	158.000	4.867	64.000	95.000	0.000
4537.500	597311.187	7044602.889	1125.931	224.000	0.012	82.000	95.000	0.000
4743.750	595087.091	7040722.827	1126.846	179.000	-1.069	84.000	95.000	0.000
4950.000	598959.588	7041219.747	1053.998	24.000	-0.171	80.000	95.000	0.000
5156.250	598872.701	7045620.988	1040.892	241.000	-13.036	56.000	95.000	0.000
5362.500	599353.872	7047743.199	537.058	184.000	-8.239	41.000	95.000	0.000
5568.750	599559.257	7047537.785	494.995	4.000	10.281	2.000	95.000	0.000
5775.000	599670.006	7045590.115	848.868	246.000	6.407	43.000	95.000	0.000
5981.250	598926.232	7045500.010	932.993	13.000	15.297	2.000	95.000	0.000
6187.500	598925.886	7045511.149	936.041	42.000	0.000	0.000	95.000	0.000
6393.750	598925.886	7045511.149	932.993	347.000	-8.117	0.000	95.000	0.000

Figure C-5. NMSim trajectory file.

An open source extension called X-Tool Pro was used to transform GPS points into UTM WGS84 X and Y coordinates in ESRI ArcMap. The ArcMap table was then exported as a text file and imported into an Excel spreadsheet to calculate the remaining fields. Altitude (elevation) in feet was converted to meters and given the field name Zpos while the speed column was renamed Vel.

To find the climb angle, first the change in altitude between each point was calculated (rise). Then the distance between each point (run) was calculated with the following formula: Distance = sqrt((X-X_{pos})(X-Xpos)+(Y-Ypos)(Y-Ypos)). Finally climb angle could be calculated using the formula: climbangle = DEGREES(ATAN(rise/run)).

The time field in the trajectory file represents the time between each point. To find the time values, the distance between points was divided by speed in meters per second (Time = distance/speed). Values for percent power (95.000) and roll (0.000) were added as a standard value across all flights, as these values did not affect the sound levels.

After all calculations were completed, the spreadsheet was saved as a formatted text file from Excel and opened in WordPad so that the NMSim compliant header information could be added (Figure C-6). From WordPad it was saved to a trajectory file (.trj).

```
Flight track trajectory variable description:
time - time in seconds from reference time
Xpos - x coordinate (UTM)
Ypos - y coordinate (UTM)
UTM Zone 5
Zpos - z coordinate in meters MSL
heading - aircraft compass bearing in degrees
climbANG - aircraft climb angle in degrees
vel - aircraft velocity in knots
power - % engine power
roll - bank angle (right wing down), degees
FLIGHT xxx
TEMP. 55
Humid. 58
```

Figure C-6. Header information added in WordPad.

In addition to the trajectory file, the NMSim modeling program requires a digital elevation model base and a unique aircraft noise source input file. The source of the digital elevation model used was the NPS Alaska Region Permanent GIS Dataset. Wyle Laboratories created aircraft noise source inputs, however they are limited to only a few aircraft types. With these three elements, the sound model was generated in the NMSim Visualizer, using the default grid resolution of 100x100. There are several available metrics in the Visualizer, but for this analysis maximum dBA was used with a decibel range of 25 to 80. Models created in the Visualizer were exported from NMSim as an ESRI ASCII grid file.

<u>ESRI ArcMap:</u>

The ASCII grids were converted into TIFF format and mosaiced into one image. The ESRI mosaic tool property setting of most importance was the mosaic method, which determined how overlap areas were to be handled. This was set for maximum cell values thus preserving the highest decibel level at any location. The desired decibel values (e.g., > 25) could be queried out in the raster calculator with a line of code, such as: setnull([RasterName] >25, [RasterName]). To determine the total area impacted, the scaled mosaic was converted from raster to polygon and merged according to decibel values: above 25 but below 40, above 40 but below 60, and above 60 (Figure C-7).

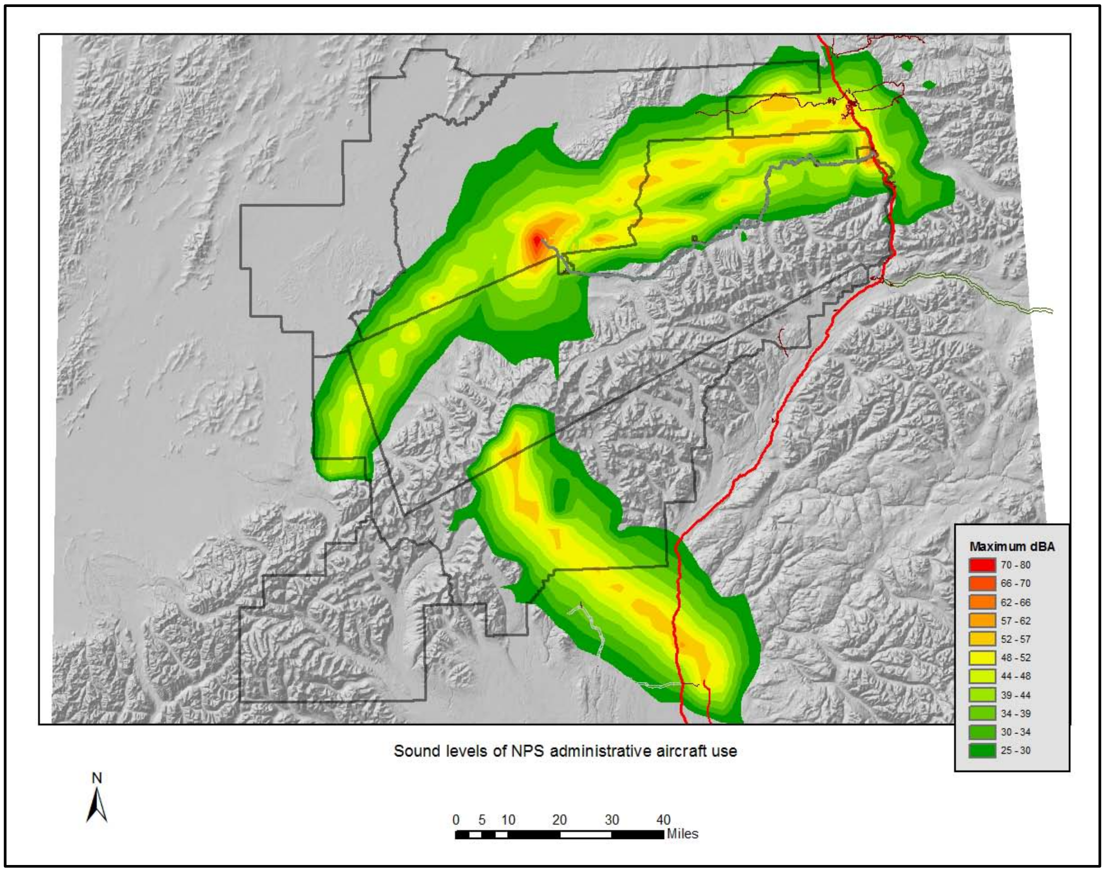

Figure C-7. Color palette assigned by decibel levels.

Results and Discussion

Table C-1 shows the estimated total and percent of area within the park impacted by the four NPS administrative flights analyzed, as determined by the NMSim modeling program.

Table C-1. Percent of area in hectares where aircraft noise from the four analyzed flights is audible.

Decibel level	Total area (Ha)	% of park area
>25dBA	732,270	55.7
>40dBA	576,094	43.8
>60dBA	5,655	0.4

While NMSim produced quality ESRI GRIDs, the program had several issues that may warrant further exploration into alternate sound modeling software. The calculations required to create trajectory files were time consuming. Proper set up of the GPS equipment prior to each flight could minimize this issue. GPS units should be set to collect X and Y values in UTM coordinates, elevation in meters, and with a longer time interval for point collection. NMSim has an internal limit of 1000 points per flight path. Longer flights have to be cut down and helicopters, which may hover in an area, must have their data reduced, which could lead to an underestimate of impact on soundscape.

Aircraft noise source files are currently limited to a few specific aircraft. The noise source file most closely representative of each aircraft analyzed was chosen for this analysis. Since this is a critical complement to the trajectory file, the creation of more source files by Wyle Laboratories would be beneficial.

There are other parameters, for example variations in land cover, that could be added to the analysis, but this information was not available to SMUMN GSS, and the cost and scope of this project did not cover the location or creation of such datasets.

Appendix D. Analysis of habitat use by soil type: Caribou, Dall's sheep, and moose

Project Description

The purpose of this project was to overlay basic current population distribution data for a selected list of species (moose, caribou, and Dall's sheep) over the NRCS soil survey data (Clark and Duffy 2006) to explore trends. Ungulate species were chosen for this study because, as herbivores, they are more closely tied to the soils and vegetation of their environment. The analysis was conducted in two parts. First the soil types and associated potential vegetation most often used by each species were identified. This was then compared to the amount of each soil type and potential vegetation type available within Denali National Park and Preserve.

Data

The soil survey and ecological classification of Denali National Park and Preserve was conducted between 1997 and 2004 to describe and map the soils across the entire park and preserve (Clark and Duffy 2006). In addition to collecting data on soil types at all locations, the survey recorded plant species at the study sites, photographed the landscape and plant communities, and gathered geomorphology data. The survey involved digging soil pits and collecting additional data at 2,204 locations across the landscape over six field seasons from 1997 to 2002, with approximately 405,000 hectares surveyed each year (Clark and Duffy 2006). For this habitat analysis the most detailed classification, the soil map unit, and the potential vegetation classification were used. The soil map unit represents an area on the landscape mapped at 1:63,360 consisting of one or more soils areas (Clark and Duffy 2006). The potential vegetation classification is derived from the soils data and divides DENA into 16 potential vegetation classes.

Location data for caribou cows were provided by Layne Adams for the time period beginning 27 September 1986 and ending 30 March 2008. These locations were collected through capturing and radio-collaring of caribou. Cow locations occurring outside of the extent of the soils data (DENA boundary) were excluded from the analysis.

Aerial surveys conducted in 2008 and 2009 measured Dall's sheep abundance in Denali (Phillips 2009). Seventeen survey units have been established in the eastern portion of the park (Plate D-1). As a result of poor weather conditions in 2008 and 2009, not all units could be surveyed each year (Phillips 2009). In 2008 all units except 6, 7, 12, and 13 were surveyed. In 2009 only units 9, 12, and 13 were surveyed. Between 2008 and 2009, unit 9 was surveyed twice and units 6 and 7 were not surveyed. To include as many units as possible without double counting a survey area, data were used for units 1-5, 8-11, and 14-16 from 2008 and units 12-13 from 2009. All sheep locations were within the extent of the NRCS soil survey data.

The most recent moose survey occurred from 3 November through 25 November 2008 (Owen and Meier 2009). For this survey, 312 sample units were selected from a statewide grid developed by ADF&G. Each unit is approximately 15.3 km^2 and is classified into low or high density strata based on preliminary flights, designation in previous surveys, or habitat characteristics. High density units are those units where five or more moose are expected to be found. Low density units are those in which fewer than 5 moose are expected. In 2008, 103 high density and 209 low density units were surveyed. The entire survey encompassed a study area of

10,004 km^2, of which 48.7% was surveyed (Owen and Meier 2009). The units surveyed and moose locations from 2008 are depicted on Plate D-2.

Methods

Available Habitat Delineation

In order to compare the soil units used by each species to the available soils, the soil survey data were summarized at different levels depending on the species location data available. For moose, the soils data were summarized within the units surveyed in 2008 as shown in Plate D-2.

For Dall's sheep, the soils data were summarized at two different extents: the soils within the surveyed units and the soils within a minimum convex polygon encompassing the surveyed units. These extents were clipped to only include areas within the extent of the soils data. The "soils surveyed" extent includes only the units surveyed: 1-5 and 8-16. This area is represented by the yellow polygons in Figure D-1. Park staff recommended analyzing soils within a minimum convex polygon extent in order to include lower elevation habitat between survey units as available habitat. A polygon was created encompassing all surveyed units including areas of lower elevation between surveyed units using the ESRI ArcGIS convex hull minimum bounding geometry tool. This area is represented by the orange polygon in Figure D-1. Park staff felt that it was safe to assume no sheep were in these areas during the survey.

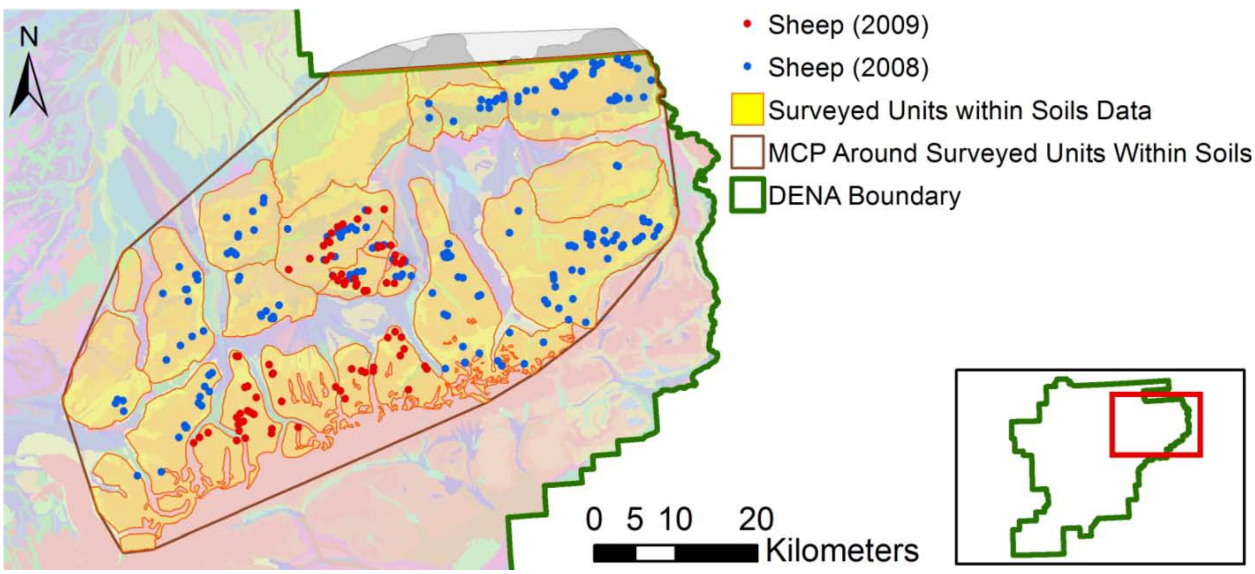

Figure D-1. Areas used to summarize soils for the Dall's sheep soils habitat analysis (DENA 2008a, DENA 2009, NPS 2010). The orange area is a minimum convex polygon surrounding units surveyed in 2008 or 2009. The yellow polygons represent the actual units surveyed in 2008 and 2009.

To determine available habitat for caribou, initially a minimum convex polygon (MCP) was created around all caribou cow locations; however, several points in the northeast were associated with a specific snow event in 1992, and including them in the MCP was deemed inappropriate (DENA, Meier, pers. comm. 2010). Instead, individual MCPs for each biological year (April through March of following year) were created (Figure D-2, left). The MCPs for all biological years except 1992 were then merged (Figure D-2, right). This addressed the issue of the 1992 snow event and also provided more detail for the study area. Cow locations from 1992 that did not occur within the merged MCP were excluded from analysis. After determining from survey data that the highest recorded caribou elevation was 7443 feet, all elevations over 7500 feet were removed from the study area. All areas of the MCP outside of the extent of the soils data were removed from the study area, because the soils data are necessary for the analysis (Figure D-3). Finally, any small polygons disconnected from the primary polygon study area were removed (no caribou observations occurred within the polygons removed).

