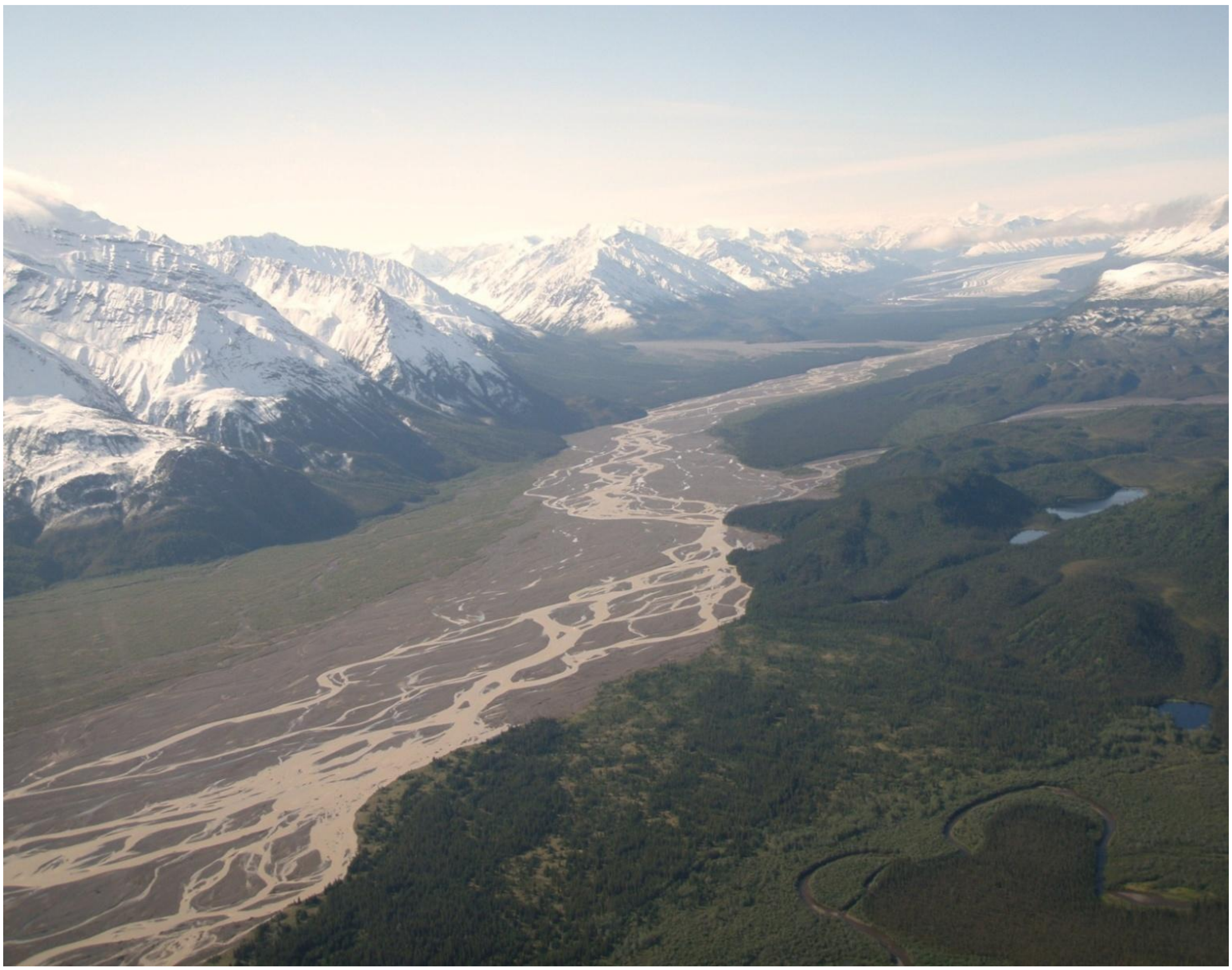
National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Wrangell-St. Elias National Park and Preserve

Natural Resource Condition Assessment

Natural Resource Report NPS/NRSS/WRD/NRR—2011/406



ON THE COVER. Nabesna River and Glacier
Photograph by: Barry Drazkowski, August 2009

Wrangell-St. Elias National Park and Preserve

Natural Resource Condition Assessment

Natural Resource Report NPS/NRSS/WRD/NRR—2011/406

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Acronyms and Abbreviations

ADF&G- Alaska Department of Fish and Game

ABOF– AK Board of Fisheries

ADNR– Alaska Department of Natural Resources

ALMS- Alaska Landbird Monitoring Survey

ANCSA- Alaska Native Claims Settlement Act

ANILCA- Alaska National Interest Land Conservation Act

AKEPIC- Alaska Exotic Plant Information Clearinghouse

AWC- Anadromous Waters Catalog

BHIMS- Bear/Human Information Management System

CPMON- Canadian Air and Precipitation Monitoring Network

CASTNET- Clean Air Status and Trends Network

CCHWG- Chisana Caribou Herd Working Group

SCAKN- Central Alaska Network

CCHWG- Chisana Caribou Herd Working Group

CIRA - Cooperative Institute for Research in the Atmosphere

CIS- Community Information System

CRWP- Copper River Watershed Project

CUA – Cooperative Unit Agreements

DENA- Denali National Park and Preserve

EPA- Environmental Protection Agency

EPMT- Exotic Plant Management Team

GIS- Geographic Information Systems

GMU- Game Management Units

GSPE- GeoSpatial Population Estimator

Acronyms and Abbreviations (continued)

GSS- GeoSpatial Services, St. Mary's University of MN

IMPROVE- Interagency Monitoring of Protected Visual Environments

LER- Lamb to ewe ratio

MCL- minimum contamination levels

NABBS- North American Breeding Bird Survey

NAAQS- National Ambient Air Quality Standards

NDVI- Normalized Difference Vegetation Index

NGO- Non-Government Organization

NHD- National Hydrological Database

NHL-National Historic Landmark

NIFC- National Interagency Fire Center

NPP- National Park and Preserve

NPS- National Park Service

NRCA – Natural Resource Condition Assessment

NRCS- Natural Resources Conservation Service

OHV- Off Highway Vehicle

ORBBS- Off-road breeding bird surveys

PCB- polychlorinated biphenyls

PDO- Pacific (inter) Decadal Oscillation

PDS- Permanent Data Set

RAWS- Remote Automated Weather Station

RZ- Reporting Zone

SNOTEL- snow course and snowpack telemetry stations

SOC- Semi-volatile compounds

Acronyms and Abbreviations (continued)

SRR- Sheep Reporting Unit

SSU- Sheep Survey Unit

TEK- Traditional ecological knowledge

UCU- Uniform Coding Units

USFS- United States Forest Service

USFWS- United States Fish and Wildlife Service

USGS- United States Geological Survey

WRST- Wrangell-St. Elias National Park and Preserve

YUCH- Yukon Charley Rivers National Preserve

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Prologue

Publisher‘s Note: This was one of several projects used to demonstrate a variety of study approaches and reporting products for a new series of natural resource condition assessments in national park units. Projects such as this one, undertaken during initial development phases for the new series, contributed to revised project standards and guidelines issued in 2009 and 2010 (applicable to projects started in 2009 or later years). Some or all of the work done for this project preceded those revisions. Consequently, aspects of this project‘s study approach and some report format and/or content details may not be consistent with the revised guidance, and may differ in comparison to what is found in more recently published reports from this series.

Publisher's Note: Some or all of the work done for this project preceded the revised guidance issued for this project series in 2009/2010. See Prologue (p. xviii) for more information.

Executive Summary

Wrangell-St. Elias National Park and Preserve (WRST) is the largest national park managed by the United States Department of Interior's National Park Service (NPS). Established in 1980 by the Alaska National Interest Lands Conservation Act (ANILCA), it encompasses nearly 13.2 million acres (20,587 square miles) in south-central Alaska (an area bigger than Maryland, Delaware, and Connecticut combined). The land area of Wrangell-St. Elias represents nearly one-third of the total land area managed by the National Park Service. In addition to being part of the National Park System, the United Nations recognized WRST as part of a 24 million acre UNESCO World Heritage Site which includes parts of nearby Glacier Bay National Park (Alaska), Kluane National Park (Canada), and Tatshenshini-Alsek Provincial Wilderness Park (Canada) (UNESCO 2010). Nearly 10 million acres within the park are designated and managed as a wilderness, making this the largest wilderness area within the National Park System. It also contains the Kennecott Mines National Historic Landmark (NHL), which was incorporated into the park in 1998. The mission of WRST is to "preserve and protect ecological integrity and heritage resources of a vast ecosystem in south-central Alaska, while providing for public use in a wilderness setting" (NPS 2006e).

In 2003, the NPS Water Resources Division received funding through the Natural Resource Challenge program to establish the Watershed Condition Assessment Program, which would oversee the systematic assessments of watershed resource conditions in NPS units. This program, now titled the Natural Resource Condition Assessment Program (NRCA), 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. Completed NRCA documents provide practical value to NPS unit managers by assisting the development of near-term resource strategies, watershed or landscape scale resource partnerships, and plans to describe and quantify desired conditions of most important resources.

The Wrangell-St. Elias Natural Resource Condition Assessment project objectives are as follows:

1) Compile existing data on natural resources,
2) Highlight significant resources and stressors within and surrounding the park,
3) Assess the condition of park natural resources based on this available data, and
4) Identify important information gaps or research needs.

NPS Alaska Regional, Central Alaska Network, and WRST natural resource management staff expectations defined at the project‘s November 3-4, 2008 scoping meeting include:

- Provide off-the-shelf data that can be quickly accessed and used in support of planning decisions (e.g. NWI, land cover, vascular plant data, and fisheries).
- Summarize data for specific park sub-divisions (e.g. sub-watersheds)
- Provide basic park descriptors (e.g. how many lakes in the park, how many peaks, how many miles of stream).
- Provide a realistic description of the park and its varied use. Many users assume that WRST is a pristine, natural environment, yet there has been on-going human use of park resources for thousands of years and it is very difficult to find a watershed or sub-watershed that is not impacted by human use.
- Provide insight into how harvest affects populations and, as a result, reference conditions.
- Compile and organize park related data sets to be available to other users (i.e., this information would be in the PDS – NPS Permanent Data set).
- Highlight Traditional Ecological Knowledge (TEK) as an important part of defining resource reference condition (however, the logistics of using TEK needs to realistically consider as a balance of time and budget).
- Utilize existing Inventory and Monitoring program data.
- Data and analysis procedures will be turned over to NPS at the end of the project.
- Explicitly state that the key resources documented in the Condition Assessment are not limited to those for which data are available.
- Include GIS products that are specific enough to be useful and focus on analyses that are needed to support the General Management Plan (GMP) (e.g. access points, visitor use information, informal trail heads).
- The NRCA document should be structured so it may be easily updated as new information becomes available.

The scope of this NRCA evolved over the duration of the project. The June 23, 2009 mid-project meeting resulted in a reduction of the originally defined 41 project components down to 27 components deemed by park resource managers to be of the highest priority. The mid-project meeting also marked the end of data and information gathering and the beginning of the project analysis phase.

Wrangell-St. Elias natural resource condition is difficult to summarize overall. The park is large and contains a diversity of landscapes and habitats. Overall, WRST‘s fish, wildlife, plant communities, and landscape resources are functioning in a healthy manner and persisting through natural environmental processes. However, it is also apparent that specific resources are affected by human presence in the area. In addition, significant data gaps exist for many of the park's natural resources.

The discussions contained in chapter four represent the most comprehensive summary of existing information on these natural resource components available today. They represent not only the most current published literature, but also unpublished park information and, most importantly, park resource specialists/experts' professional opinions and perspectives on the state of these natural resource components. It is important to recognize that even though there are significant and extensive data gaps, WRST park managers are addressing specific priorities through revised survey protocols and new survey initiatives. WRST represents a premier North American wilderness area, based on the limited human impacts, and the presence and quality of the natural resources across the large and diverse landscape. While human presence is evident in some front country areas in WRST, the back country areas of the park may be considered pristine in comparison to much of North America.

Publisher's Note: Some or all of the work done for this project preceded the revised guidance issued for this project series in 2009/2010. See Prologue (p. xv) for more information.

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 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

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]

[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

- summarize key findings by park areas[6]
- follow national NRCA guidelines and standards for study design and reporting products

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.

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

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

However, existing

[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

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

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

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

[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 NPS, the Department of the Interior, or the Office of Management and Budget

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

Chapter 2: Park Resource Setting

The Alaska Native Claims Settlement Act (ANCSA), passed by congress in 1971, authorized the Federal government to withdraw federal lands in Alaska for future use. In 1980, the Alaska National Interest Lands Conservation Act established the 13.2 million acre Wrangell-St. Elias National Park and Preserve (WRST), making it the largest of all NPS units. In 1998, the park expanded to include Kennecott Mines National Historic Landmark (NHL). WRST is also part of the larger Kluane/Wrangell-St. Elias/Glacier Bay/Tatshenshini-Alsek World Heritage Site, designated by the United Nations for its impressive complex of glaciers, high peaks, and biota (UNESCO 2010). This World Heritage Site is the largest internationally protected area in the world.

Encompassing four mountain ranges (Wrangell, St. Elias, Alaska, and Chugach) and three climate zones, WRST contains North America's largest collections of glaciers and peaks above 16,000 feet. The first Wrangell volcanoes formed about 26 million years ago (Richter et al. 1995). Mount Wrangell, one of 12 active volcanoes in WRST, is the largest and highest active volcano in Alaska, and Mount Blackburn and Mount Sanford are the 12th and 13th tallest mountains, respectively, in North America (Richter et al. 1995). A GIS analysis reveals the mountain ranges of WRST to contain 521 peaks over two thousand feet that have a minimum of one thousand feet of drop surrounding them (Description of this analysis and associated data are found in Appendix A).

Photo 1. Mt. Sanford, WRST (Photo by Kevin Stark, GSS, 2009).

Glacial topography is abundant in WRST; glaciers or permanent ice sheets cover greater than 8,000 km^2 (5,000 mi^2) of both the Alaskan portion of the St. Elias Range and the Wrangell Range (Molnia 2007). Tidewater, outlet, surging, and piedmont glaciers are all present in WRST. Tidewater glaciers, which enter the ocean and break off to form icebergs, are found along the WRST coastline. The Wrangell Mountain Range supports approximately 50 outlet glaciers greater than 8 km (~5 mi) in length including the Nabesna Glacier and the St. Elias Range holds the three largest temperate glaciers in North America: Bering Glacier, Malaspina Glacier, and Hubbard Glacier (Molnia 2007). It also contains the Bagley Icefield, which is roughly the size of the state of Rhode Island.

WRST's abundant mountains and glaciers drive the streamflow patterns and biotic processes in many of the park's lakes and rivers. WRST contains over 38,000 hectares (96,000 acres) of lakes and ponds, and over 20,000 km (14,000 miles) of flowing waters, including those that are intermittent. The biological productivity of the lakes in WRST varies with amount of glacial runoff and light transmission they receive (NPS 1990). All major rivers and streams in WRST drain from glaciers and therefore are silt-laden in summer, when glacial and snow melt are the greatest (Weeks 2003). Generally, the glacial streams of WRST have high turbidity, and high sediment load (Weeks 2003) and serve as migration routes for many anadromous fish. The Copper River, which has a yearly mean flow of approximately 55,000 cfs, supports a large salmon fishery, with subsistence, commercial, and sport harvest.

Photo 2. Nabesna Glacier and River (Photo by Kevin Stark, GSS, 2009).

WRST' major ecosystems include interior and coastal spruce forests, sloughs and bogs, rivers, streams and lakes, the Copper and Yukon River drainages, and coastal areas. Each of these areas contains a diversity of plant and animal life. Dall's sheep, caribou, and mountain goats inhabit the mountain slopes; moose wade through the sloughs and bogs; and bears roam in the mountains as well as in the lowland; sea lions and harbor seals occupy the coast. Trumpeter swans nest in the Copper River drainage and migratory birds use the drainage area as a flyway. In total, the WRST NPSpecies database acknowledges 44 mammals, 194 birds, 50 fish, 2 amphibians, and 1,315 vascular plants as present in WRST.