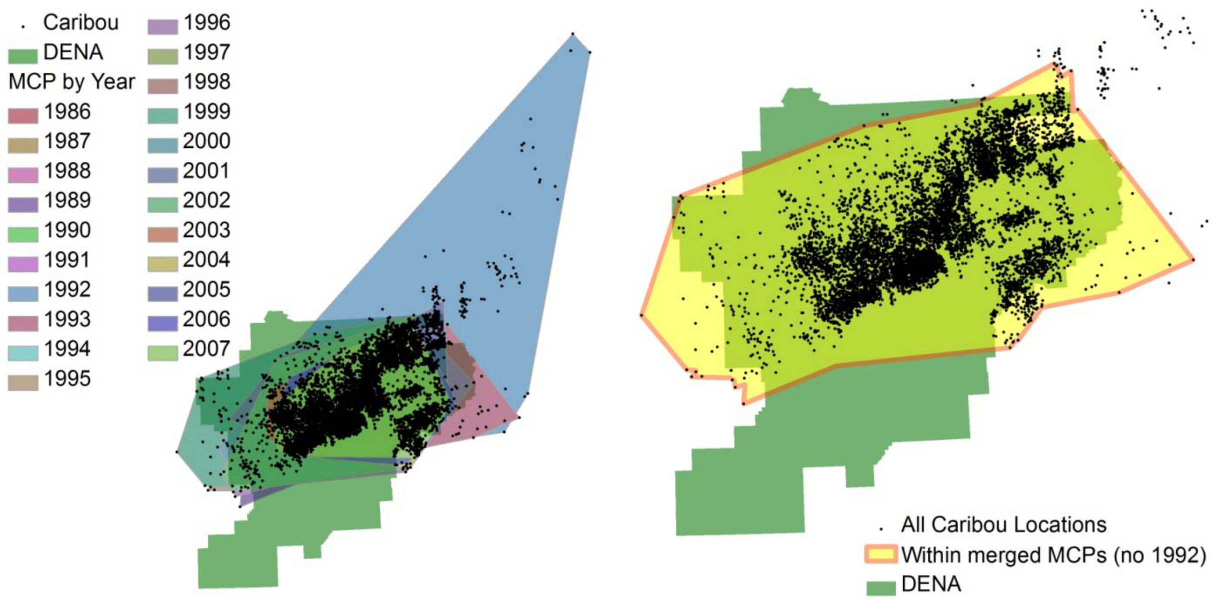

Figure D-2. MCPs for each BIO year (left). MCPs for each year were merged, excluding 1992 (right) (Adams 2010, NPS 2010).

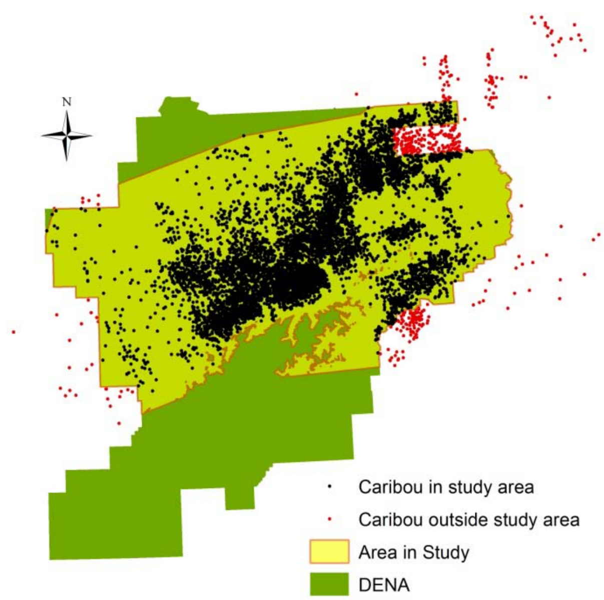

Figure D-3. Final draft study area based on analysis of MCP, exclusion of elevations over 7500 feet, the extent of the soils data, and removal of disconnected polygons (Adams 2010, NPS 2010).

Analysis

Percent of Observations: The soils data were spatially joined to the locations for each species to determine the soil map unit for each location. The percent of each species using each soil map unit was calculated. For caribou, locations were subdivided into two groups based on season. Observations from 1 May to 30 September were classified as summer, and the remaining locations were classified as winter observations. Percent of each soil type was calculated for each season.

Percent of Soils Surveyed (for moose and Dall's sheep) or Available Habitat (for caribou): The soils data were clipped to the surveyed units. A new field was added and area of each soil map unit was calculated in hectares. The percent of surveyed area for each soil type was calculated.

Percent of MCP (for Dall's sheep): The soils data were clipped to the MCP. A new field was added and area of each map unit was calculated in hectares. The percent of MCP for each soil type was calculated.

Results

Caribou

Soil Use by Cows

A total of 10,559 cow locations were analyzed in the study area (Summer = 6480, Winter = 4079). One hundred and nineteen soil types were associated with cow locations (Figure D-4). During the summer months cows were observed in 106 soil types, and during the winter months, cows were observed in 99. Overall, twenty-seven soil types were used by more than 1% of cows, but only three soil types were used by more than 5% of cows. These three soil types were Alpine Glaciated Low Diorite Mountains with Discontinuous Permafrost (7TM21); Alpine Low Mountains with Discontinuous Permafrost, Nenana Gravels (10LM); and Alpine Till Plains and Hills with Discontinuous Permafrost (7TP2).

During the summer season, twenty-five soil types were used by more than 1% of cows, and four soil types were used by more than 5% of cows. These four soil types were Alpine Glaciated Low Diorite Mountains with Discontinuous Permafrost (7TM21) (9.4%); Nonvegetated Mountains, Alaska Mountains (NV1) (6.5%); Alpine Till Plains and Hills with Discontinuous Permafrost (7TP2) (6.3%); and Alpine Till Plains with Discontinuous Permafrost (7TP) (5.7%).

Thirty soil types were used by more than 1% of cows during the winter season, and two soil types were used by more than 5% of cows. These two soil types were Alpine Low Mountains with Discontinuous Permafrost, Nenana Gravels (10LM) (10.1%) and Alpine Plains with Continuous Permafrost (11P) (9.6%).

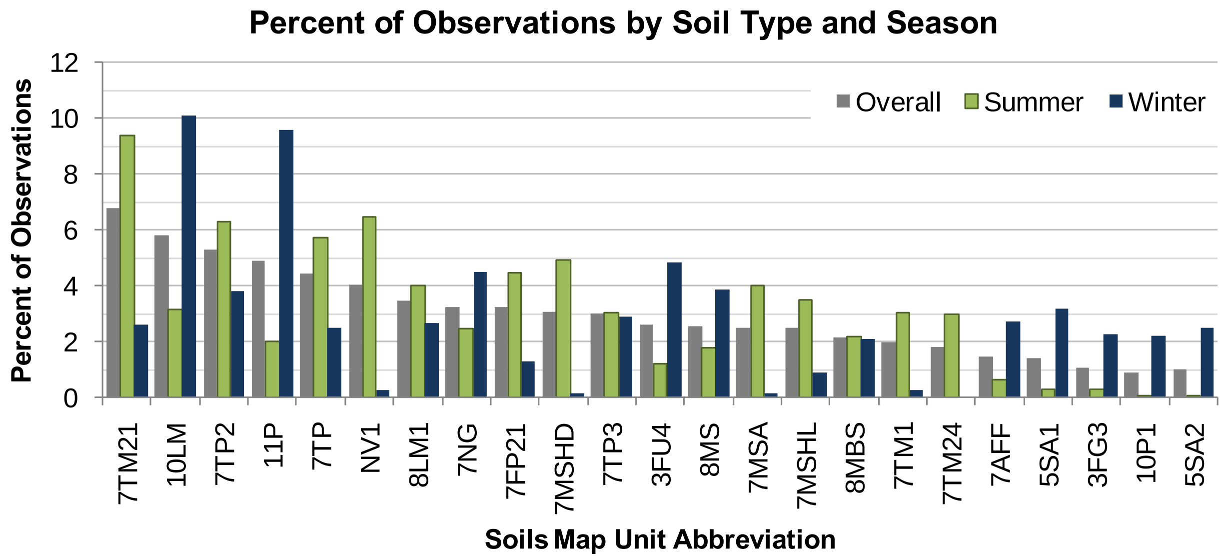

Figure D-4. Percent of cows observed in each soils map unit by season and overall (data from Adams 2010, NPS 2010). Only soil types in which more than 2% of cows were located in a season are included in this figure. The total number of cows observed was 10,559. See Table D-1 for the map unit name associated with each soils map unit abbreviation.

The potential vegetation soils attribute was also summarized (Figure D-5). Of the 10,559 total cows, the greatest number of cows (2,878 or 27%) were located in the Interior: shrub birch-ericaceous scrub vegetation class. Four potential vegetation classes comprised over 75% of the cow locations: Interior: shrub birch-ericaceous scrub (2,878 or 27%); Interior: mountain avens-ericaceous dwarf alpine scrub (2,180 or 21%); Interior: shrub birch/sedge scrub & ericaceous dwarf scrub (1,818 or 17%); and Interior: dwarf needleleaf permafrost woodland (1,525 or 14%).

Differences in distribution among vegetation types were also noted by season (Plate D-3). Results are shown in Figure D-5 for vegetation classes with greater than two percent of observations during either the winter or summer months. During the winter months, caribou cows were found in greater percentage in the following vegetation class compared to the summer months: Interior shrub birch-ericaceous scrub; Interior dwarf needleleaf permafrost woodland; and Interior tussock and shrub birch/sedge scrub. Observations of caribou cows in the summer months were greater than the winter months in the following classes: Interior mountain avens-ericaeous dwarf alpine scrub; Interior shrub birch/sedge scrub and ericaceous dwarf scrub; and non or sparsely vegetated.

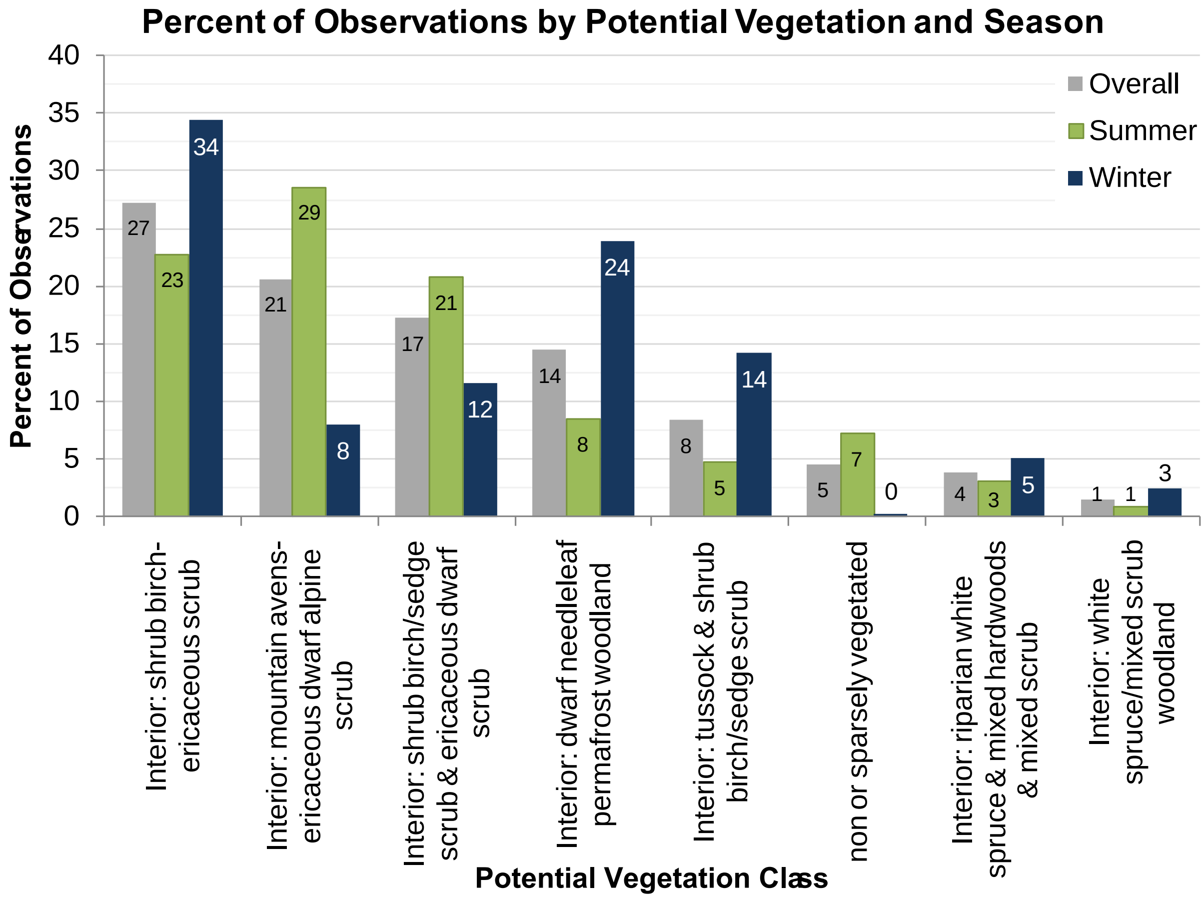

Figure D-5. Percent of cows observed in each potential vegetation class by season and overall (data from Adams 2010, NPS 2010). Only vegetation classes in which more than 2% of cows were located in a season are included in this figure.

Soil Use Compared to Available Soils

The soils associated with cow locations were compared to the available soils within the study area (Table D-1). Several soils types were used at a greater percentage compared to the available soils. The greatest difference in percentage during the summer season was 8.38% (Alpine Glaciated Low Diorite Mountains with Discontinuous Permafrost). The greatest difference during the winter months was 8.6% (Alpine Low Mountains with Discontinuous Permafrost, Nenana Gravels), with 8.3% a close second (Alpine Plains with Continuous Permafrost).

The soil type used by the fewest percent of cows compared to the available soils was Nonvegetated Mountains, Alaska Mountains. This type comprised 13% of available soils but was only used by 6.5% of cows during the summer season and 0.3% of cows during the winter season.

Table D-1. Summary of percent soil type by cow locations and within available habitat (Adams 2010, NPS 2010). Only those soils comprising at least 3% of the cow locations and/or 3% of the available habitat are included. Green shaded cells represent values greater than the percent of study area. Red shaded cells represent values less than the percent of study area.

Soils map unit	Mapunit Name	Percent of Cow Observations			Percent of Study Area
		Summer	Winter	Overall	
7TM21	Alpine Glaciated Low Diorite Mountains with Discontinuous Permafrost	9.38	2.60	6.76	1.00
10LM	Alpine Low Mountains with Discontinuous Permafrost, Nenana Gravels	3.15	10.10	5.83	1.50
7TP2	Alpine Till Plains and Hills with Discontinuous Permafrost	6.28	3.80	5.32	2.91
11P	Alpine Plains with Continuous Permafrost	1.99	9.59	4.92	1.28
7TP	Alpine Till Plains with Discontinuous Permafrost	5.71	2.48	4.46	2.15
NV1	Nonvegetated Mountains, Alaska Mountains	6.47	0.27	4.07	13.03
8LM1	Alpine Low Schist Mountains with Discontinuous Permafrost	4.01	2.65	3.49	0.60
7NG	Alpine Plains and Hills with Discontinuous Permafrost, Nenana Gravels	2.50	4.49	3.27	0.63
7FP21	Alpine Diorite Terraces and Flood Plains	4.46	1.32	3.25	0.61
7MSHD	Alpine Dark Sedimentary Mountains, High Elevation	4.94	0.17	3.10	2.59
7TP3	Boreal and Alpine Hills with Discontinuous Permafrost	3.04	2.92	2.99	1.11
3FU4	Boreal Loess Plains, Hills, and Drains with Continuous Permafrost	1.22	4.85	2.62	3.62
8MS	Alpine Schist Mountain Ridges with Discontinuous Permafrost	1.79	3.85	2.59	0.98
7MSA	Alpine Diorite Mountains, Interior	4.01	0.17	2.53	0.57
7MSHL	Alpine Mixed Lithology Mountains, High Elevation	3.50	0.93	2.51	2.17
7TM1	Alpine Glaciated Mountains with Discontinuous Permafrost, High Elevation	3.02	0.29	1.97	1.31
7TM24	Alpine Diorite Mountains with Discontinuous Permafrost	3.01	0.00	1.85	0.26
5SA1	Alpine Schist Mountains	0.29	3.21	1.42	0.79
3FG3	Boreal Loess Plains and Peat Plateaus with Continuous Permafrost	0.29	2.28	1.06	3.56
2ST	Boreal Terraces with Discontinuous Permafrost	0.17	1.74	0.78	3.40
3FG	Boreal Loess Plains with Continuous Permafrost	0.35	1.03	0.62	3.00
NV2	Nonvegetated Mountains, South Central Mountains	0.74	0.00	0.45	4.67

The potential vegetation of the soil type used by cows was also compared to the potential vegetation in the study area (Table D-2). Six vegetation classes were used at a greater percentage during the summer season compared to the available habitat. The greatest positive difference in the summer occurred in the Interior: mountain avens-ericacous dwarf alpine scrub class. This potential vegetation type was present at nearly 29% of the summer cow locations but comprised only 9% of the study area. The potential vegetation type that was used the least compared to the available habitat was Interior: dwarf needleleaf permafrost woodland. This potential vegetation class was present in nearly 35% of the study area but only 8.5% of cows were found in these map units.