Humans played a key role in shaping the natural resources in WRST, through dependence on plants and animals for subsistence. Traditional ecological knowledge (TEK) suggests that indigenous Ahtna people began harvesting salmon near Gulkana no later than 1000 AD (Simeone and Valentine 2005). During the 18^{th} and 19^{th} century, Ahtna depended significantly on caribou, with starvation occurring during years the herds did not arrive (Simeone 2006). Historically, Ahtna managed resources in a socio/territorial manner, with clan leaders regulating access and take in their respective territories (Simeone and Kari 2002). Today, fish and game are managed cooperatively by NPS and the Alaska Department of Fish & Game (ADF&G).

In conclusion, the conglomeration of peaks, glaciers, biota, and human dependence, paired with the sheer size and remoteness of the park, makes WRST unique when compared to other National Parks and most places in North America.

Photo 3. Young bull moose (Photo by Kevin Stark, GSS, 2008).

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Chapter 3: Study Approach

This NRCA was a collaborative project between NPS and St. Mary‘s University of Minnesota, GeoSpatial Services (GSS). Stakeholders in this project include WRST park resource managers, Alaska Regional Inventory and Monitoring Program staff, and Central Alaska Network Inventory and Monitoring Program staff. Before embarking on the project, it was necessary to identify the specific roles of NPS and GSS. Preliminary scoping meetings were held, and a task agreement and a scope of work document were created with cooperation between NPS and GSS. The process is detailed below.

3.1 Preliminary Scoping

A project scoping meeting, held November 3-4, 2008, with GSS and NPS staff, determined that the purpose of the WRST NRCA was to evaluate and report on current natural resource conditions, identify critical data and knowledge gaps, and highlight selected existing and emerging influences on resource condition that are cause for concern to WRST resource managers.

Certain constraints were placed on this NRCA:

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

This condition assessment provides a ―snapshot-in-time” evaluation of resource condition status for a select set of park natural resources, identified and agreed to by the project team. Project findings will aid WRST resource managers with multiple objectives:

- Developing near-term management priorities;
- Engaging in watershed or landscape scale partnership and education efforts;
- Conducting park planning (e.g., General Management Plan, Resource Stewardship Strategy);
- Reporting program performance (e.g. Department of Interior Strategic Plan‘s ―land health” goals).

3.2 NPS Involvement

Expectations for WRST staff involvement were detailed in the project scoping. Park staff participated in project development and planning, reviewed interim and final products, and participated in ecological assessments. They were also expected to fully participate and collaborate with GSS to identify sources of information, define an appropriate resource assessment structure, identify appropriately scaled resources (components), threats, and stressors, and identify indicators/measures for these resources.

WRST staff helped to identify other NPS staff to provide guidance, technical assistance, and logistical coordination for site visits and discussions with the primary investigator, analysts, and graduate research assistants. Park staff collaborated with the GSS principle investigator, during data mining and status assessment, to ensure the synthesis was consistent with the project goals.

Additionally, WRST staff members assisted by developing recommendations for additional analysis to fulfill information needs that would aid in the assessment of park resource conditions. They reviewed and commented on draft reports and all publishable material related to this project. Involvement of WRST staff in this project ensured that the park needs related to this NRCA were met by GSS.

In addition to park resource staff, Alaska NPS regional staff, and Central Alaska Network NPS staff have been involved in the development of this NRCA. The NPS Agreement Technical Representative, Russ Kucinski, initially coordinated the efforts of the principle investigator, the project work group, WRST personnel, the NPS Alaska Regional Office, and the Central Alaska Inventory & Monitoring Network. Subsequently, Sara Wesser assumed the Agreement Technical Representative role, and participated in project management decisions throughout the duration of the project. She served as a liaison with GSS for questions regarding the compliance of NPS staff with resource management objectives and policies pertinent to the completion of this project.

NPS was responsible for informing the GSS principle investigator of the specific activities required to comply with the ―NPS Interim Guidance Document Governing Code of Conduct, Peer Review, and Information Quality Correction for National Park Service Cultural and Natural Resource Disciplines" or any subsequent guidance issued by the NPS Director to replace this interim document.

3.2 Framework Development

Selection of Resources and Measures

Identifying key park resources was the foundational step of this NRCA. These key resources are represented as components in the project framework. While the framework does not include all park resources, it does include the resources that NPS staff viewed as the most significant to park management at the time the project was initiated. Along with listing the individual components, the framework also displays the measures/indicators, stressors, and reference conditions of the defined components.

For each key resource topic (or component), indicators or measures that define the current condition were identified (e.g. Fire is a component and fire-return interval is a measure or indicator of fire as an ecological process). The NPS Vital Signs program defines measures as ―the specific feature or features used to quantify an indicator, and an indicator is a subset of monitoring attributes that are particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecosystem to which they belong" (MacCluskie and Oakley 2005; Noon 2002). The selection of indictors/measures for each of the components was completed through a collaborative discussion with WRST, Regional Office, and Central Alaska Network staff.

Selection of Reference Conditions

NPS resource management staff defined reference conditions with the intent of providing a benchmark against which current natural resource conditions can be compared. Generally, reference conditions represent a historical reference in which human activity and disturbance was not a major driver of population and ecological processes or change. The majority of the reference conditions listed in the NRCA framework contains the words ―natural and healthy", relating to the legislative mandates set by ANILCA. This project attempted to utilize existing research, documentation, and Traditional Ecological Knowledge (TEK) of pre-industrial conditions to suggest natural and healthy reference conditions for the park.

Because WRST possesses a highly diverse set of resources, narrowing the scope of the project to a set of critical resources was a challenge that required significant collaboration between GSS and NPS staff. An initial framework, which was a hybrid of the framework outlined in ―*A Framework for Assessing and Reporting on Ecological Condition*" (Young and Sanzone 2002) and the National Park Service Central Alaska Network Vital Signs Monitoring Plan (MacCluskie and Oakley 2005), was developed to aid in reporting the condition of natural resources. This initial framework covered 41 separate resource topics, referred to as components, in order to ensure inclusion of important resources previously not explicitly included in the Vital Signs list.

Subsequent to the initial November 2008 scoping meeting and before the second meeting on June 23, 2009, significant resources were spent in the data-mining process for the 41 components (outlined in chapter 3.5.1). After the June mid-project meeting, the number of components was reduced and rearranged into a framework that was adapted from the ―State of Our Nation‘s Ecosystems 2008," produced by the H. John Heinz III Center for Science (Heinz 2008). The final framework, accepted after NPS review in July 2009, contains 27 components (Table 1). This framework outlines the resources (components), indicators or measures, known or perceived stressors and threats, and the reference condition for comparison to current conditions.

Table 1. Final WRST NRCA Framework.

Natural Resource Condition Assessment Framework
Wrangell-St. Elias National Park and Preserve

Component	*Indicators or Measures*	*Stressors and Threats*	*Reference Condition*
Extent and Pattern			
Landscape Pattern/Structure			
Landcover	changes in area of each landcover type and status	mineral development, development on NPS and private land, oil and gas exploration-seismic lines, OHV use and access, logging activities on non-NPS lands, and non-native invasive plant infestations, bison, and climate change	native or natural landcover extent and distribution
Forest Fires	causes, frequency, extent, & severity	landscape drying (climate change), increased fuels due to pest infestations and die off, possible increase in lightning strikes, commercial and industrial activity on adjacent lands, human caused fires, suppression of natural fires	natural fire frequency and distribution
Biological Components			
Ecosystem & Communities			
Ecosystem & Community Dynamics	plant phenology	non-native: plants, insects, and disease, and climate change	range of natural variability
Plants and Animals			
Trumpeter Swans	population status & trends, nesting status & trends	human disturbance (general human development increases) and shallow lakes drying due to climate change	natural and healthy populations
Bald Eagle	nesting territory occupancy, besting success, and mean brood size	development, access expansion, invasive non-native species, forest clearing, and climate change	natural and healthy populations
Moose	population size & distribution, age & sex composition	climate change, change in landcover resulting in loss of food and habitat, disease, hunting pressure, habitat fragmentation, potential bison competition, and increased road and trail development	natural and healthy populations, including historic population size and distribution
Brown Bears	population size & distributions, age & sex composition	human-bear conflicts, hunting, habitat fragmentation, increased human access to bear fishing and habitat areas, climate change, and subsistence	natural and healthy populations
Caribou	population size, herd size, geographic distribution, age & sex composition	incidental harvest on winter range, predation, state vs. NPS management objectives, habitat decline	natural and healthy populations, including historic population size and distribution
Dall Sheep	population size & distribution, age & sex composition	hunting pressure, winter temperatures/snow depth, subsistence, and climate change	natural and healthy populations
Wolves	population size & distribution, pack size, number of packs	predator control on adjacent lands and human presence in some front-country areas	natural and healthy populations

Table 1. Final WRST NRCA Framework (continued).

Component	Indicators or Measures	Stressors and Threats	Reference Condition
Biological Components (Continued)			
Anadromous Fish	population status & distribution, teturn rates, age and sex composition	commercial harvest in the ocean, subsistence harvest, recreational harvest, state vs. park management goals, climate change, invasive species, oil development/pipelines	natural population levels, as typified prior to significant commercial and recreational influences
Resident Fish	population status & distribution	non-native species, water quality, culverts, roads, ATV stream crossings, landcover change from non-native species, climate change affecting land cover, vertical (elevation) distribution of aquatic habitat types/characteristics, and subsistence	natural and healthy population. current inventory and geographic distribution might be the best representation of reference condition
Breeding Birds	species distribution, diversity, & abundance	climate change, invasive and non-native species, human development and access	natural and healthy populations
Kittlitz's Murrelet	population & distribution	oil spills, gillnet kill fishing, cruise ship and air flight disturbance, and climate change effects on tidewater glacier habitat	healthy population. a natural population may not be possible given its endangered status.
Forest Insects and Disease	extent & distribution of infestations	anthropogenic disturbance creating stressed tree conditions, climate warming, non-native pests	natural rates and distribution of native pest and disease infestations
Non-native Species	extent & distribution of infestations	vectors of spread: roads, ATV trails, hiking trails, landing strips, abandoned home sites, in-holder property containing non-native for ornamental and food value. Factors for establishment: human and naturally disturbed sites, climate change	no non-native plants or animals
Chemical and Physical Characteristics			
Chemical Parameters			
Air Quality	nitrogen, sulfur, & mercury deposition, visibility, ozone	airborne pollutants from regional human emission sources, global human sources, natural sources	NAAQS determined "good" values for ozone, N, S, and group 50
Water Quality	turbidity, dissolved oxygen, temperature, metals, macroinvertebrates	mining, recreation/residential/commercial development, logging, OHV use, oil and gas exploration, climate change	water quality measures dominated by natural processes

Table 1. Final WRST NRCA Framework (continued).

Component	Indicators or Measures	Stressors and Threats	Reference Condition
Chemical and Physical Characteristics (Continued)			
Physical Parameters			
Climate	temperature, precipitation	atmospheric inputs of carbon-based greenhouse gases	pre-1950's climatic averages
Glacial Features	changes in glacial extent	climate change	historical natural record of glacial extent prior to climate change
Hydrology	flood frequency, duration, and annual peak flows	climate change and culverts	natural flood frequency and intensity prior to climate change
Subsurface - Geothermal	disturbance of and intrusion in geothermally active areas	visitation, trail development, private land management, potential exploitation of geothermal resources	current state of geothermal resources
Permafrost	number & distribution of thermokarst features, lake level changes	climate change and resulting thaw of permafrost, OHV use	pre 1950's lake levels and extent of permafrost and thermokarst features
Goods and Services			
Consumptive Use			
Food, Fiber, and Water	fish and wildlife harvest numbers (distribution & trends)	dual management (fed. & state), increased use and take, increased human population (new residents in resident zone communities), competition between user groups (sport, commercial, personal use), possible influx of non-native species, concurrent jurisdiction, state mandates entering into federal regulations	estimates of natural and healthy population from historic record and traditional ecological knowledge (TEK)
Non-Consumptive Use			
Human Presence	use numbers and distribution; road/trail density; area of trails, and landing areas/strips	visitor use distribution and numbers, demand for more and developed trails, and road and facility improvements	wilderness character, depicting a natural landscape
Soundscape	decibel levels, sound distribution, undesirable human generated sound	air flights (taxi, tour, administration, research), road vehicle use, OHV use, jet-boat use, resource extraction equipment, road maintenance equipment	unimpaired wilderness park experience
Viewshed	natural undeveloped viewsheds (component of designated wilderness)	human intrusion; aviation contrails; mineral development; recreational, residential, and commercial development; oil and gas exploration; logging activities; OHV access; subdivision of non-federal lands; commercial boat and rafting operations; non-native plants; NPS infrastructure; and commercial and research flights	unimpaired wilderness park experience

3.3 Selection of Reporting Zones

Due to the park's large geographic extent and the ecologically diverse landscapes contained within it, defining resource condition on a park-wide scale is challenging if not inappropriate. For this reason, it is necessary to split the park into smaller, more ecologically homogenous subsections. These subsections, referred to hereafter as reporting zones (RZ), are more appropriate geographic and ecological groupings for explaining resource conditions at a meaningful scale. It is important to note that the RZs were developed specifically for this NRCA and do not imply any management directives or regulatory designations.

The Ecological Subsections of WRST, developed by the Alaska NPS GIS Team (2001), are the foundation for the RZs. The Ecological Subsection Maps, developed to assist inventory and monitoring in Alaska's National Parks, dissect National Park areas into a number of levels including ecoregions, sections, and subsections (NPS 2009a) (Figure 1).

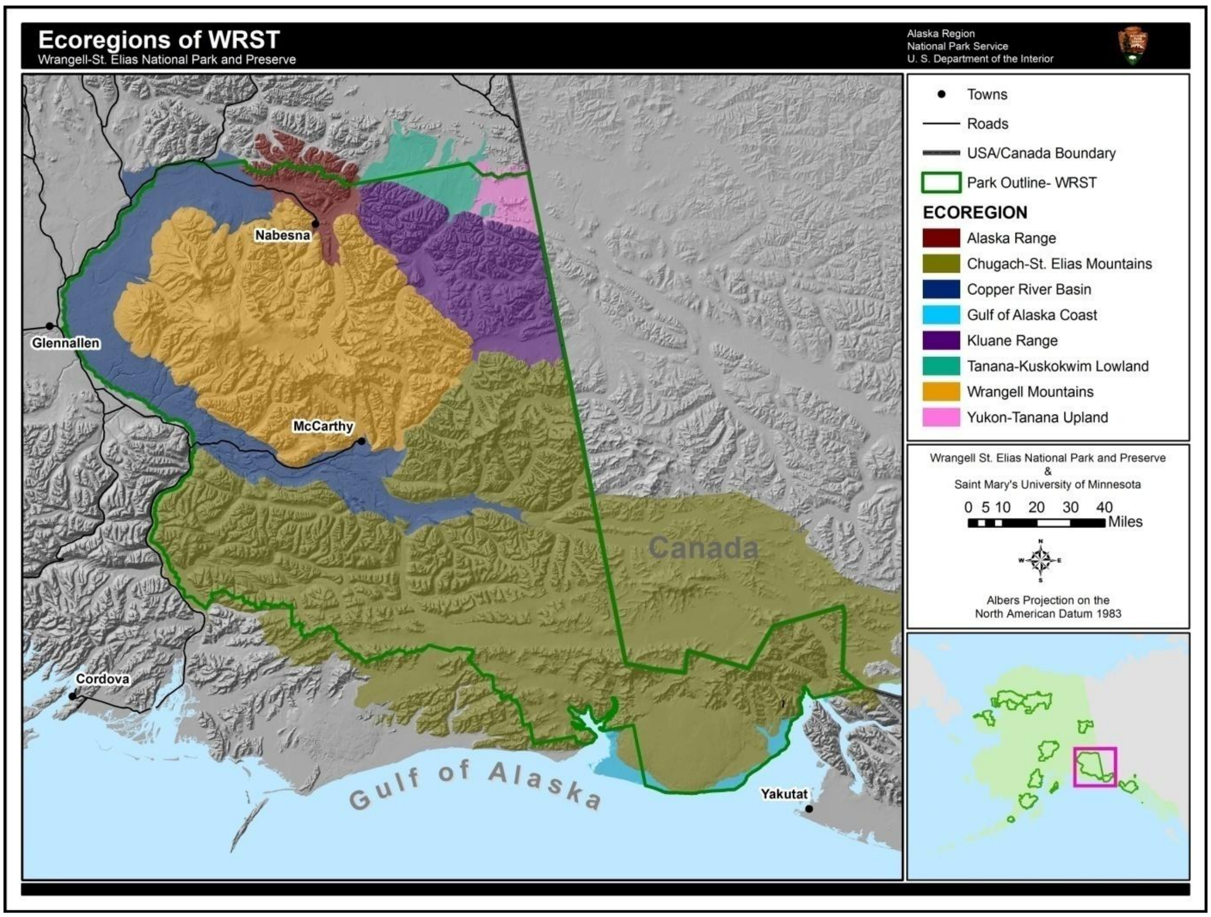

Figure 1. Ecoregions of WRST. (NPS PDS 2009a)

However, the ecoregions do not provide insight into the human use of park resources, a significant aspect of the park's landscape. Areas of high human use, identified through GIS analysis, were identified as front country areas for this NRCA; these areas have easier access to towns, roads, trails, and airstrips. Back country areas have minimal human access and influence (Figure 2).