Three potential vegetation classes were used at a greater percentage during the winter months compared to the available habitat. The greatest positive difference occurred in the Interior: shrub birch-ericaceous scrub class. This potential vegetation type was present at 34% of the cow locations but comprised only 14% of the study area. The potential vegetation type that was used the least in the winter compared to the available habitat was Non or sparsely vegetated. This potential vegetation class was present in nearly 18% of the study area but less than 0.5% of cows were found in these map units.

Table D-2. Percent of potential vegetation classifications at cow locations and throughout the study area (Adams 2010, NPS 2010). Green shaded cells represent values greater than the percent of study area. Red shaded cells represent values less than the percent of study area.

Potential Vegetation	Percent of Cow Observations			Percent of Study Area
	Summer	Winter	Overall	
Interior: shrub birch-ericaceous scrub	22.78	34.37	27.26	14.30
Interior: mountain avens-ericaceous dwarf alpine scrub	28.61	7.99	20.65	9.00
Interior: shrub birch/sedge scrub & ericaceous dwarf scrub	20.76	11.60	17.22	8.00
Interior: dwarf needleleaf permafrost woodland	8.49	23.90	14.44	34.74
Interior: tussock & shrub birch/sedge scrub	4.71	14.17	8.36	4.25
Non or sparsely vegetated	7.21	0.27	4.53	17.70
Interior: riparian white spruce & mixed hardwoods & mixed scrub	3.02	5.05	3.81	5.82
Interior: white spruce/mixed scrub woodland	0.80	2.53	1.47	3.16
South Central: ericaceous dwarf alpine scrub	1.74	0.00	1.07	0.78
South Central: Barclay willow scrub/medium herbaceous meadow mosaic	1.67	0.10	1.06	1.44
South Central: mixed paper birch-white spruce forest	0.14	0.00	0.09	0.19
South Central: riparian poplar forest & mixed willow-alder scrub & alluvium	0.05	0.00	0.03	0.13
Water	0.03	0.02	0.03	0.46
Interior: mixed paper birch-white spruce forest	0.00	0.00	0.00	0.04
South Central: Sitka alder scrub/tall herbaceous meadow mosaic	0.00	0.00	0.00	0.01

Dall's sheep

Soil Use by Sheep

Ten map units were associated with sheep locations (Figure D-6). The most common map unit associated with Dall's sheep locations is nonvegetated mountains, Alaska Mountains (NV1).

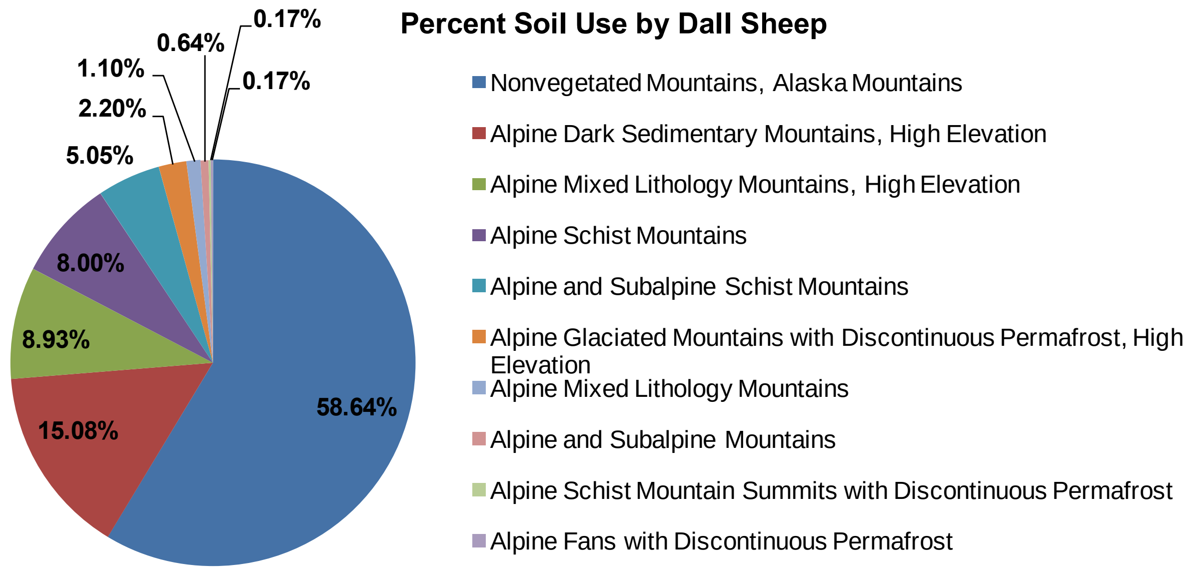

Figure D-6. Percent soil use by Dall sheep (data from DENA 2008a, DENA 2009, NPS 2010).

The potential vegetation soils attribute was also summarized (Figure D-7). Of the 1,724 total sheep, the greatest number (1,011 or 58.6%) were located in the Non or sparsely vegetated class. All sheep were located in one of four potential vegetation classes: Non or sparsely vegetated (1,011 or 58.6%); Interior: mountain avens-ericaceous dwarf alpine scrub (417 or 24%); Interior: shrub birch-ericaceous dwarf scrub (255 or 14.8%); and Interior: shrub birch/sedge scrub & ericaceous dwarf scrub (41 or 2.4%).

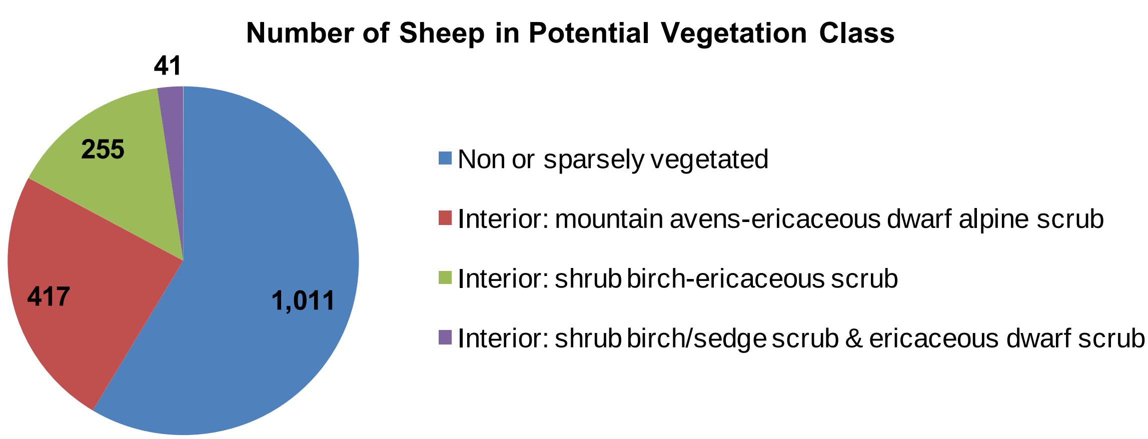

Figure D-7. Number of Dall's sheep in each potential vegetation class (data from DENA 2008a, DENA 2009, NPS 2010).

Soil Use Compared to Available Soils
The soils associated with sheep locations were compared to the available soils within the surveyed units and within the MCP (Table D-3). Five soil types were used at a higher percentage than expected based on availability in both the surveyed units and within the MCP:

Nonvegetated Mountains, Alaska Mountains (NV1); Alpine Dark Sedimentary Mountains, High Elevation (7MSHD); Alpine Mixed Lithology Mountains, High Elevation (7MSHL); Alpine Schist Mountains (5SA1); and Alpine and Subalpine Schist Mountains (5SA11). No sheep were located within the Alpine Dark Sedimentary Mountains (7MS1D), which comprised 6.13% of the surveyed area and 4.45% of the MCP.

Table D-3. Summary of percent soil type by sheep location, within surveyed units, and within the minimum convex polygon (MCP) around surveyed units (DENA 2008a, DENA 2009, NPS 2010). Only those soils comprising at least 1% of the sheep locations, soils surveyed or the MCP are included.

Soils map unit	Map unit name	Percent of Sheep	Percent of soils surveyed	Sheep use compared to soils surveyed	Percent of MCP	Sheep use compared to MCP
NV1	Nonvegetated Mountains, Alaska Mountains	58.64	30.69	More	29.59	More
7MSHD	Alpine Dark Sedimentary Mountains, High Elevation	15.08	12.07	More	8.61	More
7MSHL	Alpine Mixed Lithology Mountains, High Elevation	8.93	7.36	More	5.29	More
5SA1	Alpine Schist Mountains	8.00	4.21	More	2.95	More
5SA11	Alpine and Subalpine Schist Mountains	5.05	3.98	More	2.80	More
7TM1	Alpine Glaciated Mountains with Discontinuous Permafrost, High Elevation	2.20	6.44	Less	6.18	Less
7MS1L	Alpine Mixed Lithology Mountains	1.10	5.50	Less	4.36	Less
7SA1	Alpine and Subalpine Mountains	0.64	1.55	Less	1.08	Less
5P1	Alpine Schist Mountain Summits with Discontinuous Permafrost	0.17	0.40	Less	0.28	Less
7V5	Alpine Fans with Discontinuous Permafrost	0.17	0.21	Less	1.21	Less
7MS1D	Alpine Dark Sedimentary Mountains		6.13	Less	4.45	Less
10LM	Alpine Low Mountains with Discontinuous Permafrost, Nenana Gravels		2.94	Less	2.92	Less
7V1	Alpine Lower Mountain Slopes and Fans with Discontinuous Permafrost		2.50	Less	3.31	Less
5SA2	Alpine and Subalpine Schist Lower Mountain Slopes with Discontinuous Permafrost, Cool		1.75	Less	1.22	Less
7MS2	Boreal Glaciated Lower Mountain Slopes		1.31	Less	1.71	Less
7V11	Alpine Fans		1.30	Less	1.37	Less
7TM	Alpine Glaciated Low Mountains with Discontinuous Permafrost		1.06	Less	2.28	Less
10ES	Subalpine and Alpine Plateau Escarpments with Discontinuous Permafrost		1.05	Less	0.74	Less
7NG	Alpine Plains and Hills with Discontinuous Permafrost, Nenana Gravels		1.05	Less	1.51	Less
7FP1	Boreal Flood Plains and Terraces		0.40	Less	1.21	Less
GA	Nonvegetated Alluvium, Alaska Mountains, Alpine		0.23	Less	1.42	Less
7FP2	Alpine Flood Plains		0.18	Less	1.57	Less
7TP	Alpine Till Plains with Discontinuous Permafrost		0.18	Less	3.98	Less

The potential vegetation of the soil type used by Dall's sheep was also compared to the potential vegetation in the study area (Table D-4). Two potential vegetation classes were used at a greater percentage compared to the available habitat. Non or sparsely vegetated was used by 58.6% of sheep but comprised only 30.7% of the surveyed units and even less of the MCP. The Interior: mountain avens-ericaceous dwarf alpine scrub potential vegetation class was also used at a greater percentage compared to the available habitat. Although the Interior: shrub birch-ericaceous scrub vegetation class was used by 14.8% of Dall's sheep, it was used in a smaller proportion compared to the available 35.6% of the surveyed units.

Table D-4. Percent of potential vegetation classes used by Dall's sheep, present in surveyed units, and within the minimum convex polygon around surveyed units (DENA 2008a, DENA 2009, NPS 2010).

Potential Vegetation	Percent of Sheep	Percent of Soils Surveyed	Sheep Use Compared to Soils Surveyed	Percent of MCP	Sheep Use Compared to MCP
Non or sparsely vegetated	58.64	30.69	More	29.59	More
Interior: mountain avens-ericaceous dwarf alpine scrub	24.19	19.75	More	15.45	More
Interior: shrub birch-ericaceous scrub	14.79	35.62	Less	33.35	Less
Interior: shrub birch/sedge scrub & ericaceous dwarf scrub	2.38	8.91	Less	13.79	Less
Interior: white spruce/mixed scrub woodland		2.96	Less	3.83	Less
Interior: riparian white spruce & mixed hardwoods & mixed scrub		1.00	Less	2.46	Less
Interior: dwarf needleleaf permafrost woodland		0.67	Less	1.01	Less
Interior: tussock & shrub birch/sedge scrub		0.40	Less	0.52	Less

Moose

Soil Use by Moose
Seventy-six map units were associated with moose locations. Thirty-three soil types were used by more than one percent of moose, but only two soil types were used by more than five percent of moose. The number of moose located in each soil type is included in Figure D-8. Only those soil types where more than 2% of moose were observed are included in the figure. The two soil types in which more than 5% of moose were found are Alpine Glaciated Lower Mountain Slopes (60 of 1006 moose; 9SA44) and Alpine Schist Mountains with Discontinuous Permafrost (54 of 1006 moose; 8MBS).

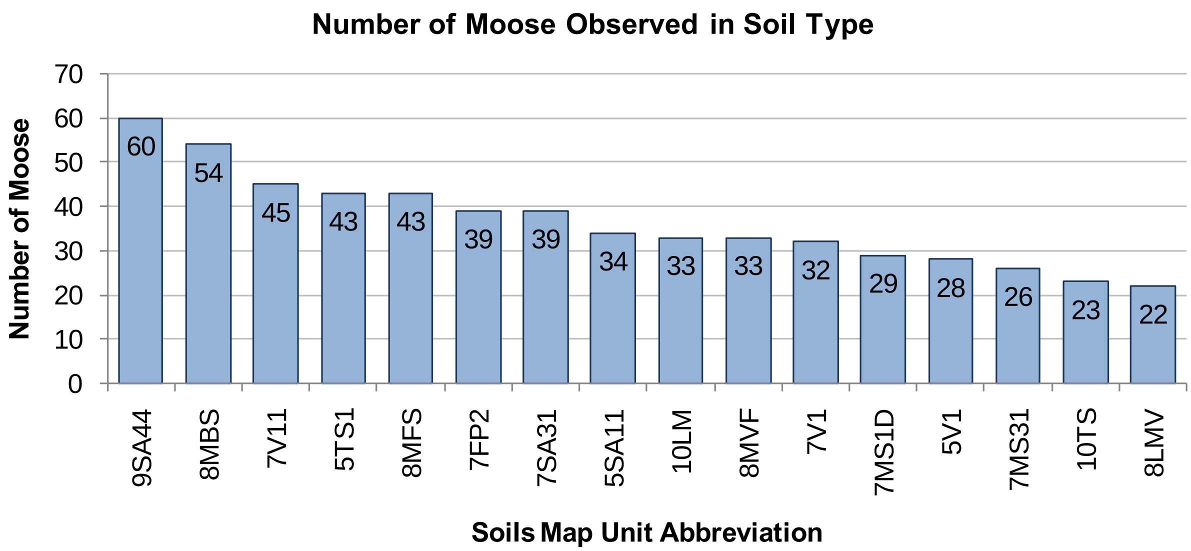

Figure D-8. Number of moose located in each soil type (data from DENA 2008b, NPS 2010). Only soil types in which more than 2% of moose were located are included in this figure. The total number of moose observed was 1,006. See Table D-5 for the map unit name associated with each map unit .

The potential vegetation soils attribute was also summarized (Figure D-9). Eleven potential vegetation classes were associated with moose locations. Of the 1,006 total moose, the greatest number (579 or 57.6%) were located in the 'Interior: shrub birch-ericaceous scrub' vegetation class.

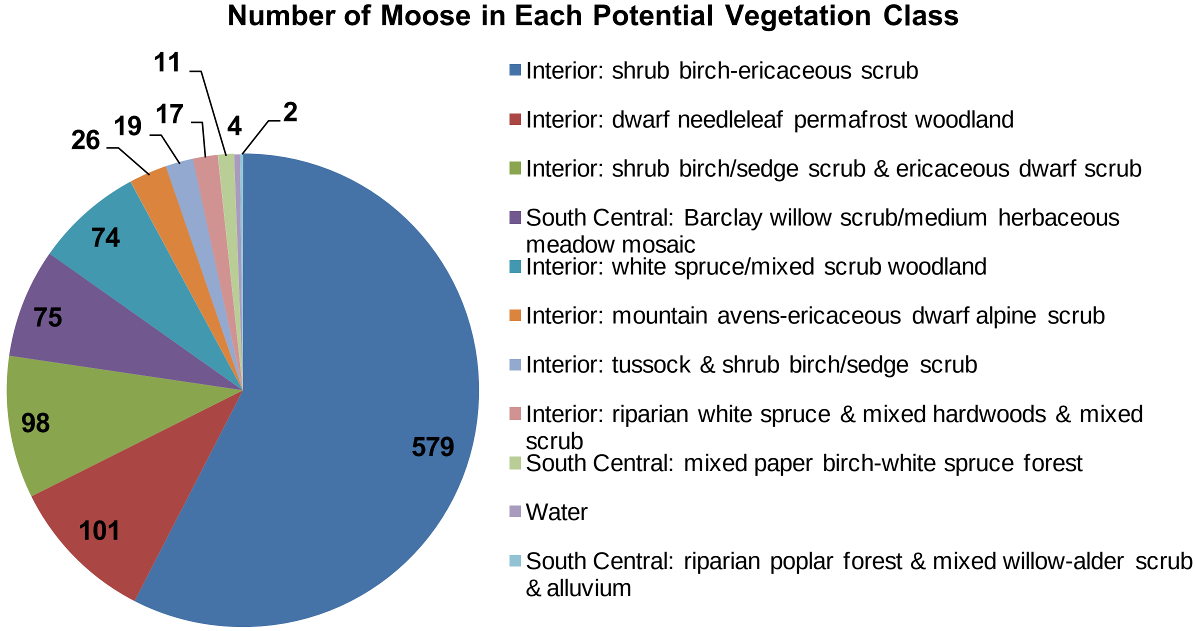

Figure D-9. Number of moose in each potential vegetation class (data from DENA 2008b, NPS 2010).

Soil Use Compared to Available Soils

The soils associated with moose locations were compared to the available soils within the surveyed units (Table D-5). Forty soil types were used at a higher percentage than expected based on availability in the surveyed units. No moose were located within the Non-vegetated Mountains, Alaska Mountains (NV1), which comprised 6.62% of the surveyed area.

Table D-5. Summary of percent soil type by moose locations and within surveyed units (DENA 2008b, NPS 2010). Only those soil types comprising more than 2% of moose locations and/or surveyed soils are included.

Soils map unit	Map Unit Name	Percent of Moose	Percent of Surveyed Soils	Moose use compared to soils surveyed
9SA44	Alpine Glaciated Lower Mountain Slopes	5.96	1.35	More
8MBS	Alpine Schist Mountains with Discontinuous Permafrost	5.37	3.23	More
7V11	Alpine Fans	4.47	0.96	More
8MFS	Alpine and Subalpine Schist Lower Mountain Slopes with Discontinuous Permafrost	4.27	0.56	More
5TS1	Alpine Schist Lower Mountain Slopes with Discontinuous Permafrost, Warm	4.27	0.23	More
7FP2	Alpine Flood Plains	3.88	1.18	More
7SA31	Subalpine Mountains	3.88	0.91	More
5SA11	Alpine and Subalpine Schist Mountains	3.38	1.00	More
10LM	Alpine Low Mountains with Discontinuous Permafrost, Nenana Gravels	3.28	3.19	More
8MVF	Boreal and Subalpine Schist Mountain Valleys	3.28	2.45	More
7V1	Alpine Lower Mountain Slopes and Fans with Discontinuous Permafrost	3.18	0.91	More
7MS1D	Alpine Dark Sedimentary Mountains	2.88	1.18	More
5V1	Alpine Schist Alluvial Fans with Discontinuous Permafrost	2.78	0.29	More
7MS31	Alpine Glaciated Mountain Summits and Benches with Discontinuous Permafrost	2.58	0.21	More
10TS	Boreal Plateaus with Continuous Permafrost	2.29	1.21	More
8LMV	Alpine and Subalpine Schist Mountain Valleys	2.19	1.06	More
7TP	Alpine Till Plains with Discontinuous Permafrost	1.49	2.60	Less
7MSHL	Alpine Mixed Lithology Mountains, High Elevation	1.29	3.86	Less
11P	Alpine Plains with Continuous Permafrost	0.99	2.33	Less
7TP2	Alpine Till Plains and Hills with Discontinuous Permafrost	0.60	2.59	Less
7MSHD	Alpine Dark Sedimentary Mountains, High Elevation	0.20	4.26	Less
1FW1	Boreal Terraces with Continuous Permafrost	0.10	2.63	Less
NV1	Nonvegetated Mountains, Alaska Mountains		6.62	Less

The potential vegetation of the soil type used by moose was also compared to the potential vegetation in the units surveyed (Table D-6). Four potential vegetation classes were used at a greater percentage compared to the available habitat. The greatest positive difference occurred in the Interior: shrub birch-ericaceous scrub class. This potential vegetation type was present at 57.6% of the moose locations but comprised only 23% of the study area. The potential vegetation type that was used the least compared to the available habitat was Interior: dwarf needleleaf permafrost woodland. This potential vegetation class was present in nearly 25% of the study area but only 10% of moose were found in these map units.

Table D-6. Percent of potential vegetation at moose locations in the units surveyed (DENA 2008b, NPS 2010).

Potential Vegetation	Percent of Moose	Percent of Soils Surveyed	Moose Use Compared to Soils Surveyed
Interior: shrub birch-ericaceous scrub	57.55	23.28	More
Interior: dwarf needleleaf permafrost woodland	10.04	25.09	Less
Interior: shrub birch/sedge scrub & ericaceous dwarf scrub	9.74	10.09	Less
South Central: Barclay willow scrub/medium herbaceous meadow mosaic	7.46	3.87	More
Interior: white spruce/mixed scrub woodland	7.36	5.26	More
Interior: mountain avens-ericaceous dwarf alpine scrub	2.58	11.35	Less
Interior: tussock & shrub birch/sedge scrub	1.89	5.52	Less
Interior: riparian white spruce & mixed hardwoods & mixed scrub	1.69	6.43	Less
South Central: mixed paper birch-white spruce forest	1.09	0.56	More
Water	0.40	0.51	Less
South Central: riparian poplar forest & mixed willow-alder scrub & alluvium	0.20	0.29	Less
Non or sparsely vegetated		6.62	Less
Interior: mixed paper birch-white spruce forest		0.69	Less
South Central: ericaceous dwarf alpine scrub		0.41	Less
South Central: Sitka alder scrub/tall herbaceous meadow mosaic		0.02	Less

Discussion

This analysis shows that each soil/potential vegetation type is not utilized equally by these three ungulate species. This information could be useful in focusing future population surveys, assessing climate change vulnerability for wildlife, and better understanding species' habitat preference and predator/prey relationships. A similar analysis could be conducted utilizing the soils database to investigate habitat preferences of other species. For example, wolf den, raptor nest, and trumpeter swan locations could be compared to soil type and potential vegetation.

Literature Cited

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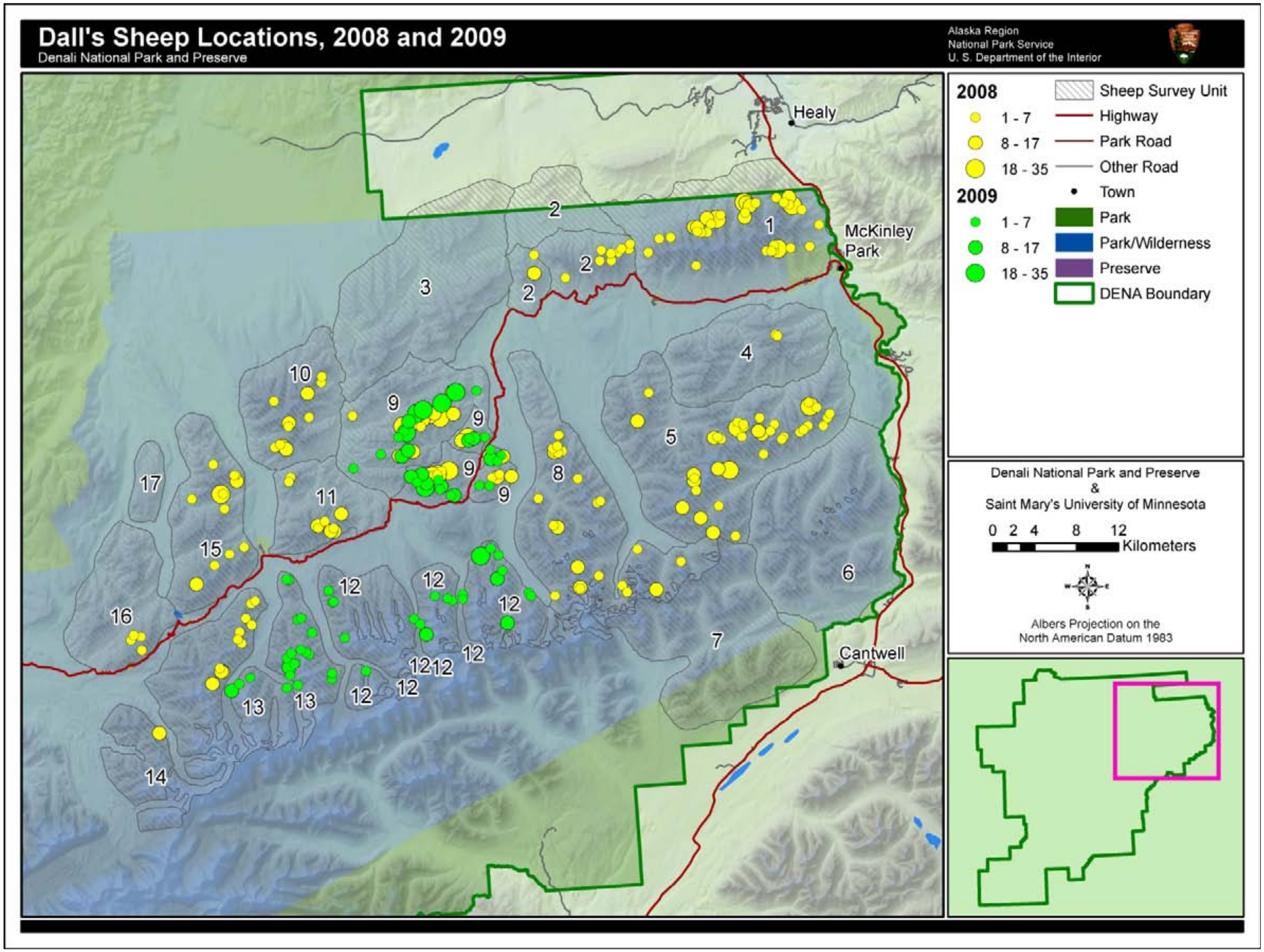

Plate D-1. Dall's sheep locations and survey units, 2008 and 2009 (DENA 2008a, DENA 2009, NPS 2010).

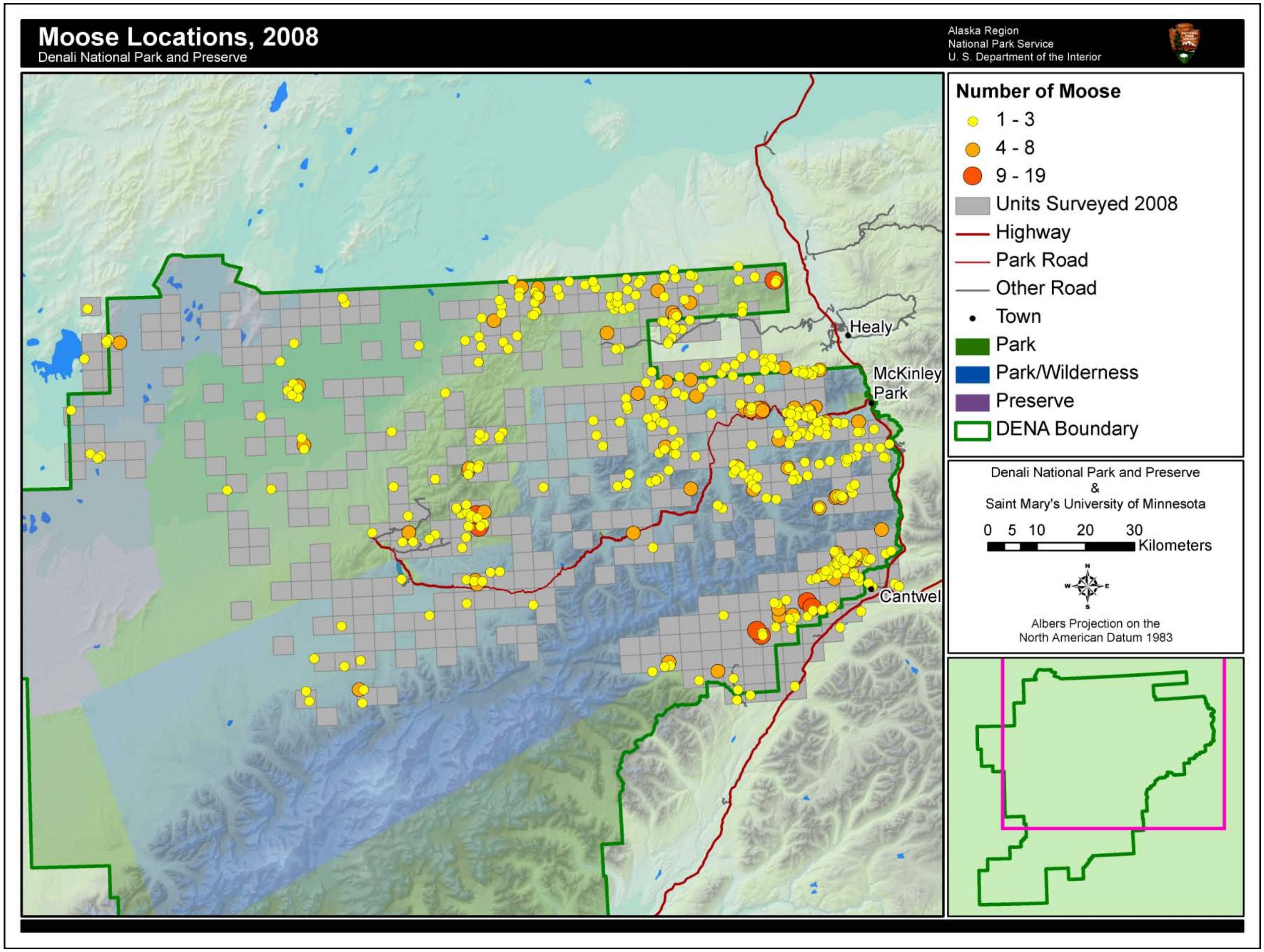

Plate D-2. Moose units surveyed and locations, 2008 (DENA 2008b, NPS 2010).