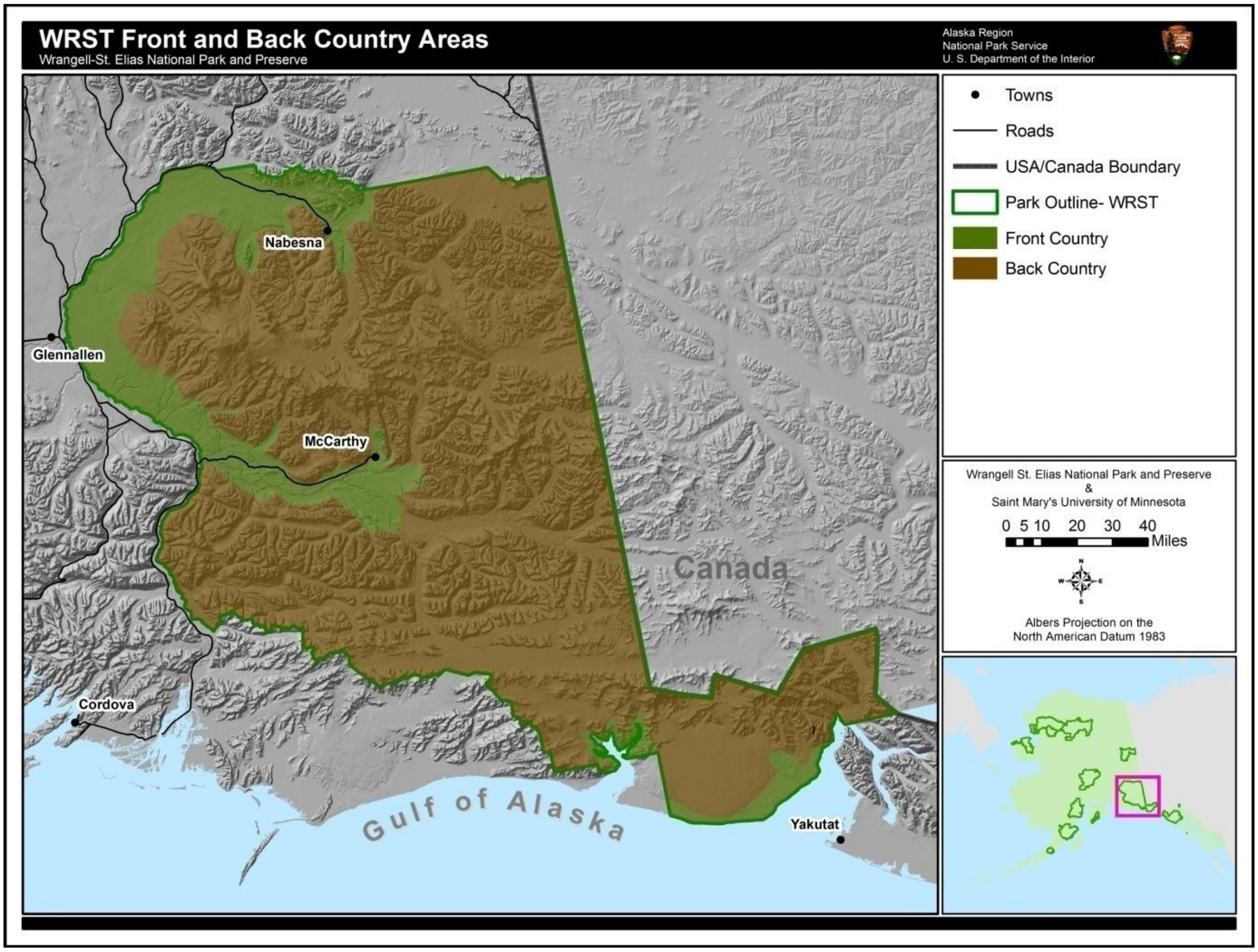

Figure 2. Front and Back Country Areas of Wrangell-St. Elias.

When designating final RZs, ecoregions were subdivided with consideration of main human use areas in order to develop RZs of adequate size to create condition statements that avoid over-generalization and allow for more accurate representations of condition. Nine RZs were established for this assessment. Four are designated as front country zones: Coastal-Icy Bay, McCarthy, Upper Copper River and Nabesna. Five are designated as back country areas: Bagley Icefield-Malaspina, St. Elias/ Chugach Mountains, Big Volcanoes, White River and Tetlin-Tanacross-North Country (Figure 3). As is shown in Figure 3, much of the original 8 ecoregions were adapted into the new set of RZs.

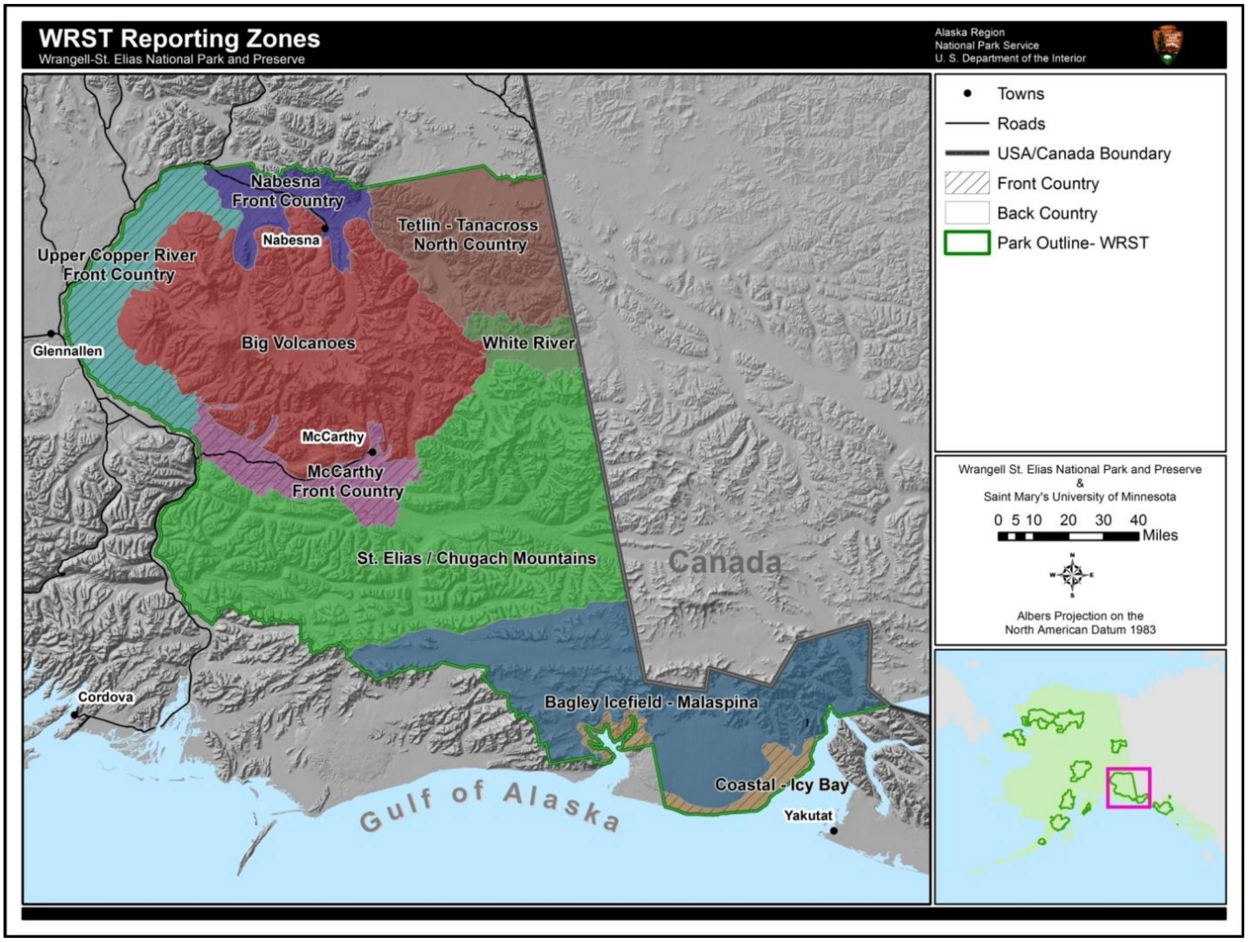

Figure 3. Reporting Zones used in WRST NRCA.

Reporting Zone Descriptions

<u>Coastal-Icy Bay Front Country</u>

Coastal–Icy Bay RZ, along the southern coastal boundary of WRST, is comprised of glaciers, rugged mountains, and hills near Icy Bay, and plains and floodplains in the Malaspina forelands. It contains a portion of land under private Native ownership, along with some non-federal public land along Icy Bay. However, the large majority of this zone is under federal ownership. According to data from Scott (2009), the only specific visitor location identified within Icy Bay was Kageet Point. Within the bay, Icy Bay Lodge operates near the park boundary. Along the Malaspina forelands a few streams are visited, most notably Esker Stream. Cruise ships regularly travel through Yakutat Bay and use the Hubbard Glacier as a viewpoint.

The town of Yakutat, located outside of WRST across Yakutat Bay, hosts guide services that travel to the Coastal-Icy Bay RZ and a small part of the Bagley Icefield–Malaspina RZ near Lucia Stream, in search of brown bear and various species of anadromous fish. In addition, many ocean fishing charters, most often targeting halibut and salmon, operate out of Yakutat (MacCluskie and Oakley 2005). The Yakutat Tlingit tribe has a long history of use of this area. Potential oil spills and resource development are a concern for marine mammals near the

Coastal–Icy Bay RZ coastline (MacCluskie and Oakley 2005). Glacial movement and isostatic rebound are among the factors that influence this landscape.

McCarthy Front Country

The McCarthy Front Country RZ is located in west-central WRST. This RZ is bordered on the west by the Copper River. The Chitina River, a major tributary of the Copper River, flows east to west through this RZ. The Chitina, originating at the confluence of the Logan, Walsh, and Chitina Glaciers, is fed by many smaller glacial streams and rivers from the surrounding Wrangell and St. Elias Mountain Ranges. The area, though dominated by low hills and plains, also contains other physiographic features such as alluvial terraces, floodplains, and some valley glaciers (e.g. Kennicott and Root glaciers).

Photo 4. Lake along McCarthy Road. (Photo by Barry Drazkowski, GSS, 2008).

Data from Scott (2009) indicate that the McCarthy RZ receives the greatest concentration of visitors of all RZs in WRST, with the Kennecott Mines NHL receiving the vast majority of reported visitors. Many large mammals reside in the McCarthy RZ, such as moose, Dall‘s sheep, brown bear, black bear, and mountain goat. Grayling, burbot, sockeye salmon, Chinook salmon, and steelhead are some of the many species of fish found in the lentic and lotic ecosystems of this RZ.

While McCarthy is the only recognized town in this RZ, many towns are located just outside the boundary of the park, including Chitina, Tonsina, Lower Tonsina, and Kenny Lake. Just north of McCarthy is the Kennecott Mines NHL, which represents the significant copper mining history in Alaska (Gilbert et al 2001). Within the NHL are many parcels of privately owned property and there is an active community there. There is private and Native corporation land along McCarthy Road, which follows the Chitina River to the town of McCarthy at the base of the Kennicott Glacier (NPS PDS 2009). The McCarthy Road is an access point for many visitor activities in the park, such as hiking, backpacking, fishing and hunting.

Upper Copper River Front Country

The Upper Copper River Front Country RZ occupies the northwestern part of WRST. This RZ is bordered by the Copper River to the west and the Wrangell Mountains to the east. Plains and low hills dominate this area with some intrusions of alluvial terraces and floodplains along the Sanford River and portions of the

Photo 5. Foreground: Upper Copper River RZ. Background: Mt. Drum, Big Volcanoes RZ (Photo by Kevin Stark, GSS, 2009).

Copper River. This zone differs from others, as it contains 41% of the land owned by Native corporations in WRST (NPS PDS 2009). The only location in this zone that experiences a significant number of recorded visitors is the Chelle landing strip (Scott 2009). This zone is inaccessible by road and experiences limited foot traffic due to few established hiking trails; thus, the federal lands in this zone sustain relatively low levels of human activity. However, annually, when portions of the Copper River freeze, trapping and other activities, particularly in the vicinity of the village of Chistochina, are common. However, since there is both federal and non-federal control of lands in this zone, differing land management objectives may allow for more intense human activity; for example, logging may occur on Native corporation lands.

Nabesna Front Country
The Nabesna Front Country RZ is on the northern border of WRST. It is bordered on the east by the Upper Copper River RZ, on the west by the Tetlin-Tanacross-North Country RZ, and on the south by the Big Volcanoes RZ. This RZ represents a diverse set of physiographic features, including low hills along the Copper River, hummocky plains near Jack and Long Lakes, valleys near the old mining community of Nabesna, rugged mountains in the Mentasta range which is part of the eastern most section of the Alaska Range, the Copper and Nabesna Rivers' floodplains, alluvial terraces along the Copper River, and alluvial fans and plains east of the Nabesna River. The predominant land cover classes in this RZ are spruce forest and low scrub.

Human use in the Nabesna RZ is high relative to other RZs, which is primarily due to the access provided by the Nabesna Road. The community of Slana and the Slana ranger station are located on the western edge of this RZ. This zone contains the highest trail density of all RZs. Areas with high visitor use in this RZ include Tanada Lake, Jacksina Creek, Copper Lake trails, and portions of the Nabesna River. All of the large mammal species in WRST are found in this RZ, except for mountain goats. This zone is also used commonly for hunting and fishing purposes. The Batzulnetas traditional fish camp is an important Ahtna cultural site within this RZ.

Photo 6. Lake in the Nabesna Reporting Zone (Photo by Kevin Stark, GSS, 2008).

Bagley Icefield-Malaspina Back Country
Glaciers and rugged mountains dominate this RZ which is located in the southeastern portion of WRST. The Malaspina Glacier, North America's largest piedmont glacier, covers roughly 5000 km^2 (3,107 mi^2), an area larger than Rhode Island (Molnia 2007). Hubbard Glacier, near Yakutat, is 121 km (75 mi) long, making it the longest tidewater glacier in Alaska. Moreover, Bagley Icefield is 204 km (127 mi) long, 10 km (6 mi) wide, and up to 914 m (3,000 ft) thick. Approximately 7,000 km^2 (2,702 mi^2) of the 9,000 km^2 (3,475 mi^2) area in this RZ is covered by some sort of glacial feature. Rising to 5,400 m (18,000 ft), Mount St. Elias is the tallest mountain in WRST. The elevation in this RZ ranges from zero to 5,400m (3.36 mi) above sea level. Mountain goats and grizzlies are the most common large mammals in this RZ.

This RZ experiences the least visitation and human activity of all RZs, primarily due to the lack of access and the dominance of snow/glaciers and barren landcover. A relatively small number of visitors are drawn to locations of various glaciers (Scott 2009). Most visitors to this area view it from the comfort of a cruise ship.

Photo 7. Hubbard Glacier's 10 km (6 mi) face near Yakutat, Bagley Icefield-Malaspina RZ. (Photo courtesy of NPS).

St. Elias/ Chugach Mountains Back Country

The St. Elias Range runs parallel to the Gulf of Alaska coast through central WRST and comprises the north eastern portion of this RZ and is ideal habitat for Dall‘s sheep. Also represented in this RZ are the Chugach Mountains, located northwest of the Bagley Ice Field. Much of this RZ is characterized by rugged mountains, which is ideal habitat for Dall‘s sheep and mountain goats. The lower Copper River is an important breeding ground for bald eagles and trumpeter swans. Other main physiographic features represented include rugged volcanic mountains (Mt. Bona), river valleys (e.g., Bremner, Tana, Hanagita, and Tebay Rivers), glaciers (e.g., Bremner, Logan, Walsh, Chitina, Bernard, and Russell), moderately rugged mountains, hill slopes, alluvial fans, and floodplains. The majority of land in this RZ is classified as barren or glacial.

Some of the land area in this RZ is near the Bremner River, and the Bremner Historic Mining District had intensive and sustained human presence in the early to mid-twentieth century (White 2000). A patchwork of land in the northwest corner, near the Copper River, is under Native corporation ownership. Private lands occur at the base of MacColl Ridge, adjacent to Tebay Lakes, and scattered throughout the RZ. However, the majority of this RZ is managed as Park and is designated wilderness with the exception of select areas near the Bremner River, Tebay Lakes, Chitina River valley, MacColl Ridge, and the Bernard Glacier. Based on Commercial Use Authorization (CUA) reports Iceberg Lake is the most visited site in this RZ, with other notable locations sustaining periodic visitation, including Hubert's landing strip, Moose Valley West Fork landing strip, Mount Bona, Hanagita Lake, and Tebay Lakes (Scott 2009).

Big Volcanoes Back Country

Abundant volcanic mountains and glaciers are key features in this RZ. However, several other physiographic features are represented in this RZ: the Wrangell Icecap, rugged mountains, rugged mesas (e.g., Jaeger Mesa), rounded mountains, mountain foot slopes (e.g., Mt. Drum and Sanford foot slopes), and some valley glaciers, U-shaped valleys (e.g., Kuskulana and Gilahina Rivers), and floodplains (e.g., Sanford River). Mt. Wrangell, one of many impressive peaks in the Wrangell Range, is the largest and highest active volcano in Alaska. The Wrangell Range is also home to more than 50 glaciers that are greater than 8 km (5 mi) in length. Glacial and snow melt from the Wrangell Range feeds the hydrological cycle in WRST. Chiefly, land cover in this RZ is classified as barren or glacial.

Photo 8. Mt. Drum, Big Volcanoes RZ. (Photo by Kevin Stark, GSS, 2009).

The large mammals in this RZ include Dall‘s sheep, the Mentasta caribou herd which calve here, and grizzlies, wolves, and moose. A few of the most commonly visited locations include landing strips at Skolai, Glacier Creek, and Wolverine Plateau; the Nizina, Gates, and Nabesna Glaciers; Donoho Lakes, Chitistone Pass, and Mount Sanford (Scott 2009).

Photo 9. Chisana Airstrip, Tetlin-Tanacross-North Country RZ (Photo by Kevin Stark, GSS, 2009).

<u>Tetlin-Tanacross-North Country Back Country</u>

This RZ is located in the northeastern part of WRST. Completely within the Yukon River drainage, this zone contains the Chisana River and portions of the Nabesna and White River basins. It is bordered on the east by the U.S./Canada border and to the south by the St. Elias/Chugach Mountains. On the west, this zone is bordered by the Wrangell Range. Physiographic features include the rugged Nutzotin Mountains, hills, valleys, hummocky plains, and Chisana floodplains. While nearly twenty percent of the land surface is classified as barren, a broad diversity of vegetation structures are present; the majority being low scrub or spruce forest and a small proportion a blend of mixed forest, broadleaf forest, and herbaceous or sparse landcover. The Chisana caribou herd, the only woodland herd in Alaska, calve and summer here.

This RZ is completely within the Preserve and is almost exclusively federal land. A small segment in the southwestern part of the zone is designated and managed as wilderness. The historic mining communities of Chisana and Gold Hill lie within this RZ and historically had a considerable human and equine presence. In addition, the Cooper Pass trail was maintained between Chisana and Nabesna. Private lands primarily exist in the community of Chisana. According to recent examination of visitation in WRST, the Chisana airport and Horsfeld airstrips receive the most visits of any locations identified in this RZ (Scott 2009).

White River Back Country

The White River Basin is the key feature in this RZ, which is also within the Yukon River drainage. This basin is almost completely within the Kluane Range ecoregion. The physiographic characteristics in this basin vary, including such features as mountains, hills, hummocky plains, floodplains, and alluvial fans. The majority of its vegetated surface is spruce forest and low scrub.

This RZ contains both park and preserve, the majority of which is designated wilderness and is almost exclusively federally-owned. Private land exists at Ptarmigan Lake and hunting, fishing, and trapping occur in this area. An established trail from Beaver Creek, Canada and Chisana is used to bring horses in for fishing and hunting concessioners. Human presence in the form of float trips on the White River has been reported. In addition, Solo Creek and Solo Lake areas are identified as specific locations used for backcountry experiences (Scott 2009).

Management/Thematic Overlays

WRST contains areas designated as wilderness and non-wilderness for both park areas and preserve areas. While park and preserve, wilderness and non-wilderness designations provide the management boundaries for WRST, the RZs were only created to fulfill the purposes of the NRCA.

3.4 Study Methodologies

This condition assessment involved reviewing existing literature and data for each of the components in the framework. Where appropriate, data were analyzed in order to provide summaries (e.g. stream miles) or, in some cases, to create new spatial representations (e.g. fall moose elevation associations). After gathering all existing and current data regarding the natural resource components of interest, a qualitative statement was created comparing the current natural resource conditions to the reference conditions when possible.

Individual Component Assessments

Data Mining

Data mining began during the first scoping meeting, at which time WRST staff provided data and literature in multiple forms, including NPS reports and monitoring plans, other reports from various state and federal agencies, published and unpublished research documents, NGO (non-government organization) reports, databases, tabular data, and charts. Spatial data were provided in the form of the Alaska NPS Permanent Data set (abbreviated here-to-fore as NPS PDS 2009) and other data were provided directly from WRST NPS staff. Access was also granted to various NPS online data and bibliography sources, such as NPSpecies and NatureBib. NPSpecies and NatureBib are now combined in the NR Info portal. Supplemental data and literature were also acquired by 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 natural resource components designated at the scoping meeting. The data mining process culminated in the development of component specific summary documents, which outlined the thoroughness and relevancy of the available literature and data. The summary documents were forwarded to NPS staff for recommendations regarding most relevant literature and data analysis direction.

Data Analyses and Development

Data analyses and development tasks were performed for specific components based on summary documents developed in the data mining process and subsequent recommendations and insights provided by NPS staff. Data analyses and development were component specific and methodology of individual analyses can be found within the component assessment sections (Chapter 4).

Component Rough Draft Preparation and Review

Preparation of the natural resource component rough draft documents was a highly cooperative process, relying heavily on the expertise of WRST and other NPS staff. This process began with telephone communications with natural resource component experts in order to verify the most relevant data and literature sources and also formulate ideas about current condition. Information gained in these initial conversations allowed for the development of rough drafts that were then forwarded to the respective natural resource experts for review and comments.

Final Component Assessment Development

Final component assessments were developed after receiving reviews and comments provided by component experts. Additionally, contact with experts was maintained throughout the process in order to address additional questions and comments pertaining to rough draft reviews and to ensure accurate representation of WRST and CAKN staff knowledge. The final component assessment documents represent the most relevant and timely data available for each component based on the recommendations and insight provided by NPS staff.

Component Assessment Format

Component assessments are presented, each containing the following sections.

Condition Graphic

The condition graphic provides a spatial representation of component conditions for each of the RZs described in section 3.3. This graphic, intended to give readers a visual representation of component condition, does not replace the written statements of condition which provide an in-depth description of component conditions in WRST.

Figure 4 shows the symbols used to describe condition at the RZ level. The circle color indicates condition or level of concern based on the data, literature, and best professional judgment from WRST staff. Specifically, red circles signify that a resource is of significant concern to park management. Yellow circles signify that a resource of moderate concern to park management. Blue circles denote that a component is currently in good condition. Gray circles signify that there is insufficient data to make a statement about component condition.

Arrows inside of the circles signify the trend of the condition or concern of a particular component based on current literature and data. Upward pointing blue arrows signify that the component is improving in recent history. Right pointing yellow arrows signify that the component's condition is currently stable. Downward pointing red arrows specify that component condition appears to be declining. Gray triple arrows specify that the component condition trend is currently unknown.

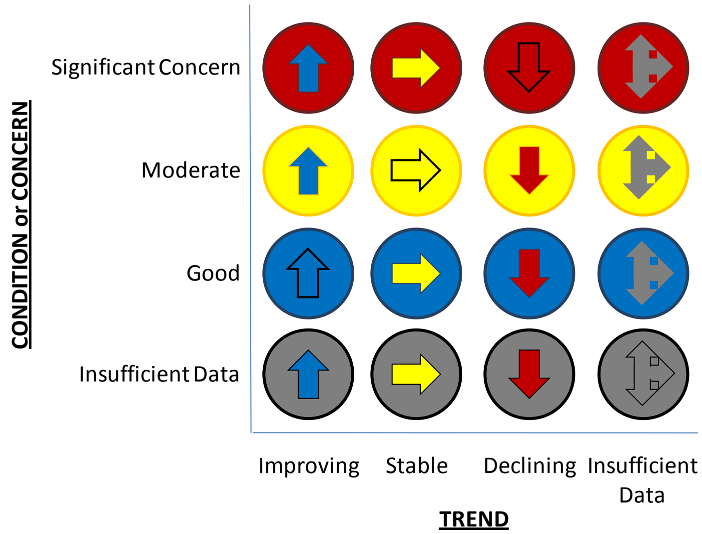

Figure 4. Designation symbols used for individual indicator assessments. Condition or concern designations run along the vertical axis and trend designations along the horizontal.

Initial current condition designations (i.e. made by the authors during component rough draft preparation) were reviewed by NPS resource experts and often changed to provide a more accurate representation of their perception of condition. When applicable, condition designations were made with respect to the defined reference condition for the component. Oftentimes, it was difficult to determine an accurate reference condition due to lack of data evidence; thus, it was necessary to rely more heavily on park experts‘ professional opinions of the quality and parameters of the reference condition.

Figure 5 is an example of the final graphic depicting current condition that is used in each of the component assessments. As shown in the above graphic, condition symbols represent designations for the entire RZ, but on occasion, a component is not present in a particular RZ. This results in the designation of N/A. Defining condition to the RZ level helps in avoiding generalization of a particular resource.

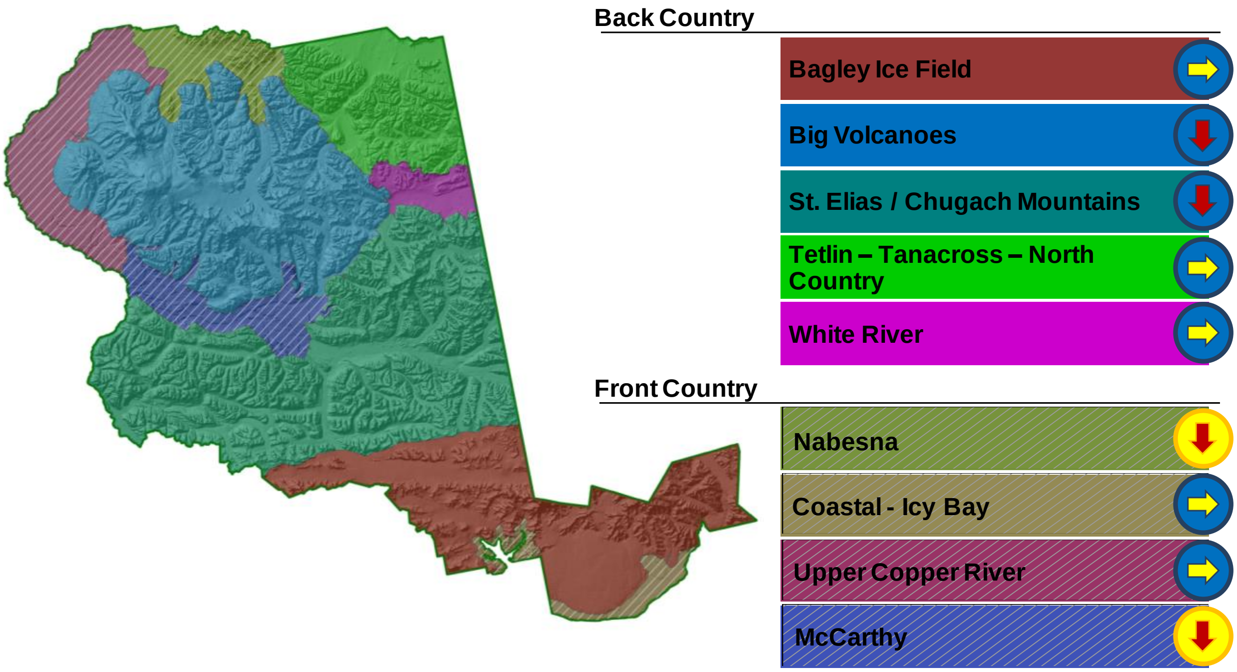

Figure 5. Example of the final condition graphic used in the component assessments.

Condition

The condition section of the component assessments provides a summary of the condition for the component which is based on available literature, data, and opinions provided by park experts. This section highlights the key elements used in defining the condition assignments in the condition graphic.

Background or Distribution and Background

This section provides a history of the resource in WRST and, where applicable, informs the reader of the distribution of that resource in the park. It explains characteristics of the component that help the reader understand subsequent sections of the document. Common topics covered in this section include management history, relationships to other components, TEK, and life history (for biota). For components with well-defined distributions, a plate that provides the spatial representation of that distribution often accompanies this section.

Reference Condition

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

Topic Specific Measures (multiple sections)

These sections provide summaries of the available data and relevant literature that serve as evidence for the specific measures used to define the condition of each natural resource component. Component measures were defined in the scoping process and are outlined in the framework (Table 1).

Stressors

This section provides a summary of the threats to each component based on available data, literature, and expert opinion. Relevant stressors were described in the scoping process and are outlined in the framework (Table 1 located in section 3.1, pages 9-11).

Data Needs
This section outlines data needs for each component. If addressed, this would then be beneficial in determining the condition of a given component in the future.