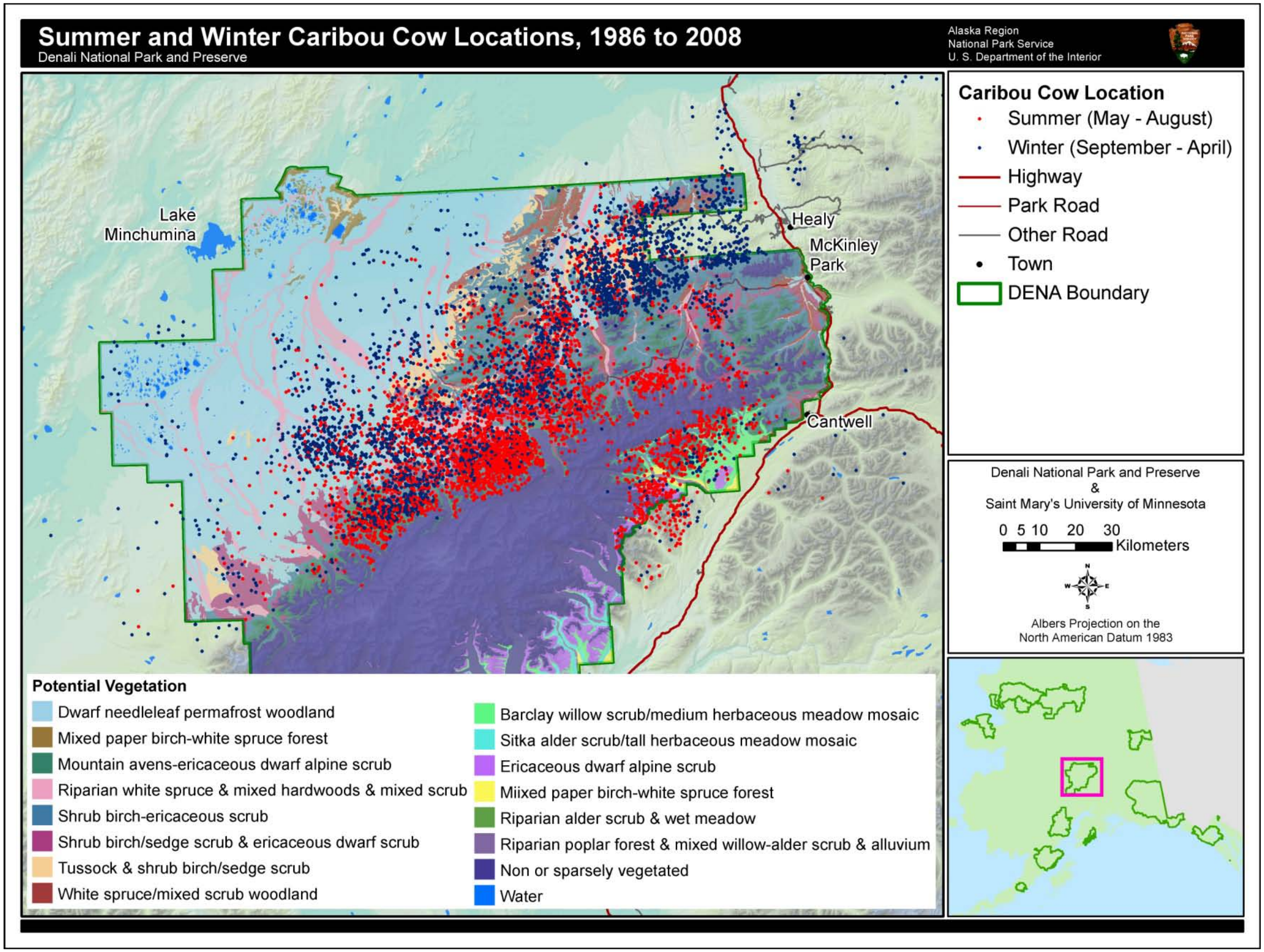

Plate D-3. Seasonal caribou locations and potential vegetation types (Adams 2010, NPS 2010).

Appendix E. Human Influence Project

Background

The purpose of this project was to develop a map showing areas of cumulative human influence within the park and preserve. Data layers recommended for inclusion included airstrips, buildings, campgrounds, cabins, ORV trails and snow machine routes, climbing routes, railroads, roads, social trails, traditional use trails and areas, utilities, trap lines, exotic plant infestations, and subsistence harvest. The map was to represent the core feature and an area of influence buffer around the feature. The logical extent of these buffers was to be determined both anecdotally and through research review. Usage of features was examined from the standpoint of both frequency and intensity.

Methods

Feature Classification

Following initial review of datasets and literature related to human influence, it was decided to consider features from two points of view: locations of human activity and physical features created by humans. These are defined as follows:

- Physical features: physical features created by humans that exist whether or not a human is present; these features represent human influence because they are unnatural additions to the landscape.

- Activity features: human presence in the landscape; these features represent human influence because the human activity produces noise, introduces visible features, and provides access points to the surrounding landscape.

Features were organized into these two types of human influence in order to more clearly define them in terms of intensity and frequency of use. Within the activity and physical feature categories, features were further organized into sub-categories for easier querying and symbology. The activity and physical categories and features are listed in Table E-1 and Table E-2.

Table E-1. Physical features, categories, and geometry types.

Category	Feature	Point	Polyline	Polygon
Buildings	Historic Cabin	X		
	Building (other)			X
Clearings	Airstrip or Landing Zone	X	X	X
	Campsite	X		
Fences and Guardrails	Fence		X	
	Guardrail		X	
	Retaining Wall		X	
Roads and Railroads	Railroad		X	
	Road			X
Trails and Routes	Climbing Route		X	
	OHV Trail		X	
	Sidewalk			X
	Snow Machine Trail		X	
	Social Trail		X	
	Traditional Use Trail		X	X
	Trails (other)		X	
Utilities	Alarm		X	
	Electric		X	
	LPG		X	
	Phone		X	
	Pipeline		X	
	Sewer		X	
	Water		X	
Vegetation	Exotic Plant			X
Water Related Structures	Culvert		X	
	Dam		X	
	Ditch		X	
	OHV Bridge	X		
	Road Bridge			X

Table E-2. Activity features, categories, and geometry types.

Category	Feature	Point	Polyline	Polygon	Zones (polygon)
Foot Travel	Pedestrian			X	
	Climbing		X		X
	Hiking		X		
	Backcountry		X		X
Harvest	Hunting				X
	Traditional Use		X	X	X
	Trapping		X		
Occupancy	Buildings			X	
	Camping	X			
	Concessions			X	
	Historic Cabins	X			
Vehicle	Aircraft Landing / Take-off	X	X	X	X
	Aircraft Overflight				X
	Automobile		X		
	Bicycle		X		
	Boat		X		
	OHV		X		
	Snow Machine		X		
	Train		X		

Various spatial datasets were evaluated for inclusion in this project. The National Park Service Permanent GIS Dataset (NPS 2010) was reviewed for applicable spatial layers. Additional layers were provided by DENA staff or created based on anecdotal descriptions by DENA staff. In some cases more than one dataset existed for a type of feature. In these situations, the datasets were evaluated for perceived accuracy. Datasets that were perceived to be more accurate or have more complete attribute information were incorporated first. The additional datasets were then used if they provided additional features or attribute information. Effort was made to avoid overlapping or duplicate features; however, in some cases a feature may be represented by two or more data sources using different geometry types (e.g., points and polygons). In these situations, the multiple geometry types were typically retained for more flexibility in cartographic representation. Each source is cited in the full metadata for the associated geodatabase.

Feature Ranking

In order to examine features from both a frequency and intensity point of view, a ranking system was developed to be applied across all features, thus allowing a relative comparison of human influence across the park and preserve landscape. The intensity of physical features were ranked based on the physical impact of the feature on the landscape, considering whether unnatural material had been added or vegetation had been removed and the permanence of the feature on the landscape. The intensity of all physical features was not known or did not fit clearly into one ranking, but all features were given an initial ranking that could be modified in the future when more information is available. The ranking of physical features is described in Table E-3.

Table E-3. Ranking of physical feature intensity.

Rank	Description
1	Trampled Vegetation / Snow – Periodic (periodic disturbance with no visual evidence of disturbance)
2	Trampled Vegetation / Snow - Continuous (continuous disturbance with visual evidence)
3	Compacted Soil / Bare Soil
4	Gravel (introduced pervious surface)
5	Paved (introduced impervious surface)

For this project, the intensity of human activity is viewed as a result of both the amount of activity occurring at one time (referred to as 'concentration') and the frequency of the activity. Therefore, activity features were assigned separate rankings based on the concentration of activity and the frequency of activity. Concentration and frequency were ranked on a scale of one to five and are described in Table E-4 below.

Table E-4. Activity feature concentration and frequency rankings.

Rank	Concentration	Frequency
1	1-3 People	Annually
2	4 to 12 People	Monthly
3	More than 12 People	Weekly
4	Automobile and OHV	Daily
5	Trains and Aircraft Landing or Take-off	Hourly

The concentration and frequency scores were then used to calculate activity feature intensity using the following equation:

$$\text{Intensity} = \frac{\text{Concentration X Frequency}}{5}$$

Zone of Influence Development

Two zones of influence were considered for this project: physical footprint and visibility, which are described here:

Physical footprint: Footprints of physical features were created using known or estimated dimensions of point and line features and the original dimensions of polygon features. This effort was made to provide an estimate of the actual size of the physical feature footprint on the landscape. The methods for determining dimensions and creating footprints were unique to each feature and are described in detail in the geodatabase metadata.

Visibility: A viewshed analysis was conducted using an ESRI ArcGIS spatial analyst tool. Due to limitations of the tool and processing requirements, including all features in the viewshed analysis was deemed unfeasible. Viewing the output of the viewshed, one would not be able to determine which feature was visible from each location. For a more meaningful result, the main park road was selected for viewshed analysis and the analysis was limited to the area within five miles of the park road. The ESRI Construct Points tool was used to create a point every 200 meters along the park road. These points were then input into the viewshed tool. Visibility was assessed using a 60 meter digital elevation model of Denali National Park and Preserve. A z-factor of 0.3048 was used to account for the fact that the x,y units were in meters and the z units were in feet. The output raster values indicate the number of points visible from each 60 meter cell in the digital elevation model.

Geodatabase Design

A geodatabase was designed to organize the resulting datasets. Careful thought was given to design the database in a way that would allow for future updating and revision. Features are organized in the geodatabase in a way that also allows for querying and flexibility in how they are viewed. Spatial layers are organized in three feature datasets within the geodatabase: Activity Features, Physical Features, and Zones of Influence. Within the Activity Features and Physical Features datasets, features are organized into classes based on geometry (points, lines, and polygons). Subtypes were created for each feature type in order to set default values for certain attributes. The Activity Features dataset also contains an Activity Zones class to hold large activity areas such as traditional use areas and backcountry activity zones, which represent an area of activity as opposed to a center of activity. The Zones of Influence feature dataset contains a feature class representing the footprint area of influence. The raster results of the viewshed analysis are stored within the geodatabase but not within a feature dataset. A diagram of the overall database schema can be viewed in Figure E-1, Figure E-2, and Figure E-3, and depicts the schema of a physical and activity feature class, including subtypes with associated domains and default values.

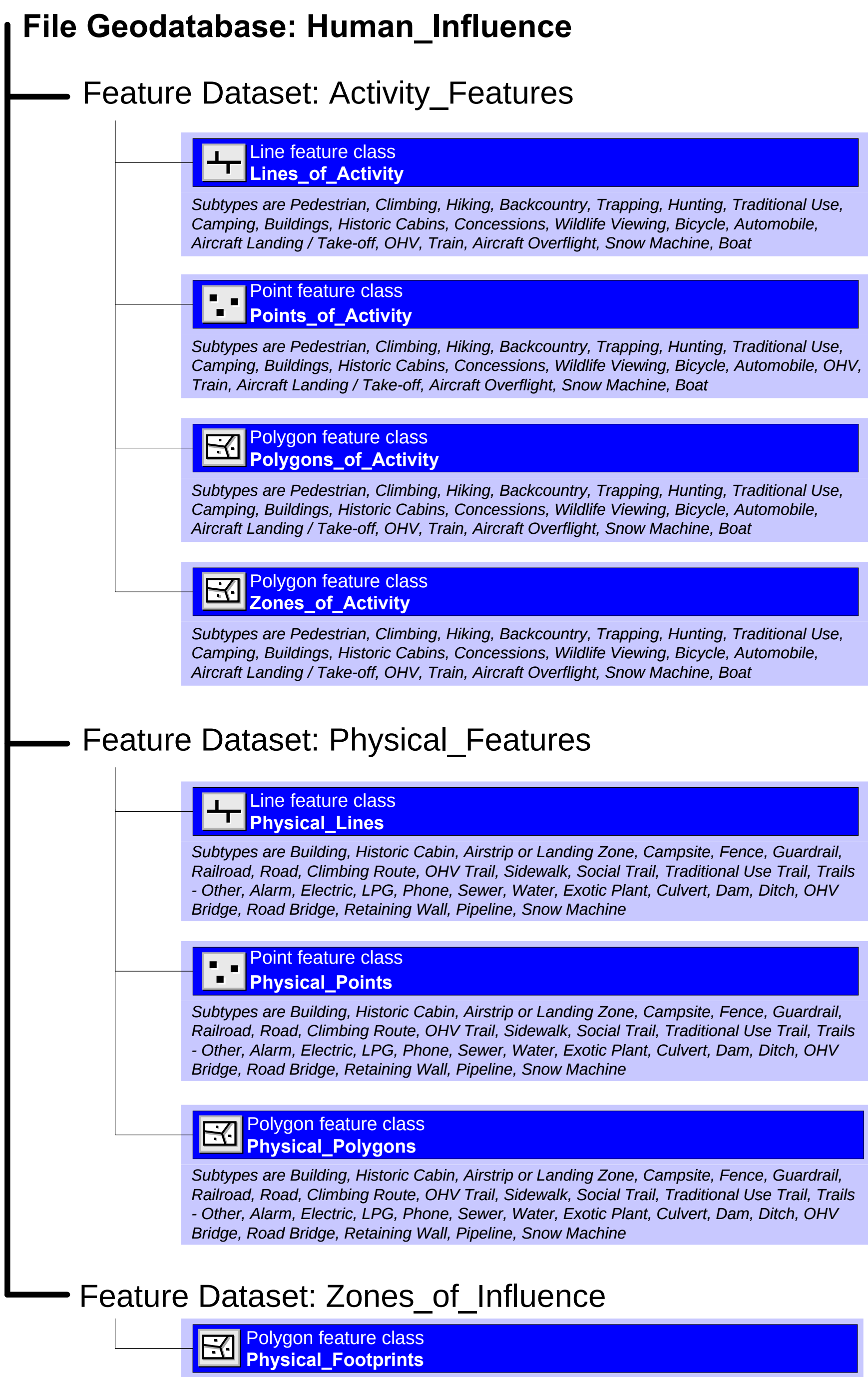

Figure E-1. Overview of the human influence geodatabase schema. Not depicted is the viewshed raster which is also stored within the geodatabase.

Simple feature class
Physical_Points

Geometry *Point*
Contains M values *No*
Contains Z values *No*

Field name	Data type	Allow nulls	Default value	Domain	Precision	Scale	Length
OBJECTID	Object ID						
SHAPE	Geometry	Yes					
CATEGORY	String	Yes		PCategory			30
FEATURE	Short integer	Yes	1	PFeature	0		
INTENSITY	Short integer	Yes		PIntensity	0		
NAME	String	Yes					50
SOURCE	String	Yes					50
NOTES	String	Yes					100

Subtypes of Physical_Points

Subtype field *FEATURE*
Default subtype *1*

List of defined default values and domains for subtypes in this class

Subtype Code	Subtype Description	Field name	Default value	Domain
1	Building	CATEGORY	Buildings	PCategory
		INTENSITY	5	PIntensity
2	Historic Cabin	CATEGORY	Buildings	PCategory
		INTENSITY	5	PIntensity
3	Airstrip or Landing Zone	CATEGORY	Clearings	PCategory
		INTENSITY	2	PIntensity
4	Campsite	CATEGORY	Clearings	PCategory
		INTENSITY	3	PIntensity
5	Fence	CATEGORY	Fences and Guardrails	PCategory
		INTENSITY	2	PIntensity
6	Guardrail	CATEGORY	Fences and Guardrails	PCategory
		INTENSITY	3	PIntensity
7	Railroad	CATEGORY	Roads and Railroads	PCategory
		INTENSITY	5	PIntensity
8	Road	CATEGORY	Roads and Railroads	PCategory
		INTENSITY	4	PIntensity
9	Climbing Route	CATEGORY	Trails and Routes	PCategory
		INTENSITY	2	PIntensity
10	OHV Trail	CATEGORY	Trails and Routes	PCategory
		INTENSITY	2	PIntensity
11	Sidewalk	CATEGORY	Trails and Routes	PCategory
		INTENSITY	5	PIntensity
12	Social Trail	CATEGORY	Trails and Routes	PCategory
		INTENSITY	2	PIntensity
13	Traditional Use Trail	CATEGORY	Trails and Routes	PCategory
		INTENSITY	2	PIntensity
14	Trails - Other	CATEGORY	Trails and Routes	PCategory
		INTENSITY	2	PIntensity
15	Alarm	CATEGORY	Utilities	PCategory
		INTENSITY	2	PIntensity
16	Electric	CATEGORY	Utilities	PCategory
		INTENSITY	2	PIntensity
17	LPG	CATEGORY	Utilities	PCategory
		INTENSITY	1	PIntensity
18	Phone	CATEGORY	Utilities	PCategory
		INTENSITY	2	PIntensity
19	Sewer	CATEGORY	Utilities	PCategory
		INTENSITY	1	PIntensity
21	Water	CATEGORY	Utilities	PCategory
		INTENSITY	1	PIntensity
22	Exotic Plant	CATEGORY	Vegetation	PCategory
		INTENSITY	2	PIntensity
23	Culvert	CATEGORY	Water Related Structures	PCategory
		INTENSITY	5	PIntensity
24	Dam	CATEGORY	Water Related Structures	PCategory
		INTENSITY	5	PIntensity
25	Ditch	CATEGORY	Water Related Structures	PCategory
		INTENSITY	2	PIntensity
26	OHV Bridge	CATEGORY	Water Related Structures	PCategory
		INTENSITY	5	PIntensity
27	Road Bridge	CATEGORY	Water Related Structures	PCategory
		INTENSITY	5	PIntensity
28	Retaining Wall	CATEGORY	Fences and Guardrails	PCategory
		INTENSITY	5	PIntensity
29	Pipeline	CATEGORY	Utilities	PCategory
		INTENSITY	1	PIntensity
30	Snow Machine	CATEGORY	Trails and Routes	PCategory
		INTENSITY	2	PIntensity

Figure E-2. Physical features with associated domains and default values.