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Chapter 4: Component Condition Summaries

This chapter presents the background, analysis, and condition summaries for the key natural resource components defined through the scoping process and outlined in the framework. Each component condition summary includes the following sections:

1. Condition Graphic and Condition Summary

2. Distribution and Background

3. Reference Condition

4. Topic Specific Measure (multiple sections)

5. Threats and Stressors

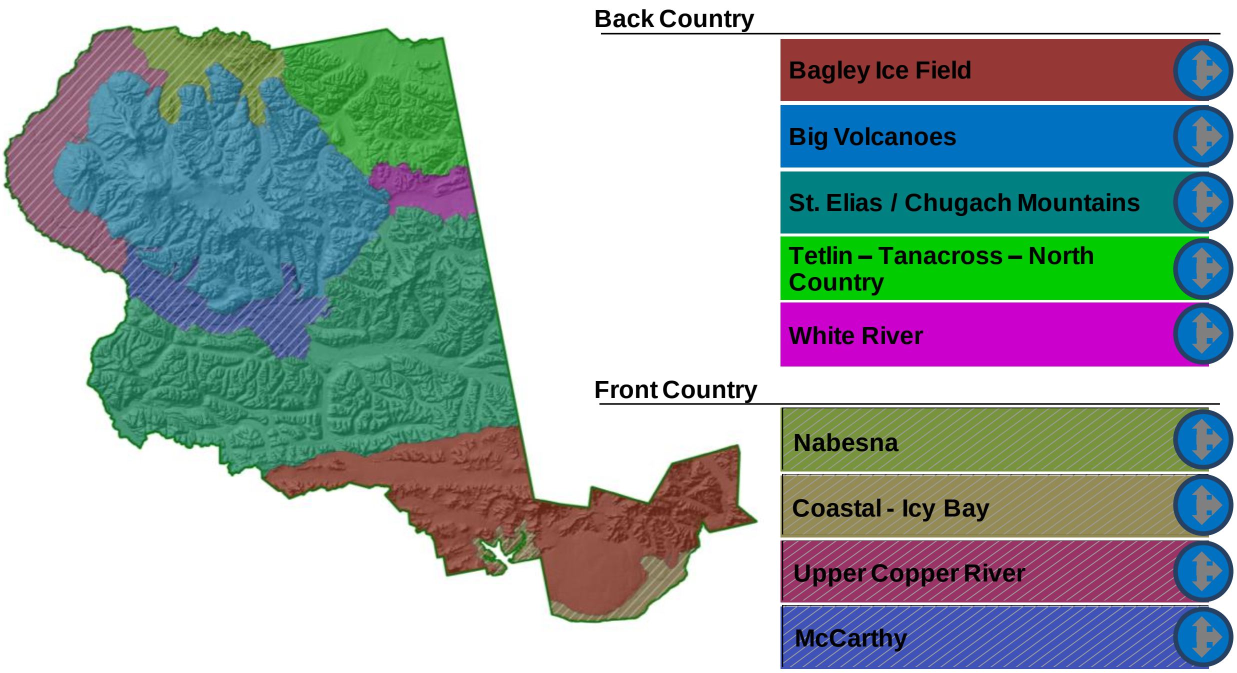
6. Data Needs

7. Literature Cited

4.1 Landcover

Indicators and Measures

Changes in Area of Landcover Type and Status



Condition

The condition and trend of landcover is dependent on several ecosystem components, including forest health, fire, non-native species, permafrost, glaciers, hydrology, ecosystem dynamics, climate, and human presence. Changes in the landscape of interior Alaska have been observed. For instance, Roland (2006) notes "large glaciers are melting and rapidly receding up valleys, ancient permafrost is degrading and turning soils into soupy gelatin, woody vegetation is spreading dramatically into open areas, and boreal ponds and wetlands are shrinking". Climate appears to be the main driver of most of the observed changes in landcover, and climate experiences a variety of cycles over varying time scales. There are other natural events that create changes in landcover as well, such as succession, fire, and disease. The direct human impact on landcover is still relatively small in WRST. The number of roads, amount of development, and park visitation are low relative to the size of the park. Because of this pristine nature the condition of landcover is good. There is not enough information to determine the trend in landcover.

Background
WRST is comprised of massive vistas, visually diverse scenery of intact native ecological communities, and natural, undeveloped viewsheds (WRST 2009). The diverse landscape is dominated by geologic, glacial, and riparian landscapes (WRST 2009). In an inventory of vascular plant flora conducted in WRST, 917 taxa were found in the park (Cook et al. 2007). Park resource staff continues to find and document additional vascular plant species in WRST. The park‘s landcover is important for habitat, hydrology, and ecosystem processes and, as a result, landcover has been designated as a vital sign for the Central Alaska Network (MacCluskie and Oakley 2005).

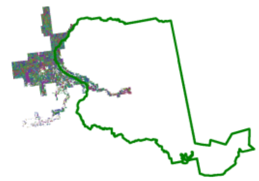
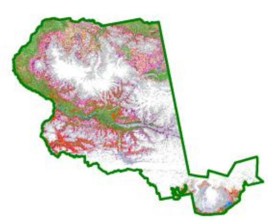
Reference Condition
Landcover is a naturally dynamic ecosystem component. Natural events such as glacial outburst floods, fire, windthrow, insect and disease infestation, and vegetation succession can change landcover temporally or permanently (Bowersox 2002, Trowbridge n.d.). Therefore, determining a reference condition is a challenge. The Copper River Project landcover data set is the earliest digital landcover data set that encompasses a substantial portion of the park. Natural events, could have caused changes in landcover that would not be a cause for concern. For the purpose of the NRCA, reference condition is defined as ―native vegetation and natural landcover extent and distribution."

Data

Landcover
Multiple spatial landcover data sets exist for WRST spanning more than thirty years. Comparing data sets and time periods is difficult because of variations in coverage, resolution, and method of classification (Table 2). The most recent mapping effort was initiated in 2003 by the Alaska Regional Office of the NPS as part of the Inventory and Monitoring (I&M) Program (Stumpf 2007). The goal of the project was to provide basic park-wide vegetation information that would be useful for resource managers. The data set was designed to meet NPS standards, be compatible with other I&M Program mapping programs, and provide information necessary for designing monitoring programs (Stumpf 2007). The final product was derived from a combination of remote mapping using Landsat satellite imagery and field data collection. The vegetation classification was correlated to The Alaska Vegetation Classification (Viereck et al. 1992). Rather than producing static categorical maps, a detailed landcover database was produced which retained pixel level information. This detail allows for the derivation of maps specific to a resource management need (e.g. habitat evaluation and fire fuels modeling). See Stumpf (2007) for a more detailed description of the methodology used to create the most recent park-wide landcover data set.

The reader is encouraged to review Cook et al. (2007) for a more detailed inventory of the vegetation of WRST, including rare plants and summaries by park region.

Table 2. WRST landcover data sets. (NPS PDS 2009a)

Name	Description	Coverage
Copper River Project	*Data Year:* 1975-1979 *Published Year:* 1984 *Cell Size:* 58.96 meters *Creator:* USGS/EROS *Classification:* 20 classes	
Copper River Veg. Study-WRST Group	*Data Year:* 1984-1985 *Published Year:* 1985 *Cell Size:* NA (Vector) *Creator:* State of Alaska, Geological and Geophysical Surveys, Fairbanks, Alaska *Classification: Developed for the Copper River Resource Mapping Project*	
Yakutat	*Data Year:* 1989 *Published Year:* 1989 *Cell Size:* 58.92 meters *Creator:* USGS/EROS *Classification:* Alaska Interim Land Cover Mapping Program (U.S.G.S. 1987, Shasby and Carneggie 1986, Fitzpatrick-Lins et al. 1989)	
WRST 1997	*Data Year:* 1995-1997 *Published Year:* 1997 *Cell Size:* 30 meters *Creator:* Pacific Meridian Resources, Alaska Regional Office, National Park Service *Classification:* 27 classes (22 vegetated; 5 non-vegetated)	
Alaska National Land Cover Database	*Data Year:* 1985-2002 *Published Year:* 2003 *Cell Size:* 30 meters *Creator:* U.S. Geological Survey *Classification:* National Land Cover Classification	
WRST 2008	*Data Year:* 2004-2007 *Published Year:* 2007 *Cell Size:* 28.5 meters *Creator:* ABR Inc. *Classification:* Modification of The Alaska Vegetation Classification (Viereck et al. 1992)	

Land Status

The NPS Alaska Regional Office maintains a data set containing land status information (NPS PDS 2009b). Ownership data exist for access, utility, right of ways, easements, primary land, subsurface, and selected land.

Indicator Results

Area of Each Landcover Type

Landcover percentages were calculated for the entire park and each RZ using the most recent landcover data set (Table 3). This summary utilized the vegetation structure attribute. The percentages of each vegetation structure in the park and in each RZ are depicted in Figure 6.

Table 3. Square kilometers of vegetation structure category by reporting zone. (NPS PDS 2009a)

	Reporting Zone									
Vegetation Structure	**Bagely Icefield - Malaspina**	**Big Volcanoes**	**Coastal Icy Bay**	**Upper Copper River**	**McCarthy**	**Nabesna**	**St. Elias/ Chugach Mountains**	**Tetlin - Tanacross - North Country**	**White River**	**Total**
Barren	2,001	4,168	248	39	116	175	5,371	960	92	13,170
Broadleaf Forest	15	152	62	93	157	62	328	93	14	975
Bryoid Herbaceous	1	158	0	1	2	10	106	49	2	330
Dwarf Scrub	3	1,051		32	34	95	1,072	400	70	2,757
Forb Herbaceous	42	63	28	13	7	16	106	25	9	309
Graminoid Herbaceous	13	408	23	58	14	167	144	354	91	1,273
Low Scrub	57	1,017	100	355	73	523	1,081	1,079	260	4,544
Mixed Forest	34	115	128	304	255	70	285	179	40	1,410
Needleleaf Forest	8	433	68	2,213	1,215	549	809	1,073	347	6,715
Snow / Glacier	7,020	3,672	61	0	6	1	4,346	50	0	15,155
Sparse	142	1,246	30	36	55	90	1,230	418	59	3,306
Tall Scrub	112	541	155	149	166	73	1,309	165	17	2,688
Unknown	5	55	4	1	5	5	106	39	1	222
Water	10	16	70	20	85	54	84	23	26	389
Total	9,462	13,095	980	3,314	2,189	1,890	16,377	4,907	1029	5,3243

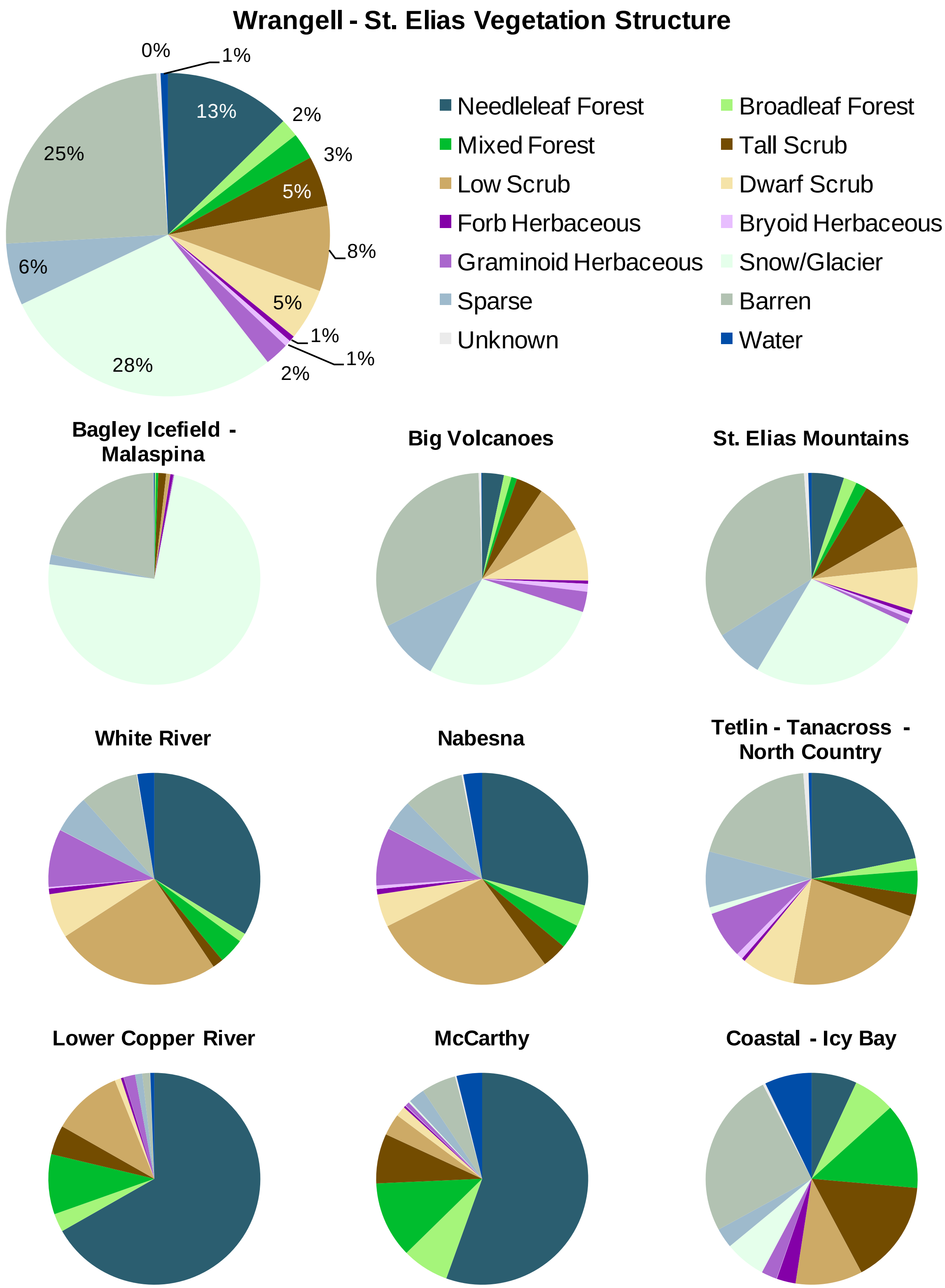


Figure 6. Vegetation structure for WRST by reporting zone, 2004-2007. (NPS PDS 2009a)

Landcover Diversity

The Shannon-Wiener diversity index and measure of evenness were calculated using the 2008 landcover class data set for each RZ and for the entire WRST (Figure 7, Figure 8) (NPS PDS 2009a). Any classes of unknown type were excluded from the analysis. The diversity index was highest for the Nabesna RZ and lowest for Bagley Icefield – Malaspina. Coastal Icy Bay was less diverse than Nabesna, but its landcover was more evenly distributed among the classes.

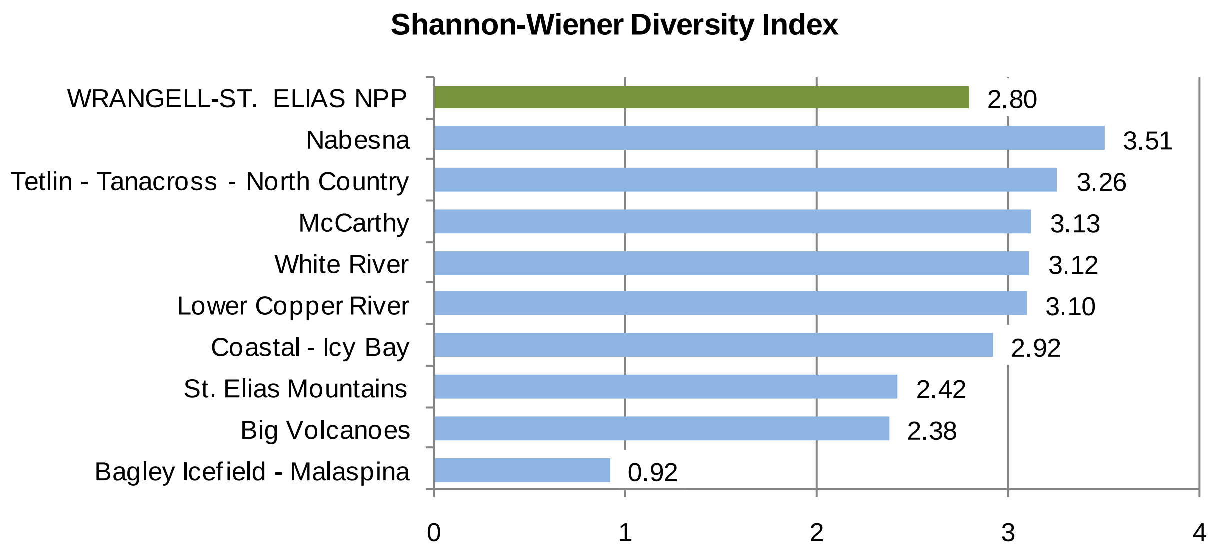


Figure 7. Shannon-Wiener Diversity Index using the landcover class by reporting zone (blue) and for the entire park (green), WRST, 2004-2007.(NPS PDS 2009a)

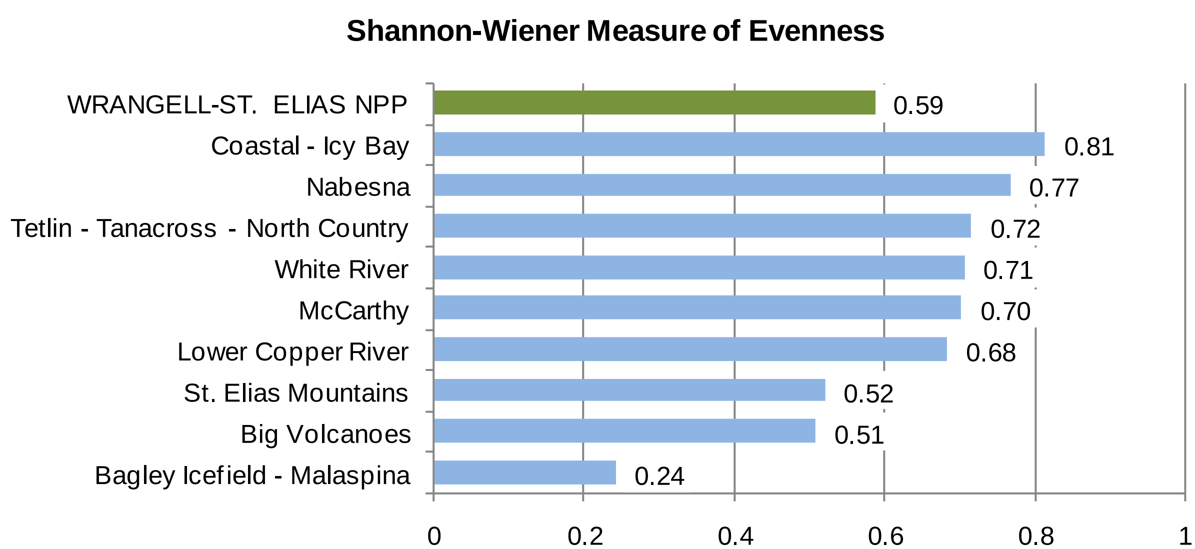


Figure 8. Shannon-Wiener Measure of Evenness using landcover class by reporting zone (blue) and for the entire park (green), WRST, 2004-2007. (NPS PDS 2009a)

Landcover Change
Due to the significant differences between the data sets regarding coverage, resolution, and method of classification, an analysis of landcover change using spatial data sets was not attempted. Any landcover change analysis conducted using these data sets should be treated with caution.

Changes in lake size and extent are types of landcover change that have been documented in the park (McGuire et al. 2003, McGuire 2004, Riordan 2005). Riordan (2005) measured the size and number of lakes in the Copper River Basin based on aerial and satellite imagery from roughly 1950 to 2000. The Copper River Basin study area experienced a 28% reduction in water area from 1950-2000 and a loss of 55 water bodies (from 101 to 46) (Riordan 2005). Reductions in water area and number of water bodies were found in other regions of Alaska as part of the same study (Riordan 2005, CAKN Inventory and Monitoring Program 2008). A shallow lakes monitoring effort in the Central Alaska Network began in 2006 (Larson 2006). Initial efforts were focused in Denali National Park and Preserve (Larson 2006), but monitoring began in WRST in the summer of 2009. Data from WRST have not yet been analyzed.

Current Land Status
Management of land is guided by the goals of the owners and any applicable laws governing the land; therefore, knowledge of land ownership is important for understanding landcover and landcover change. Privately owned land has the potential for more rapid change in landcover than public land. Land ownership percentages (as of 2009) were calculated for the entire park to report current land status (Table 4). Nearly 95% of the park is federally owned, with the remaining land primarily in the private ANCSA Native ownership category. Historic ownership data for the park have not been analyzed.

Table 4. Total square kilometers by land ownership type and reporting zone. (NPS PDS 2009b)

Reporting Zone	Federal	Non-Federal Public	Private	Private ANCSA Native	Total
Bagley Icefield - Malaspina	9,461.2	13.7	0.0	3.4	9,478.3
Big Volcanoes	12,585.2	9.7	18.1	482.4	13,095.5
Coastal - Icy Bay	941.4	21.4	1.6	41.0	1,005.4
Upper Copper River	1,915.5	63.7	3.7	1,361.2	3,344.1
McCarthy	1,618.5	122.8	35.2	412.5	2,189.1
Nabesna	1,882.3	0.0	8.7	0.0	1,891.0
St. Elias/ Chugach Mountains	15,961.8	0.7	2.4	419.2	16,384.1
Tetlin - Tanacross - North Country	4,907.4	0.0	1.2	0.0	4,908.6
White River	1,028.8	0.0	0.1	0.0	1,028.9
Total	50,302.0	232.0	71.0	2,719.7	53,324.7
Percent	94.3%	0.4%	0.1%	5.1%	100.0%

Stressors
The condition and trend of landcover is dependent on several ecosystem components, including forest health, fire, non-native species, permafrost, glaciers, hydrology, ecosystem dynamics, climate, and human presence. Insect damage (e.g. spruce bark beetle (*Dendroctonus rufipennis Kirby*)), thawing permafrost, melting glaciers, and forest fires are examples of events that can change landcover. The condition and trend of these components provide some indication, though not a complete picture, of the condition and trend of landcover (Table 5). The park also identified

mineral development, development on NPS and private land, oil and gas exploration-seismic lines, OHV access, and logging activities as landcover stressors.

Table 5. Summary of condition and trend of NRCA components which contribute to landcover.

Component	Bagley Ice Field	Big Volcanoes	St. Elias/ Chugach Mountains	Tetlin-Tanacross-North Country	White River	Nabesna	Coastal – Icy Bay	Upper Copper River	McCarthy
Forest Fires	N/A	Red ↑→↓	Red ↑→↓	Red ↑→↓	Red ↑→↓	Red ↑→↓	N/A	Red ↑→↓	Red ↑→↓
Ecosystem Dynamics	Gray ↑→↓	Gray ↑→↓	Gray ↑→↓	Gray ↑→↓	Gray ↑→↓	Gray ↑→↓	Gray ↑→↓	Gray ↑→↓	Gray ↑→↓
Forest Insects and Disease	Blue →	Yellow ↑→↓	Red →	Yellow ↑→↓	Yellow ↑→↓	Yellow ↑→↓	Blue →	Red →	Red →
Non-natives	Blue ↑→↓	Blue ↑→↓	Blue ↑→↓	Blue ↑→↓	Blue ↑→↓	Yellow →	Blue ↑→↓	Yellow →	Yellow →
Glacial Features	Red ↓	Red ↓	Red ↓	Red ↓	Red ↓	Red ↓	Red ↓	N/A	Red ↓
Hydrology	Gray ↑→↓	Gray ↑→↓	Gray ↑→↓	Gray ↑→↓	Gray ↑→↓	Gray ↑→↓	Gray ↑→↓	Gray ↑→↓	Gray ↑→↓
Soils/Permafrost	Gray ↑→↓	Gray ↑→↓	Gray ↑→↓	Gray ↑→↓	Gray ↑→↓	Gray ↑→↓	Gray ↑→↓	Gray ↑→↓	Gray ↑→↓
Human Presence	Blue ↑→↓	Blue ↑→↓	Blue ↑→↓	Blue ↑→↓	Blue ↑→↓	Yellow ↑→↓	Blue ↑→↓	Blue ↑→↓	Yellow ↑→↓

The Central Alaska Network has reported evidence of possible significant long term climate change underway (Sousanes 2008). Unusually mild winters throughout much of Alaska in recent years and a substantial increase in temperatures during the 1990s are interpreted by many as signs of large scale warming of the Earth's surface (Redmond and Simeral 2006). Significant changes in landcover can result from changes in climate. The reduction in the area and number of lakes in various regions in Alaska since the 1950s is documented and associated with increases in temperature (Riordan 2005). Increases in temperature lead to increased evapotranspiration rates, increases in the size of the active permafrost layer which increases the water holding capacity, and increases in the size of taliks (zones of unfrozen soil between blocks of frozen soil or between the permafrost and active layers) (Riordan 2005, Figure 9). Increased subsurface drainage, changing plant communities, and the drying of soils are additional changes associated with increasing temperatures (Riordan 2005).

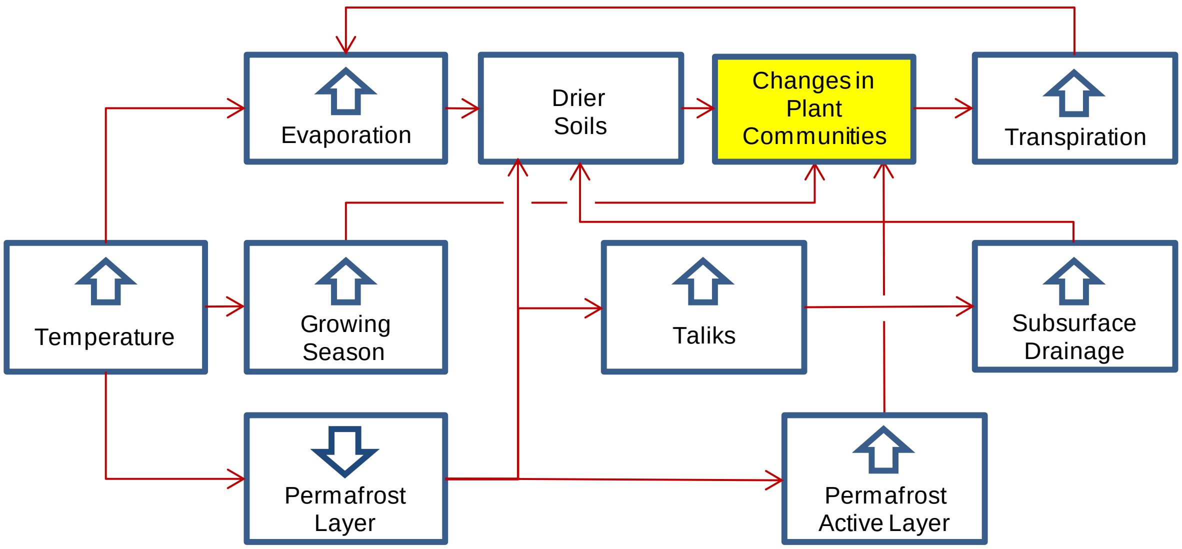


Figure 9. Effects of increasing temperatures on landcover. Adapted from Riordan (2005).

Reporting Zones
Vegetation structure, diversity, and land ownership are summarized, by RZ, in previous tables and figures and in Plate 1 and Plate 2.

Data Needs
Ongoing monitoring of landcover at regular intervals using a consistent classification system is needed to determine condition. If change is detected, more research is needed to determine causal relationships. An update to the landcover spatial data set would be especially useful following the substantial Chakina Fire in 2009, which burned approximately 2.5% of the forested area in WRST.

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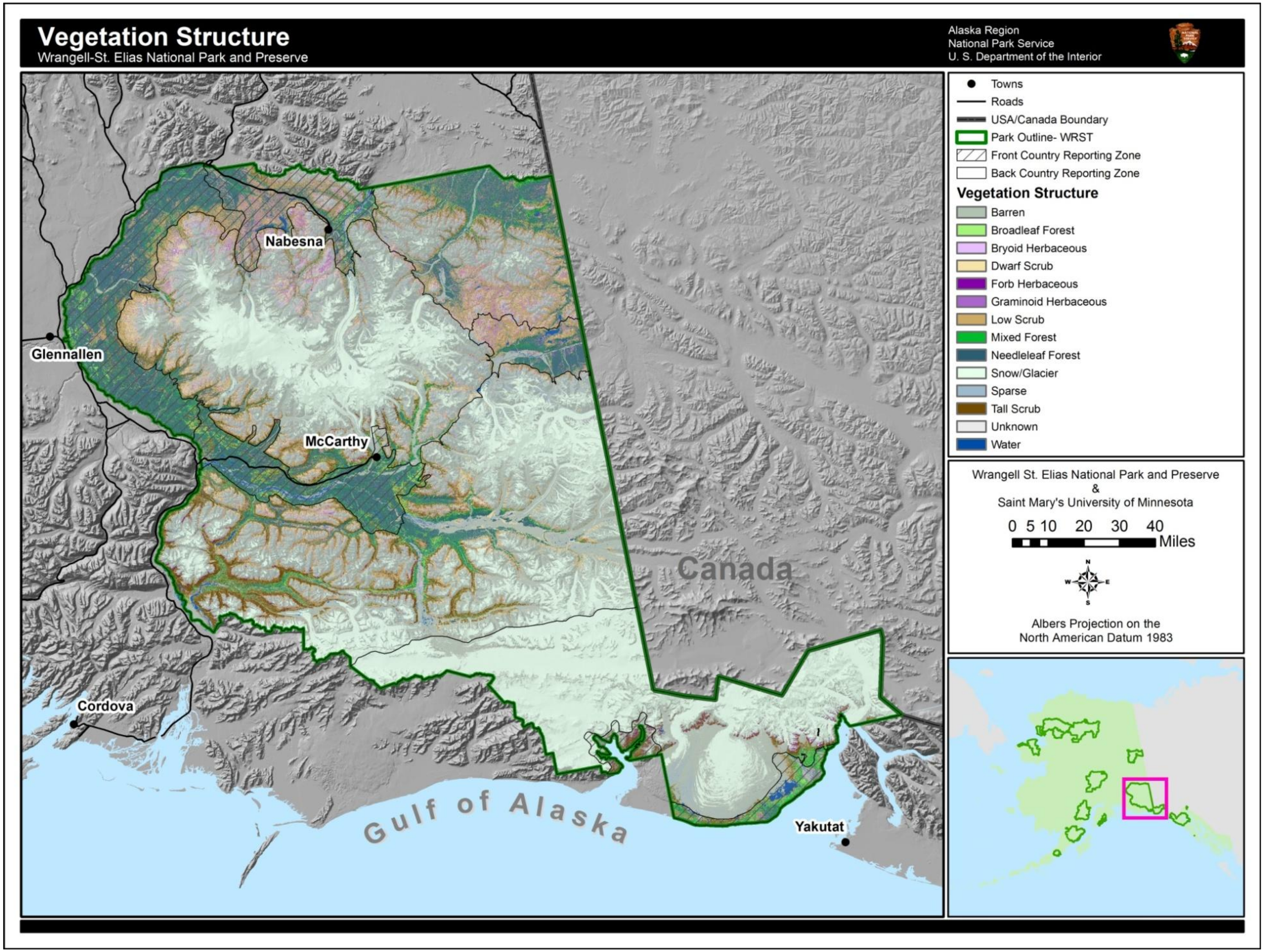


Plate 1. Vegetation structure in WRST. (NPS PDS 2009a)