Simple feature class
Polygons_of_Activity

Geometry *Polygon*
Contains M values *No*
Contains Z values *No*

Field name	Data type	Allow nulls	Default value	Domain	Precision	Scale	Length
OBJECTID	Object ID						
SHAPE	Geometry	Yes					
SHAPE_Length	Double	Yes			0	0	
SHAPE_Area	Double	Yes			0	0	
CATEGORY	String	Yes		ACategory			30
FEATURE	Short integer	Yes	1	AFeature	0		
CONCENTRATION	Short integer	Yes		Act_Concentration	0		
FREQUENCY	Short integer	Yes		Act_Frequency	0		
INTENSITY	Float	Yes		Act_Intensity	0	0	
DECIBELS	Short integer	Yes			0		
NAME	String	Yes					50
SOURCE	String	Yes					50
NOTES	String	Yes					100

Subtypes of Polygons_of_Activity

Subtype field *FEATURE*
Default subtype *1*

List of defined default values and domains for subtypes in this class

Subtype Code	Subtype Description	Field name	Default value	Domain
1	PEDESTRIAN	CATEGORY	Foot Travel	ACategory
		CONCENTRATION	2	Act_Concentration
		FREQUENCY	5	Act_Frequency
		INTENSITY		Act_Intensity
2	CLIMBING	CATEGORY	Foot Travel	ACategory
		CONCENTRATION	2	Act_Concentration
		FREQUENCY	3	Act_Frequency
		INTENSITY		Act_Intensity
3	HIKING	CATEGORY	Foot Travel	ACategory
		CONCENTRATION	1	Act_Concentration
		FREQUENCY	4	Act_Frequency
		INTENSITY		Act_Intensity
4	BACKCOUNTRY	CATEGORY	Foot Travel	ACategory
		CONCENTRATION	1	Act_Concentration
		FREQUENCY	3	Act_Frequency
		INTENSITY		Act_Intensity
5	TRAPPING	CATEGORY	Harvest	ACategory
		CONCENTRATION	1	Act_Concentration
		FREQUENCY	3	Act_Frequency
		INTENSITY		Act_Intensity
6	HUNTING	CATEGORY	Harvest	ACategory
		CONCENTRATION	1	Act_Concentration
		FREQUENCY	3	Act_Frequency
		INTENSITY		Act_Intensity
7	TRADITIONAL USE	CATEGORY	Harvest	ACategory
		CONCENTRATION	1	Act_Concentration
		FREQUENCY	3	Act_Frequency
		INTENSITY		Act_Intensity
8	CAMPING	CATEGORY	Occupancy	ACategory
		CONCENTRATION	1	Act_Concentration
		FREQUENCY	3	Act_Frequency
		INTENSITY		Act_Intensity
9	BUILDINGS	CATEGORY	Occupancy	ACategory
		CONCENTRATION	3	Act_Concentration
		FREQUENCY	5	Act_Frequency
		INTENSITY		Act_Intensity
10	HISTORIC CABINS	CATEGORY	Occupancy	ACategory
		CONCENTRATION	1	Act_Concentration
		FREQUENCY	2	Act_Frequency
		INTENSITY		Act_Intensity
11	CONCESSIONS	CATEGORY	Occupancy	ACategory
		CONCENTRATION	3	Act_Concentration
		FREQUENCY	5	Act_Frequency
		INTENSITY		Act_Intensity
13	BICYCLE	CATEGORY	Vehicle	ACategory
		CONCENTRATION	1	Act_Concentration
		FREQUENCY	4	Act_Frequency
		INTENSITY		Act_Intensity
14	AUTOMOBILE	CATEGORY	Vehicle	ACategory
		CONCENTRATION	4	Act_Concentration
		FREQUENCY	5	Act_Frequency
		INTENSITY		Act_Intensity
15	AIRCRAFT LANDING / TAKE-OFF	CATEGORY	Vehicle	ACategory
		CONCENTRATION	5	Act_Concentration
		FREQUENCY	3	Act_Frequency
		INTENSITY		Act_Intensity
16	OHV	CATEGORY	Vehicle	ACategory
		CONCENTRATION	4	Act_Concentration
		FREQUENCY	3	Act_Frequency
		INTENSITY		Act_Intensity
17	TRAIN	CATEGORY	Vehicle	ACategory
		CONCENTRATION	5	Act_Concentration
		FREQUENCY	4	Act_Frequency
		INTENSITY		Act_Intensity
18	AIRCRAFT OVERFLIGHT	CATEGORY	Vehicle	ACategory
		CONCENTRATION	2	Act_Concentration
		FREQUENCY	5	Act_Frequency
		INTENSITY		Act_Intensity
19	SNOW MACHINE	CATEGORY	Vehicle	ACategory
		CONCENTRATION	4	Act_Concentration
		FREQUENCY	3	Act_Frequency
		INTENSITY		Act_Intensity
20	BOAT	CATEGORY	Vehicle	ACategory
		CONCENTRATION	4	Act_Concentration
		FREQUENCY	3	Act_Frequency
		INTENSITY		Act_Intensity

Figure E-3. Activity feature subtypes with associated domains and default values.

Coded value domain
PCategory

Description	*Valid physical categories*
Field type	*String*
Split policy	*Default value*
Merge policy	*Default value*

Code	Description
Buildings	Buildings
Clearings	Clearings
Fences and Guardrails	Fences and Guardrails
Roads and Railroads	Roads and Railroads
Trails and Routes	Trails and Routes
Utilities	Utilities
Vegetation	Vegetation
Water Related Structures	Water Related Structures

Coded value domain
PIntensity

Description	*Valid physical feature intensity ratings*
Field type	*Short integer*
Split policy	*Default value*
Merge policy	*Default value*

Code	Description
1	Trampled Vegetation or Snow (Periodic with no long term evidence)
2	Trampled Vegetation or Snow (Continuously disturbed)
3	Compacted and/or Bare Soil
4	Gravel; Introduced Pervious Surface
5	Paved; Impervious Surface

Coded value domain
PFeature

Description	*Valid physical features*
Field type	*Short integer*
Split policy	*Default value*
Merge policy	*Default value*

Code	Description
1	Building
2	Historic Cabin
3	Airstrip or Landing Zone
4	Campsite
5	Fence
6	Guardrail
7	Railroad
8	Road
9	Climbing Route
10	OHV Trail
11	Sidewalk
12	Social Trail
13	Traditional Use Trail
14	Trails - Other
15	Alarm
16	Electric
17	LPG
18	Phone
19	Sewer
21	Water
22	Exotic Plant
23	Culvert
24	Dam
25	Ditch
26	OHV Bridge
27	Road Bridge
28	Retaining Wall
29	Pipeline
30	Snow Machine

Figure E-4. Domains created for the physical features within the human influence geodatabase. These domains were used to limit acceptable attribute values and create consistency throughout the database.

Coded value domain
ACategory

Description *Valid activity*
Field type *categories*
Split policy *String*
Merge policy *Duplicate*

Code	Description
Foot Travel	Foot travel
Harvest	Trapping, hunting, and other traditional use harvest
Occupancy	Occupancy by humans
Vehicle	Travel using a vehicle

Coded value domain
AFeature

Description *Activity Feature*
Field type *Types*
Split policy *Short integer*
Merge policy *Duplicate*

Code	Description
1	Pedestrian
2	Climbing
3	Hiking
4	Backcountry
5	Trapping
6	Hunting
7	Traditional Use
8	Camping
9	Buildings
10	Historic Cabins
11	Concessions
12	Wildlife Viewing
13	Bicycle
14	Automobile
15	Aircraft Landing / Take-off
16	OHV
17	Train
18	Aircraft Overflight
19	Train
20	Boat

Coded value domain
Act_Concentration

Description *Activity Concentration*
Field type *Ratings*
Split policy *Short integer*
Merge policy *Duplicate*

Code	Description
1	1 to 3 people
2	4 to 12 people
3	More than 12 people / Aircraft overflight
4	Auto and OHV
5	Train and Aircraft Land / Take off

Coded value domain
Act_Frequency

Description *Activity Frequency*
Field type *Ratings*
Split policy *Short integer*
Merge policy *Duplicate*

Code	Description
1	Annually
2	Monthly
3	Weekly
4	Daily
5	Hourly

Range domain
Act_Intensity

Description *Valid Activity Intensity*
Field type *Ratings*
Split policy *Float*
Merge policy *Duplicate*

Minimum value	Maximum value
0	5

Figure E-5. Domains created for the activity features within the human influence geodatabase. These domains were used to limit acceptable attribute values and create consistency throughout the database.

Results

The resulting geodatabase is provided to DENA for continued use and possible enhancement. Maps depicting physical and activity feature intensity across the landscape are included as Plate E-1 through Plate E-6. Maps depicting physical footprints and viewshed zones of influence are included as Plate E-7 and Plate E-8.

Discussion

The resulting maps provide an indication of the extent and intensity of human influence in specific areas of DENA. Maps such as these could be used to track changes in human influence over time. The geodatabase provides much more flexibility in isolating specific features of interest. A researcher could identify all human influence locations within a certain distance of a point and identify the type of feature at each location. Another use would be to query a particular type of human influence and display just that feature across the landscape.

There are many possibilities for future enhancements to the geodatabase. Viewshed analyses could be conducted on additional features and repeated including vegetation as a factor in visibility. Feature concentration, frequency, and intensity scores could be updated when new information becomes available. Additional soundscape analysis could be conducted, and fields indicating which season a human influence is present on the landscape could be added to allow for season-specific analyses. Also, additional predictive analysis could be conducted to estimate the likelihood an individual would access an area of the park based on various measures of accessibility as was done in Theobald et al. (2010).

Literature Cited

Denali National Park and Preserve. 2006. Denali National Park and Preserve final backcountry management plan. National Park Service, Denali Park, Alaska.

National Park Service. 2010. Permanent GIS dataset. National Park Service, Alaska Regional Office, Anchorage, Alaska.

Theobald, D. M., J. B. Norman, III, and P. Newman. 2010. Estimating visitor use of protected areas by modeling accessibility: A case study of Rocky Mountain National Park, Colorado. Journal of Conservation Planning 6:1-20.

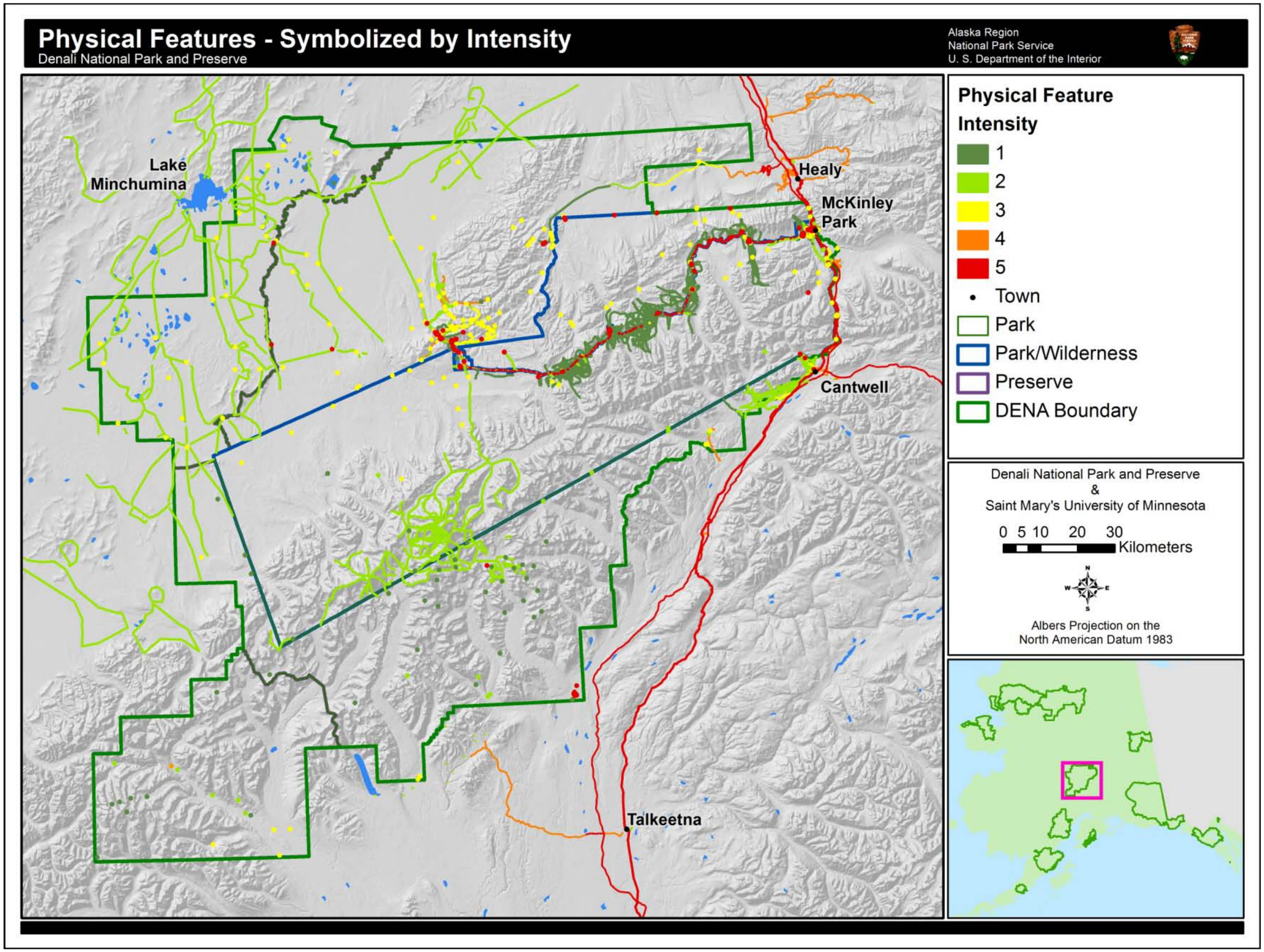

Plate E-1. Physical feature points, lines, and polygons symbolized based on feature intensity.