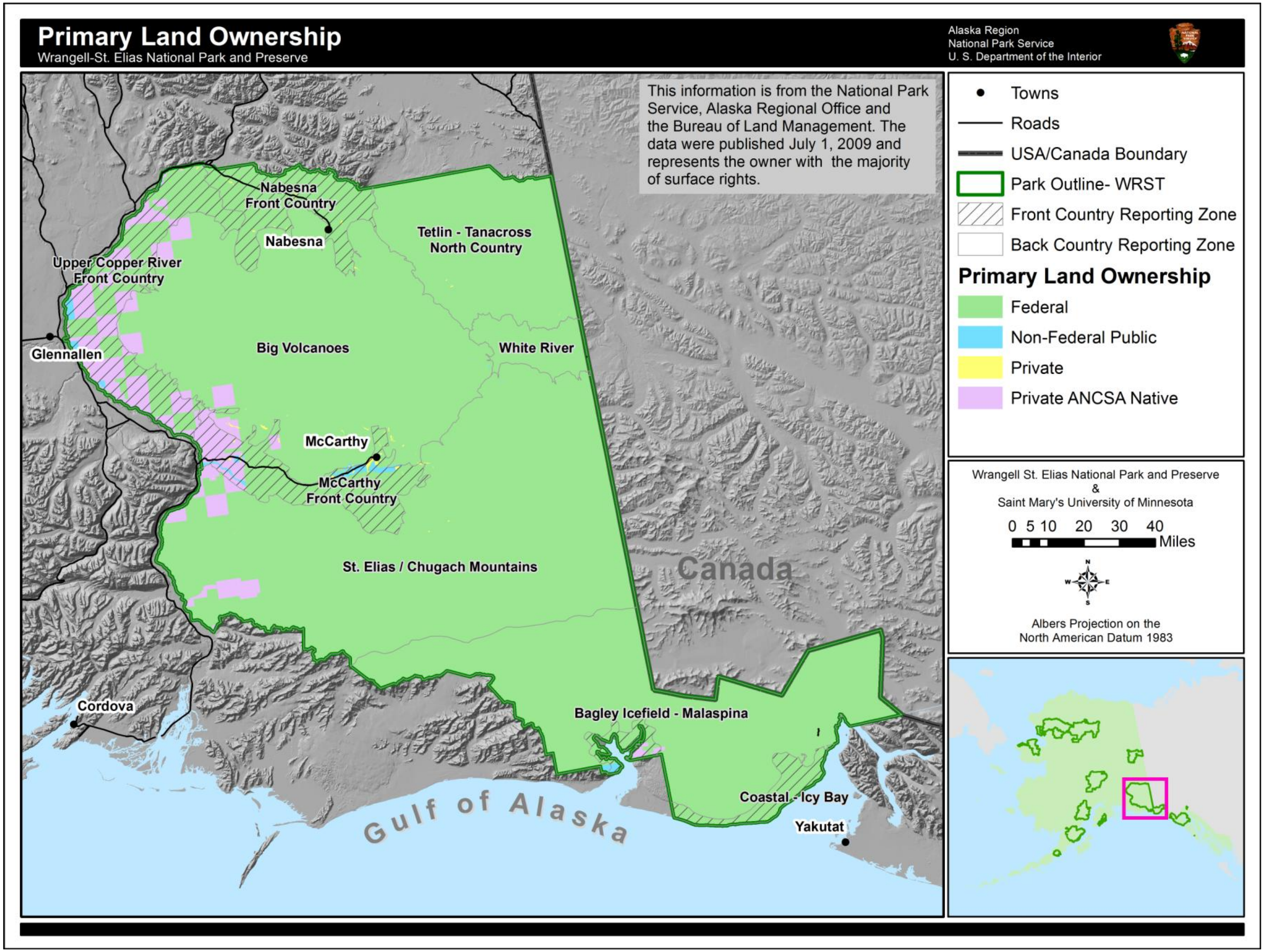
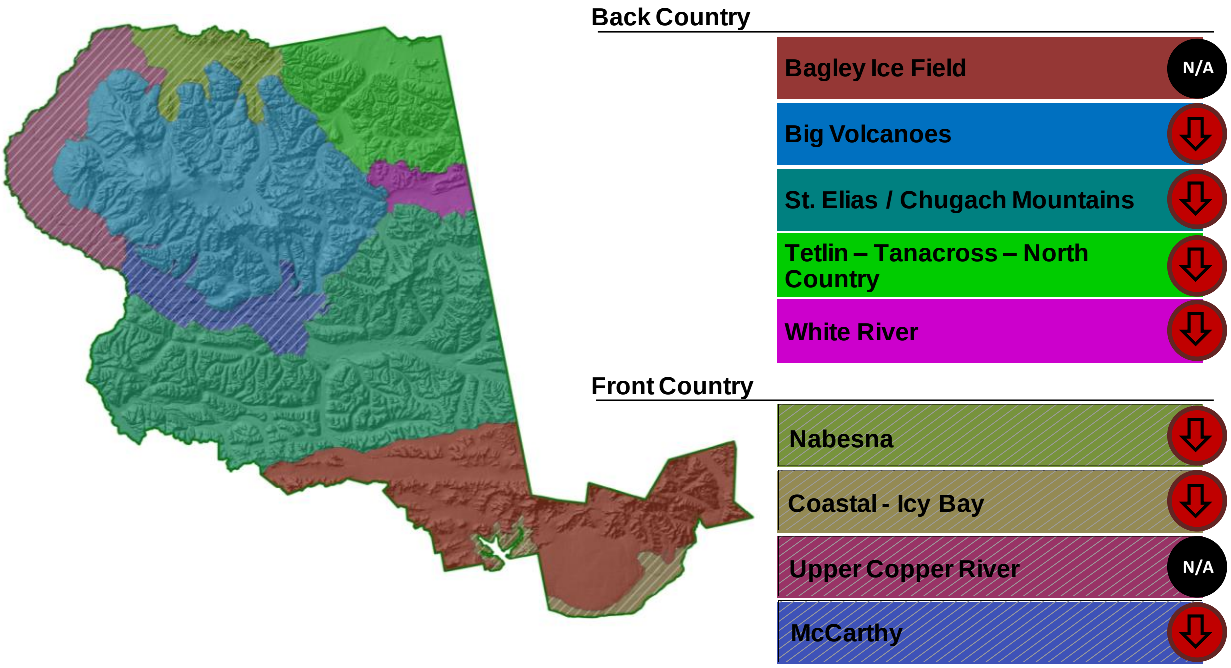


Plate 2. Land ownership in WRST. (NPS-PDS 2009b)

4.2 Forest Fires

Indicators and Measures

Causes, Frequency, Extent, & Severity



Condition

Fires are a natural part of the cycle for boreal forests like those in WRST. A change in long term trends in these fires is a significant concern; however, there is insufficient information to determine what the historical trends have been. This condition of concern is due to multiple factors. Changes in fire frequency resulting from climate change are likely to have major consequences on the dynamics of boreal forest ecosystems (Lynch et al. 2004). Although spruce beetles (*Dendroctonus rufipennis*) are native insects in WRST, forest fire fuel loads may have increased due in large part to spruce beetle caused tree mortality. It is predicted that these beetle-killed trees will influence fire behavior and present a hazard for over seven decades (Lamb et al. 2009). Invasive plants can also change fuel properties which affect fire behavior, and ultimately, alter fire regime characteristics such as frequency, intensity, extent, type, and seasonality of fire (Brooks et al. 2004). Previously burned areas also offer mechanisms for the establishment of invasive plant species and have the potential to perpetuate their spread. Human activity such as fire suppression and inadvertent fire ignition can alter successional processes that are driven by fire in WRST. Nearly one third of current forest cover is under an increased fire suppression status, classified as full (27%) or critical (1%), decreasing the likelihood of a natural fire regime to exist in these areas. Finally, since 1955, humans have caused the majority (72%) of the recorded fires in WRST. (NPS PDS 2009b)

Trends in fire causes, frequency, extent, or severity have not yet been established for WRST.

Lutz (1956) suggests that ―aboriginal man” was the cause of fires before European settlement of Alaska, but that European settlers were the cause of even more fires in the boreal forest. It is unknown if human fires are more common today than prior to increases in settlement within the WRST area. Fire records from agencies that suppress fires and historic accounts in WRST (NPS PDS 2009a, 2009b) are insufficient for long term trend analysis, on a millennial or even a centennial scale. These data cover a short time span and are, therefore not comparable to the 150 to 200 year fire return interval estimated in the Chitina River valley by Lynch et al. (2004). From the 1950s to the 2000s, decadal fire extent totals appear to be increasing. However, it is unknown if fire extents and ignition points were consistently recorded in earlier decades. Fire extent in WRST is low, relative to interior portions of Alaska. However, there were some very large fires in the early 1900s and the recent Chakina Fire was extensive. The 2009 Chakina Fire nearly doubled the total recorded area burned from 1955 to 2009. Measures of fire severity in WRST represent a data gap and could contribute to a more comprehensive understanding of overall fire condition in the park.

Background

Fire is a natural disturbance linked to the dynamics of many plant communities and animal populations, with an important influence on the non-maritime portions of WRST (Allen, 2005). When compared to Denali National Park (DENA), Yukon Charley Rivers National Park (YUCH) and other parts of interior Alaska, WRST appears to have a longer fire return-interval (NPS 2009a). Still, fire is one of the most influential disturbance processes in boreal ecosystems, and is a ‗Vital Sign‘ for the Central Alaska Network (MacCluskie and Oakley 2005).

The natural role of wildland fire varies considerably across the landscape of WRST, with higher elevations lacking substantial fuels, and coastal areas south of the Bagley Ice Field where fire is nearly absent due to high humidity and precipitation (NPS 2009a). Fire, however has been a key component in the boreal forest communities of the Copper River Basin for thousands of years. The recurrence of periodic fires throughout history in this area has favored plants and animals that are adapted to fire-derived change in the ecosystem (NPS 2009a). The most significant of these plants are black spruce (*Picea mariana*) and white spruce (*Picea glauca*). They depend on ground fire to clear organic layers creating an exposed fertile seedbed for reproduction (NPS 2009a). Black spruce trees also produce semi-serotinous cones and are partially dependent upon fire for stand-replacement. Although much of WRST contains discontinuous permafrost, fire still plays an important role in the regulation of the permafrost tables. Ricketts et al. (1999) found that even relatively small burns of 1 to 40 ha can melt the permafrost table and have a dramatic effect on soil hydrology and structure.

Reference condition

Reference condition is defined as: natural fire frequency (fire return interval), extent, and severity prior to climate change, major settlement in the area, and fire suppression activities to protect anthropogenic values.

Lutz (1956) suggests that fires were commonly caused by lightning, but, in the author‘s terms, ―aboriginal” and ―white” man were an even more prolific source of fires, with ―white man” causing more fires than the ―aboriginal man.” These fires reportedly resulted in large burned areas. For example, W. R. Ambercrombie noted that in 1900 ―thousands of acres” were burned in the vicinity of the Slana River, and on a journey from McCarthy to White River, von Bergen traveled most of the time through burned forest (Lutz 1956). R. R. Robinson of the BLM also reported two fires in present day WRST: the Sourdough Hill fire, which started by railroad sparks in 1915 and burned approximately 155,804 ha (385,000 acres) in the Chitina River valley; and the Kennecott fire, started to provide fuelwood for sale at the Kennecott mine, which burned approximately 25,900 ha (64,000 acres) (Lutz 1959).

Gabriel and Tande (1983) suggest that the quantity and quality of available fire history information is often limited in the historical record of an area. As a result, reconstruction of probable fire history requires the use of physical historical sources such as tree-ring records, and pollen and charcoal stratigraphy. Recent investigations of charcoal in WRST estimated that mean fire return intervals for the Chokasna Lake site were 210 +/- 80 years from 3800 before present (BP) to present and 150 +/- 80 years after 2000 BC in the Moose Lake study site (Lynch et al. 2004). Surprisingly, fires at these sites were more frequent under wetter climatic conditions (Lynch et al. 2004). A combination of increased fire ignition and possibly inter-annual moisture variability may have provided the condition for more frequent fires under generally wetter climate conditions; however, differences in vegetation composition and fuel type associated with local factors can result in diverse fire regimes under the same regional climate (Hu et al. 2006). It is important to note that the Chokasna and Moose Lake study sites mentioned above are in the Chitina River valley and represent an area of WRST in which lighting strikes are relatively rare, especially in comparison to the northeastern edge of the park where lightning is much more common (Plate 3).

Understanding fire regime history, before human records of fires, requires relatively new scientific investigations. Hu (2006) suggests that advancement in the understanding of climate-fire-vegetation interactions in the Alaskan boreal biome will require a network of charcoal records across various ecoregions, quantitative paleoclimate reconstructions, and improved knowledge of how sedimentary charcoal represents fire events.

Fire terms
The following terms are from the NPS fire and aviation website (NPS 2009c) unless otherwise cited.

Fire Cause – The source of an ignition for a fire. For statistical purposes fires are grouped into broad cause classes. The nine general causes used in the U.S. are lighting, campfire, smoking, debris burning, incendiary, machine use (equipment), railroad, children, and miscellaneous (NWGC 2008).

Fire Extent – The area burned per time period or event.

Fire Frequency – The return interval or recurrence interval of fire in a given area over a specific time.

Fire Regime – The combination of fire frequency, predictability, intensity, seasonality, and size characteristics of fire in a particular ecosystem.

Fire Season – Period(s) of the year during which wildland fires are likely to occur, spread and affect resource values sufficient to warrant organized fire management activities. A legally enacted time during which burning activities are regulated by state or local authority.

Fire Intensity – the energy output from a fire. Depending on the need, this can be expressed as reaction intensity, fire-line intensity, temperature, heating duration, or radiant energy (Keeley 2008).

Fire Severity **–** Degree to which a site has been altered or disrupted by fire, the degree of ecological change. It is dependent on intensity and residence of the burn. An intense fire may not necessarily be severe. For trees, severity is often measured as percentage of basal area removed. In most studies it is measured by aboveground and below ground organic matter loss (Keeley 2008).

Fuel – Combustible material. Includes materials that feed a fire, such as vegetation (e.g. grass, leaves, ground litter, plants, shrubs and trees).

Fuel Loading – A build up of fire fuels within a landscape, especially easily ignitable, fast burning fuels, such as dead or dry trees and branches.

Fire causes

Overall, humans ignite the majority of fires, as lightning is less frequent and is often accompanied by rain in the park (Allen 2004). Approximately 72% of fires in WRST are human-caused, and 28% of the fires are of natural origin (Figure 10). Campfires are the most common anthropogenic source of recorded fires in WRST, followed by miscellaneous human causes, smoking, and incendiary (Table 6).

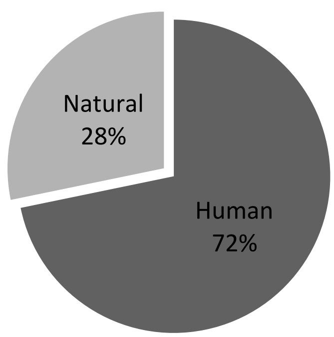


Figure 10. Natural vs. human causes of fires, WRST, 1950-2008. (NPS PDS 2009a)

Table 6. General fire causes within WRST, 1955-2008. (NPS PDS 2009a)

Cause	Number of Fires
Campfire	26
Lightning	24
miscellaneous	10
Smoking	9
Incendiary	8
Fire use	7
Railroads	1
Total	85

Although humans are responsible for starting the majority of the fires in Alaska, lightning-caused fires typically account for over 90% of the total burned area in Alaska, annually (McGuiney et al. 2005). The Alaska Interagency Coordination Center (AICC 2009a), which serves as a focal point for all federal and state agencies involved in wildland-fire management and suppression in Alaska, manages a lightning strike data set. From 1986 to 2008, the four years with the greatest number of lightning strikes occurred within the last decade (2001, 2004, 2005, and 2007) for an area within 100 miles of WRST (Figure 11). However, McGuiney et al. (2005) indicate that the state-wide lightning count system was upgraded in 2000. It is unknown if this has affected the numbers of detected lightning strikes compared with the previous system.