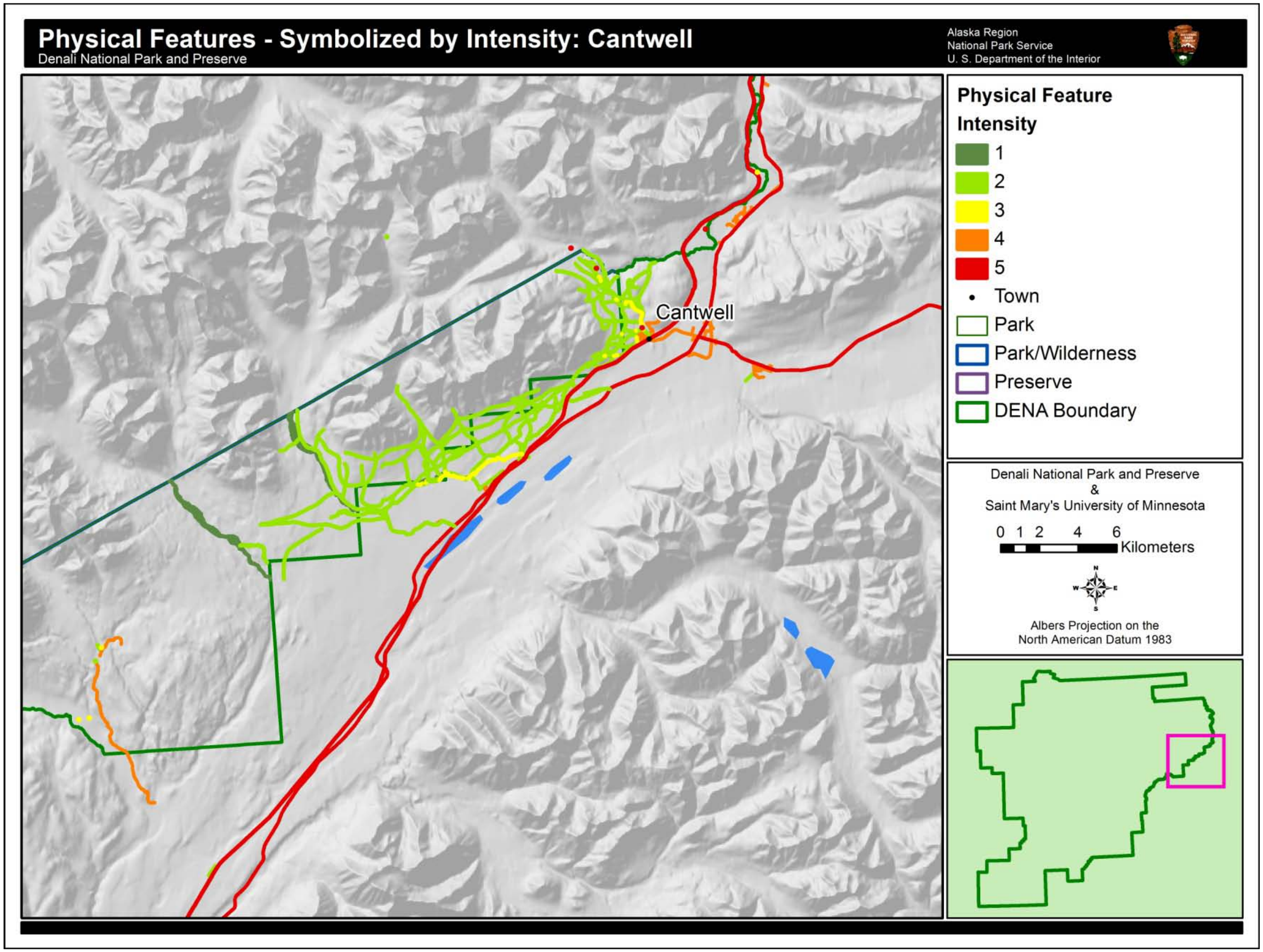

Plate E-2. Physical feature points, lines, and polygons symbolized based on feature intensity: Cantwell area.

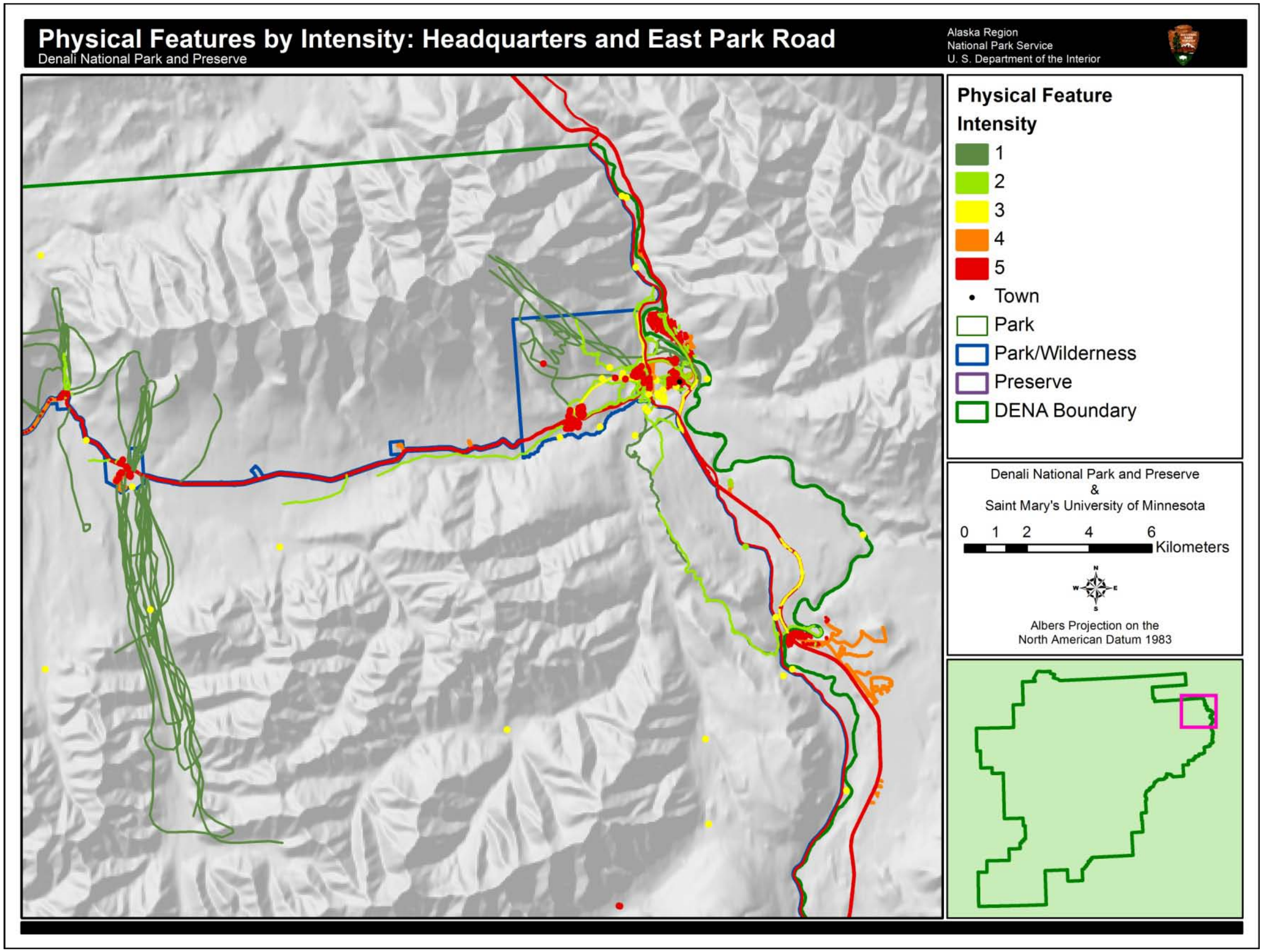

Plate E-3. Physical feature points, lines, and polygons symbolized based on feature intensity: Headquarters and east Park Road.

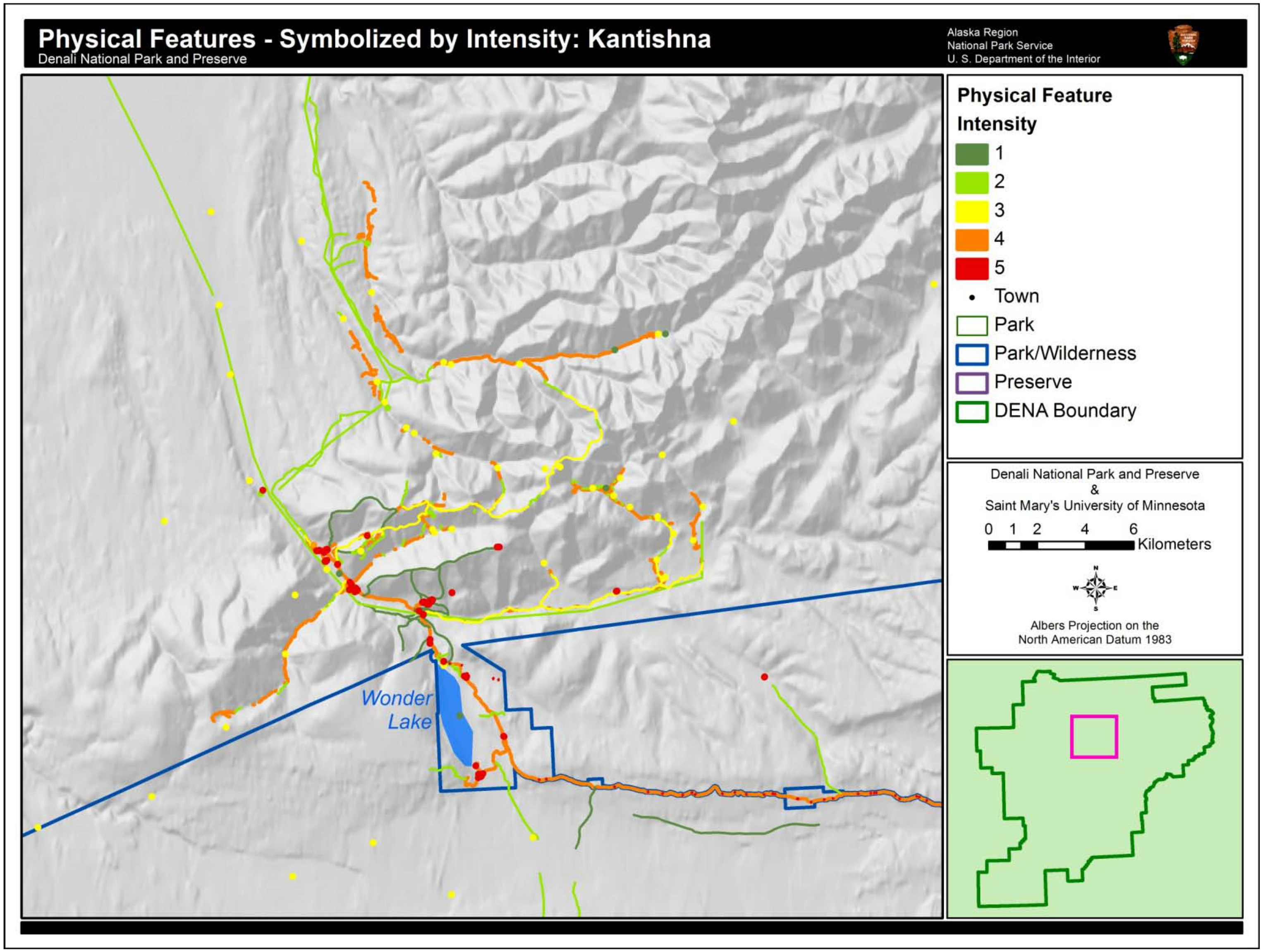

Plate E-4. Physical feature points, lines, and polygons symbolized based on feature intensity: Kantishna area.

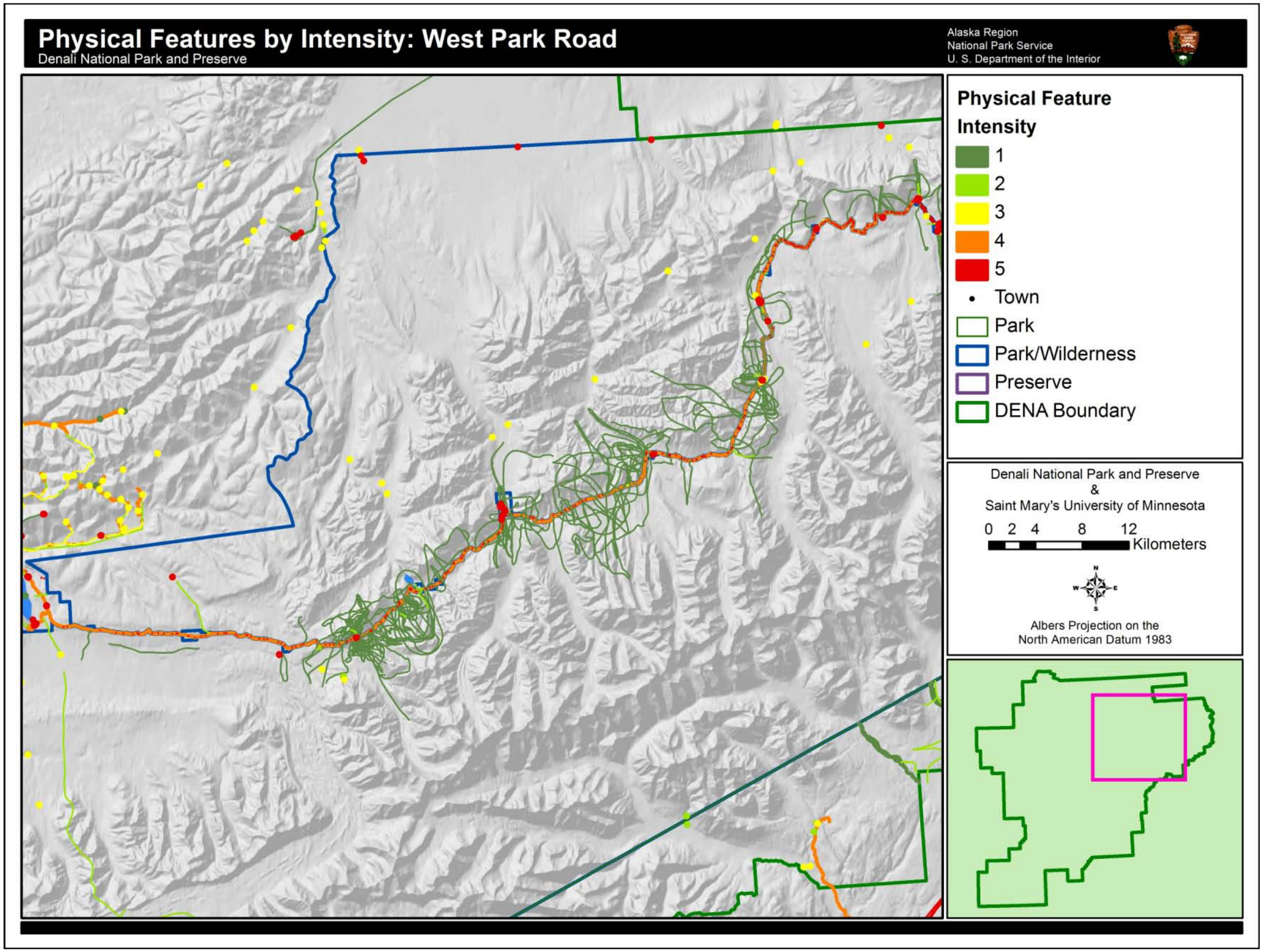

Plate E-5. Physical feature points, lines, and polygons symbolized based on feature intensity: west Park Road.

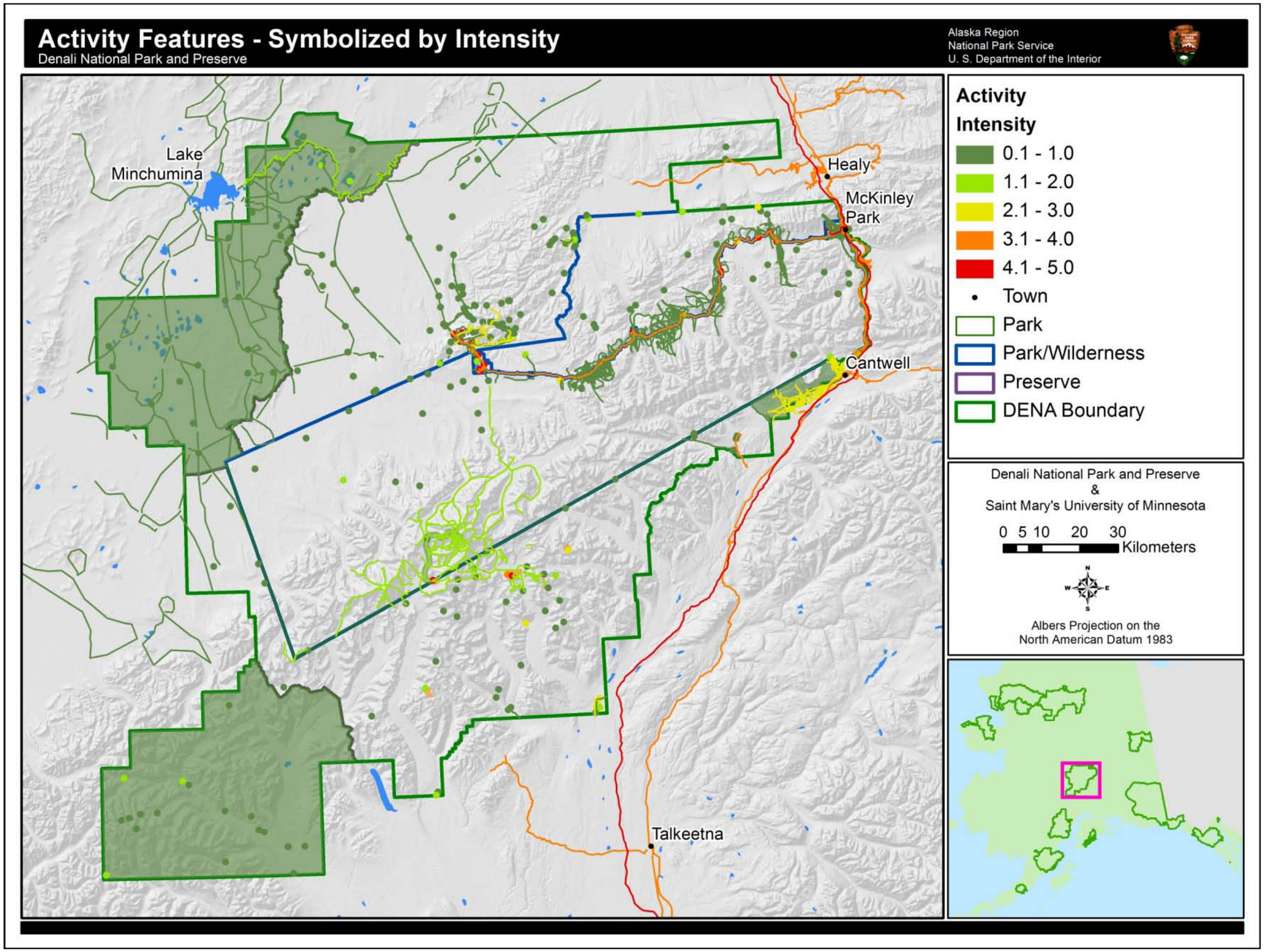

Plate E-6. Activity points, lines, polygons, and zones symbolized based on intensity of activity.

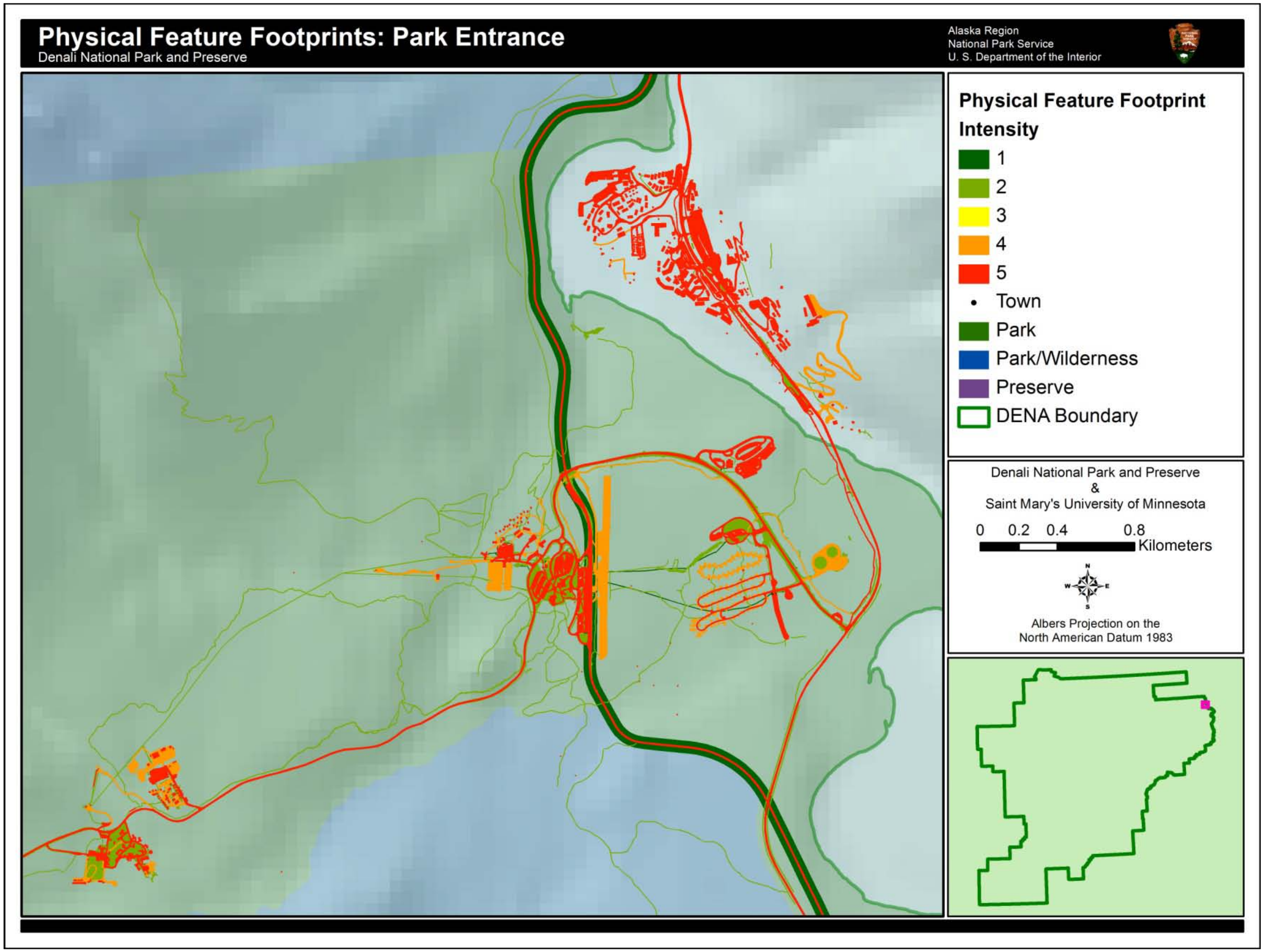

Plate E-7. Physical feature footprints: Park entrance. Features symbolized based on intensity.

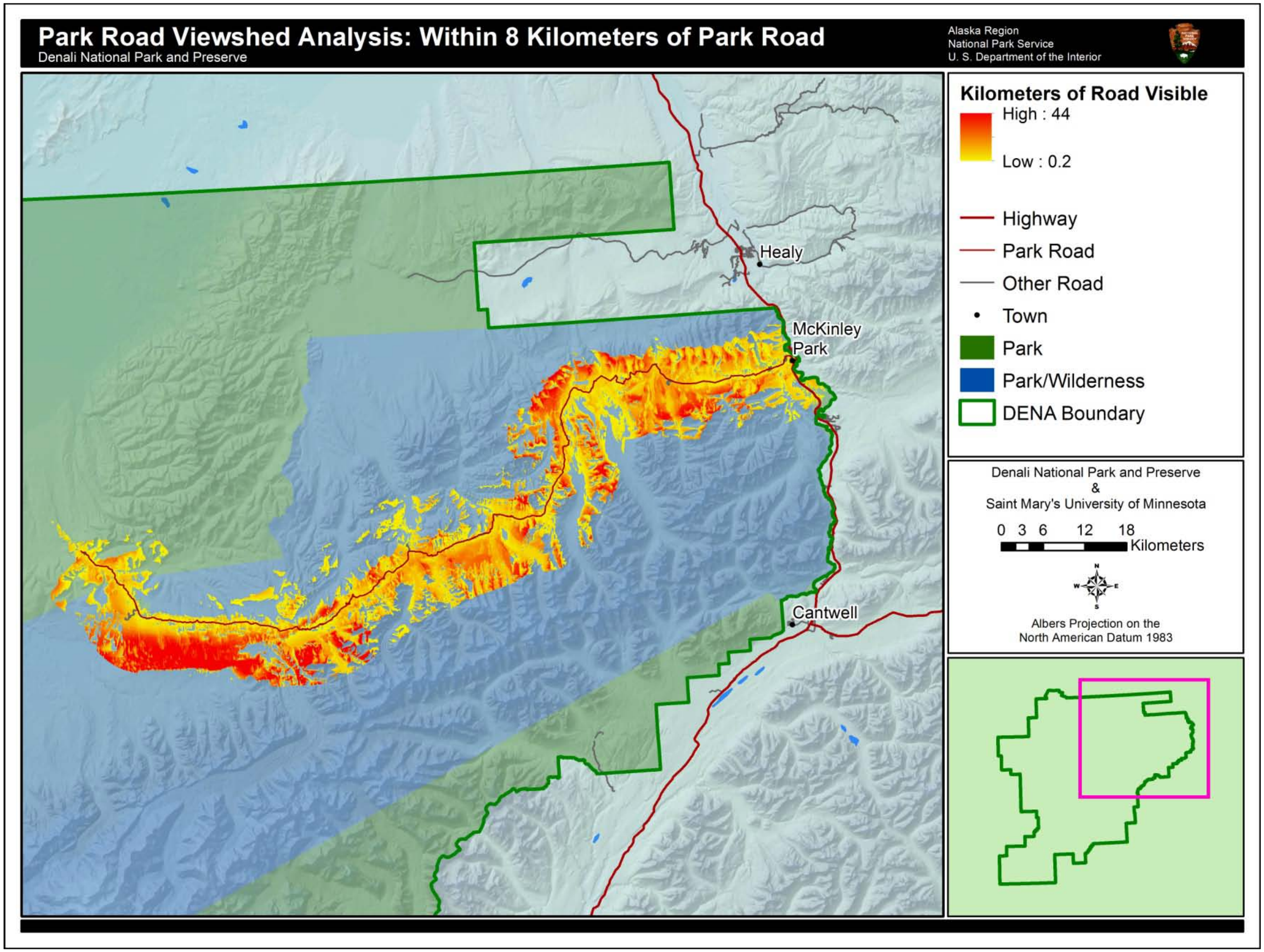

Plate E-8. Park Road viewshed. Created using 60 meter elevation model and points placed every 200 meters along the Park Road.

Appendix F. Lichen species known to occur in Denali National Park and Preserve (from NPLichen, found at http://www.nelson.wisc.edu/nplichen/park.php?park= Denali&choice1=species).

Acarospora smaragdula
Alectoria nigricans
Alectoria ochroleuca
Allantoparmelia alpicola
Amandinea punctata
Amygdalaria elegantior
Amygdalaria panaeola
Amygdalaria pelobotryon
Anaptychia palmulata
Arctoparmelia centrifuga
Arctoparmelia incurva
Arctoparmelia separata
Arthrorhaphis alpina
Asahinea chrysantha
Asahinea scholanderi
Aspicilia cinerea
Aspicilia disserpens
Aspicilia supertegens
Bacidia bagliettoana
Baeomyces placophyllus
Baeomyces rufus
Bellemerea alpina
Brodoa oroarctica
Bryocaulon divergens
Bryonora castanea
Bryoria glabra
Bryoria lanestris
Bryoria nadvornikiana
Bryoria nitidula
Bryoria simplicior
Bryoria trichodes
Caloplaca cerina
Caloplaca ferruginea
Caloplaca holocarpa
Caloplaca insularis
Caloplaca jungermanniae
Caloplaca saxicola
Caloplaca xanthostigmoidea
Calvitimela armeniaca
Candelariella vitellina
Catapyrenium cinereum
Cetraria aculeata
Cetraria ericetorum
Cetraria islandica
Cetraria nigricans
Cetraria odontella
Cetrariella delisei
Cladonia acuminata
Cladonia alaskana
Cladonia amaurocraea
Cladonia arbuscula
Cladonia arbuscula subsp. *beringiana*
Cladonia bacilliformis
Cladonia borealis
Cladonia botrytes
Cladonia cariosa
Cladonia carneola
Cladonia cenotea
Cladonia cervicornis
Cladonia cervicornis subsp. *verticillata*
Cladonia chlorophaea
Cladonia coccifera
Cladonia coniocraea
Cladonia cornuta subsp. *groenlandica*
Cladonia crispata
Cladonia deformis
Cladonia fimbriata
Cladonia furcata
Cladonia gracilis
Cladonia gracilis subsp. *turbinata*
Cladonia macilenta var. *bacillaris*
Cladonia macrophylla
Cladonia metacorallifera
Cladonia mitis
Cladonia phyllophora
Cladonia pleurota
Cladonia pocillum
Cladonia pyxidata
Cladonia rangiferina
Cladonia squamosa
Cladonia stellaris
Cladonia stricta
Cladonia subfurcata
Cladonia subsquamosa
Cladonia subulata
Cladonia sulphurina
Cladonia wainioi
Collema furfuraceum
Collema fuscovirens
Dactylina arctica
Dactylina beringica
Dactylina ramulosa
Dendriscocaulon umhausense
Diploschistes scruposus
Epicoccum purpurascens
Epilichen scabrosus

Euopsis pulvinata
Evernia divaricata
Evernia mesomorpha
Evernia prunastri
Flavocetraria cucullata
Flavocetraria minuscula
Flavocetraria nivalis
Gyalecta foveolaris
Hymenelia epulotica
Hypogymnia austerodes
Hypogymnia bitteri
Hypogymnia physodes
Hypogymnia subobscura
Icmadophila ericetorum
Ionaspis odora
Japewia tornoënsis
Lasallia pensylvanica
Lecanora chlarotera
Lecanora epibryon
Lecanora impudens
Lecanora intricata
Lecanora muralis
Lecanora polytropa
Lecanora varia
Lecidea diapensiae
Lecidea lapicida
Lecidella euphorea
Lecidoma demissum
Lempholemma polyanthes
Leptogium hirsutum
Leptogium lichenoides
Leptogium saturninum
Lobaria linita
Lobaria retigera
Lobaria scrobiculata
Masonhalea richardsonii
Massalongia carnosa
Melanelia commixta
Melanelia disjuncta
Melanelia hepatizon
Melanelia stygia
Melanelia tominii
Melanohalea infumata
Melanohalea trabeculata
Micarea misella
Mycobilimbia carneoalbida
Mycobilimbia lobulata
Nephroma arcticum
Nephroma bellum
Nephroma expallidum
Nephroma parile
Ochrolechia frigida
Ophioparma lapponica
Pannaria conoplea
Parmelia fraudans
Parmelia omphalodes
Parmelia saxatilis
Parmelia sulcata
Parmeliopsis ambigua
Parmeliopsis hyperopta
Peltigera aphthosa
Peltigera canina
Peltigera didactyla
Peltigera lepidophora
Peltigera leucophlebia
Peltigera malacea
Peltigera polydactylon
Peltigera retifoveata
Peltigera rufescens
Peltigera scabrosa
Peltigera venosa
Pertusaria carneopallida
Pertusaria dactylina
Pertusaria saximontana
Pertusaria subdactylina
Phaeocalicium populneum
Phaeophyscia constipata
Phaeophyscia orbicularis
Phaeorrhiza nimbosa
Physcia aipolia
Physcia caesia
Physconia detersa
Physconia muscigena
Pilophorus robustus
Placidium lachneum
Placopsis gelida
Placynthiella uliginosa
Placynthium nigrum
Platismatia lacunosa
Polyblastia theleodes
Porpidia flavocaerulescens
Porpidia macrocarpa
Protoblastenia rupestris
Protopannaria pezizoides
Protoparmelia badia
Protothelenella sphinctrinoides
Pseudephebe minuscula
Pseudephebe pubescens
Psora rubiformis
Psoroma hypnorum
Pycnothelia papillaria
Ramalina roesleri
Rhizocarpon chioneum
Rhizocarpon copelandii
Rhizocarpon geographicum
Rhizocarpon rittokense
Rhizocarpon viridiatrum
Rhizoplaca chrysoleuca
Rhizoplaca melanophthalma
Rhizoplaca peltata
Rinodina archaea
Rinodina mniaraea

Rinodina turfacea
Sagiolechia rhexoblephara
Santessoniella arctophila
Solorina bispora
Solorina crocea
Solorina octospora
Solorina saccata
Solorina spongiosa
Sphaerophorus fragilis
Sphaerophorus globosus
Sporastatia testudinea
Staurothele clopimoides
Staurothele fissa
Stereocaulon alpinum
Stereocaulon botryosum
Stereocaulon glareosum
Stereocaulon paschale
Stereocaulon rivulorum
Stereocaulon subcoralloides
Stereocaulon tomentosum
Stereocaulon vesuvianum
Sticta arctica
Tephromela atra
Thamnolia vermicularis
Toninia squalida
Trapeliopsis granulosa
Tremolecia atrata
Tuckermannopsis sepincola
Umbilicaria cinereorufescens
Umbilicaria cylindrica
Umbilicaria deusta
Umbilicaria hyperborea
Umbilicaria lyngei
Umbilicaria proboscidea
Umbilicaria scholanderi
Umbilicaria torrefacta
Umbilicaria vellea
Umbilicaria virginis
Usnea hirta
Usnea substerilis
Vestergrenopsis isidiata
Vulpicida pinastri
Vulpicida tilesii
Xanthoparmelia stenophylla
Xanthoria candelaria
Xanthoria elegans
Xanthoria elegans var. *splendens*
Xylographa parallela
Xylographa vitilig

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