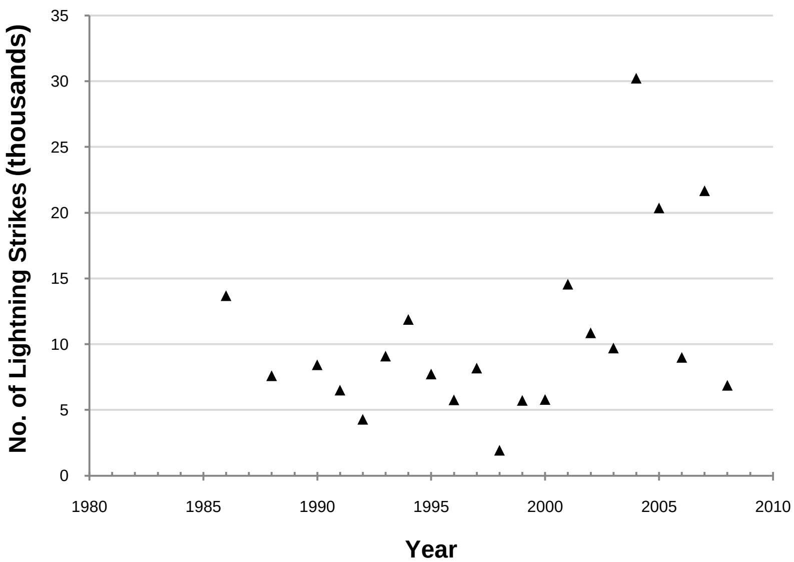


Figure 11. Total annual lighting strike count within a 100 mile radius of WRST, 1986-2008. (AICC 2009a) Note: An upgraded lightning detection system was implemented in 2000 with unknown effects on lightning strike detections. $Note_2$: No data for 1987 or 1989.

Fire frequency

Fire frequency in south-central Alaska is low compared with interior Alaska (Lynch et al. 2004). In WRST, a total of 89 fires were recorded from 1955 to 2009 (average 1.6 annually) (NPS PDS 2009a). Although the fire frequency information presented here is as accurate as possible, it is important to note that: 1) the NPS fires database is continually updated, with historic fires added as they are discovered through various means (Jennifer Barnes, NPS Fire Ecologist, pers. comm.) and 2) formal fire reporting began in the 1940s, but intensive aerial fire monitoring did not begin until the late 1970s during which occurred was increasingly more vigilant and accurate fire delineation (Hu et al. 2006). The number of recorded fires in WRST has been increasing since the 1950s (Figure 12, Figure 13).

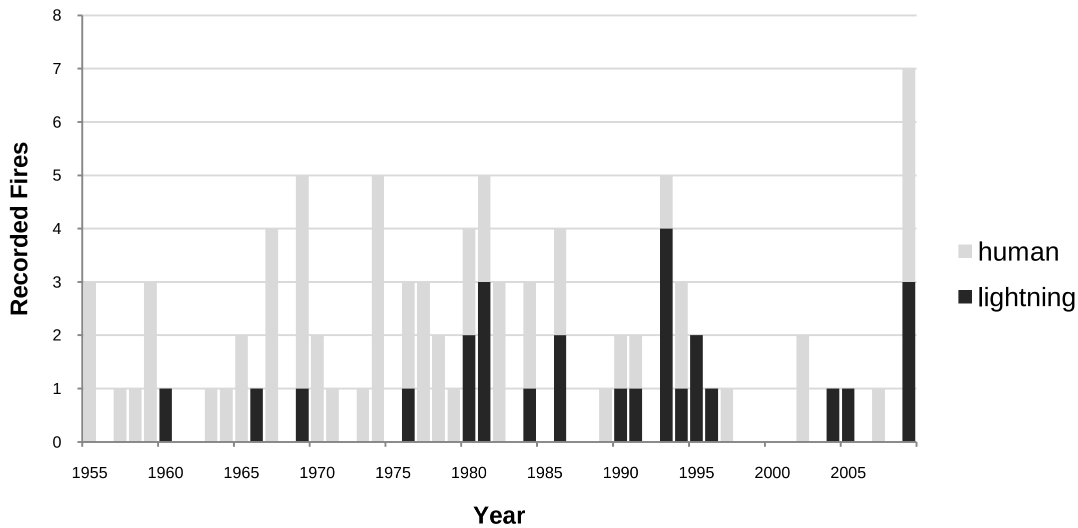


Figure 12. Fire frequency and cause, WRST, 1955-2009. (NPS PDS 2009a).

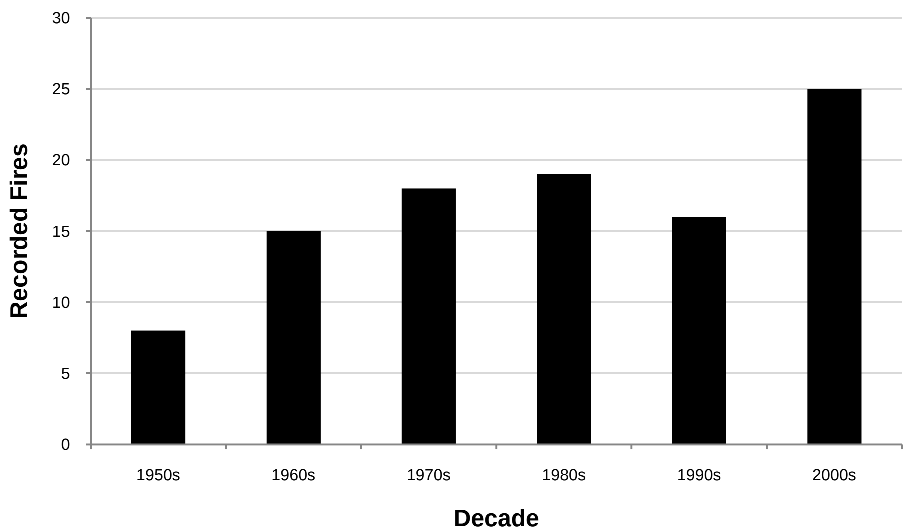


Figure 13. Number of fires by decade in WRST. (NPS PDS 2009a).

Fire extent

Approximately 36,366 ha (89,862 acres) burned in WRST, according to the NPS Fire Alaska point data and Historic Fire Perimeter data (NPS PDS 2009a, 2009b), which reports total area burned for ignition points within the park from 1942 to 2009 (Table 7). This includes fires in 1942, 1953, and 1954 that started on non-park lands adjacent to WRST and burning beyond the northern and eastern boundaries into WRST.

The 2009 fire season was particularly significant regarding total area burned, primarily due to the 23,033 ha (56,915 acre) Chakina Fire near the Chakina River (Plate 3). This fire burned approximately 2.5% of the forested area of WRST (NPS PDS 2009c). However, as mentioned, earlier historic records show that large fires are not unknown in WRST.

Table 7. Area burned by forest fires, WRST, 1915-2009. (1915-2008: NPS PDS 2009a and 2009b, 2009: AICC 2009b)

Years	Total area burned (ha)	Average Area Burned/yr (ha)	Average fire size (ha)	Fire frequency (# of fires)[a]	Average frequency (fires/yr)
1915	181,299	-	90,650	2	2
1942 to 2009	36,366	534.8	391	93	1.4
1915 & (1942 to 2009)	217,665	2,291.2	2,291	95	*

[a] This includes fire ignitions that started outside the park and burned over the border.
*Data were not consistently collected from 1915 to 1942.

Until the implementation of wildland fire suppression by various organizations and formal record keeping of Alaska fire activity, anecdotal records of notable fires by explorers were the only written record. Historical records, written by late 19th and early 20th Euro-American settlers in the Copper River Basin, document a select few fire events in or near WRST from 1889 to 1948. The notable fires of this time are listed below (fires outside the present day boundary of WRST are indicated with asterisks):

1898*- Several large fires near Klutina Lake and north of the Tazlina River were described by Abercrombie in one of the earliest written fire records

1915 - Sourdough Hill Fire burned 155,400 ha (384,000) acres from Chitina to the Kennicott River and north to mountains. The fire was presumably set by sparks from the CR&NWRR (Copper River & Northwestern Railroad) (Lutz 1956)

1915 - Kennicott Fire burned 25,900 ha (64,000 acres) near the mining town of Kennecott. The fire was intentionally set to produce fuel wood to sell at the Kennecott Mine (Lutz 1956).

1923- A forest fire near the Mother Lode mine was reported by the McCarthy Weekly News to be threatening bridges on the Mother Lode Trail on July 28 (Loso 1998).

1926 – Chititu fire near Chititu Mine. The evidence of large fire comes from Ted Lambert's Collection 1926 Chititu photo album. The fire was discovered June 27th, 1926, and burned through the Chititu Mine camp. The cause and size are unknown, but estimated at >1000 acres.

1927*- The Willow Creek Fire burned 51,800 ha (128,000 acres). The fire was started by construction crews, and burned between the Copper River and the Tonsina River with the Richardson Highway as the western boundary (Lutz 1956).

1947* - The Tazlina Fire burned 50,586 ha (125,000 acres) between Tazlina Lake and the Glenn Highway. The cause is unknown (Lutz 1956).

1948 - A large forest fire which burned near Lakina River. The post-fire stands are still visible from the McCarthy Road (AICC 2009).

Many of the fires in the area have occurred just north of WRST during the recorded fire period of approximately 1940 to present. This is likely due to higher lightning density and human population in those areas relative to other areas of the park (Plate 4). It is also important to note that when including fires within a 10 mile buffer around the park, the number of acres burned increases dramatically (Figure 14).

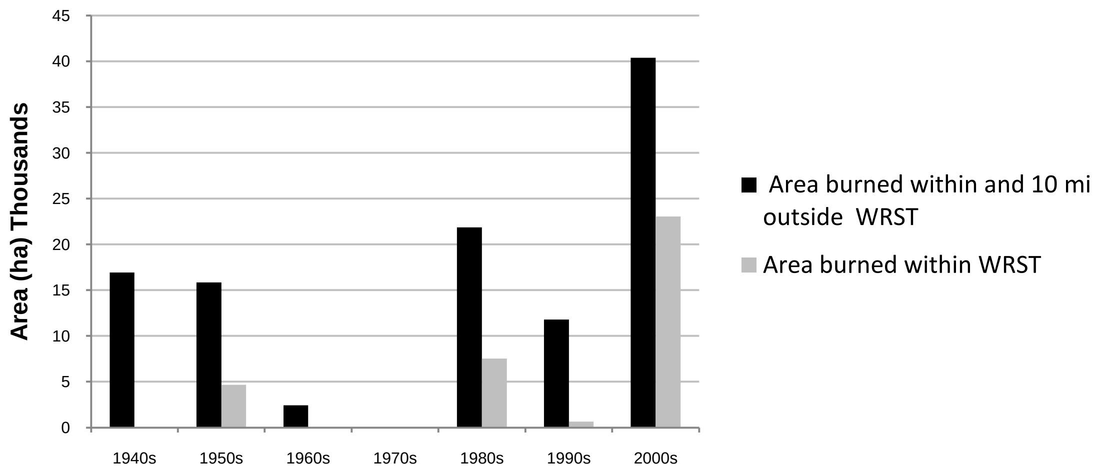


Figure 14. Fire area by decade within WRST and within a ten miles of WRST. (NPS PDS 2009a, b). Note: Fires less than 40.5 ha (100 acres) in size are included in WRST, but not reported outside of WRST in these data.

Fire distribution

From 1942 to 2008, approximately 58% of recorded fires in Alaska have occurred within one mile of the road system (AICCb, 2009). This was determined by spatially selecting fire history points that were within a one mile buffer of the Alaska Department of Transportation‘s (AKDOT) NavStar GPS centerline (NPS-PDS 2009e). In WRST, approximately 29% of recorded fires are within one mile of the McCarthy and Nabesna roads (Fires – NPS PDS 2009) (Plate 3). In addition, during the same time period, 55% of the recorded fires have occurred within 1 mile of a road, OHV trail, or hiking trail, within the park. This was determined by spatially selecting fire history points using a one mile buffer around the 1984 Trail Inventory data, the Trails Illustrated routes data, and the AKDOT‘s NavStar GPS centerline (NPS – PDS 2009e). These road corridors represent areas of higher human-use intensity and are reflective of the high percentage (72%) of fires caused by humans in WRST. The distribution of fires surrounding the park tends to follow the major roads, primarily the Richardson, Glenn, Tok-cutoff, and Alaskan Highways.

Fire distribution by RZ is more concentrated in the Upper Copper River, McCarthy, and Nabesna RZs (Table 8). These areas have seen more human activity as indicated by the number of total human-caused fire ignitions. They also contain significant coniferous forest stands, both black spruce (*Picea mariana*) and white spruce (*Picea glauca*), which may allow more lightning ignition to result in large, observable fires.

Table 8. General fire causes, by reporting zone, WRST, 1942-2009. (NPS PDS 2009a)

Reporting Zone	Campfire	Fire use	Smoking	Incendiary	Railroads	Miscellaneous	Total (human)	Lightning	Total	% of WRST Total
Bagley Icefield - Malaspina (BIM)	0	0	0	0	0	0	0	0	0	0
Big Volcanoes (BVL)	3	1	1	0	0	0	5	1	6	7
Coastal - Icy Bay (CIB)	0	0	0	0	0	0	0	0	0	0
Upper Copper River (LCR)	5	2	3	3	0	2	15	12	27	32
McCarthy (MCC)	10	4	1	2	2	5	24	2	26	31
Nabesna (NAB)	1	0	3	1	0	0	5	3	8	9
St. Elias/ Chugach Mountains (SEM)	6	0	0	2	0	2	10	1	11	12
Tetlin-Tanacross North Country (TTN)	0	0	0	0	0	1	1	6	7	8
White River (WHR)	1	0	0	0	0	0	1	0	1	1
Totals:	26	7	8	8	2	10	61	25	86	

Fire management

The Alaska Interagency Wildland Fire Management Plan (AIWFMP 1998) has four predetermined fire management options. Listed in order of high to low fire suppression resource allocation, these include critical, full, modified, and limited (Plate 4). Examination of the percentages of each type of wildland fire management options across the entire landscape of WRST, a small percentage (0.2%) of the total land area is identified as critical and full (6%) (Table 9). WRST contains a total of 910,375 hectares (2,249,577 acres) of forested land, including needleleaf, broadleaf, and mixed forests, accounting for 17.1 % of the total land area in WRST (NPS PDS 2009c). When comparing percentage of total land area in the four management options to the percentage of the four management options in forested land, the percent of critical fire protection area increases slightly and the percentage of full fire management area increases significantly 27% of the total forest land area.

Table 9. Area and percentage of fire management types. Note: this includes private lands within the boundary of WRST. Fire management options 2010.

Management type	All land in WRST[a]		Forested Lands of WRST	
	(acres)	% of total	(acres)	% of total
Critical	26931	0[b]	18,973	1
Full	830648	6	602,674	27
Modified	217,790	2	124,866	6
Limited	12,098,049	92	1,501,185	67
Totals:	13,173,418	100	2,247,698	101[c]

[a] This represents all land within the boundaries of WRST. The majority of non-federal lands in WRST are under 'critical' or 'full' fire management type.
[b] This was less than on half of one percent.
[c] Over one hundred due to rounding.

Stressors

NPS resource staff identified several thematic stressors on the fire regimes in WRST, including climate change, fuel loading by insects and disease infestation, non-native plant and insect infestations, commercial and industrial activity, and human caused fires.

The complex interactions between forest fire and climatic change affect species composition and ecosystem processes (Hu et al. 2006). Specifically, boreal ecosystems near altitudinal tree line are highly sensitive to climatic change and future warming may result in a major shift in the altitudinal forest-tundra boundary in the Copper River Basin (Tinner et al. 2008). Responses by boreal ecosystems to warming are also amplified by changes in moisture balances and fire regime feedbacks (Tinner et al. 2008).

During dry periods, the Copper River Basin has an abundance of forest fire fuel from black spruce and white spruce trees. Fuel loads have increased over the past decade due to spruce beetle damaged forests, and the resulting beetle-killed trees are predicted to influence fire behavior and present a hazard for over seven decades (Lamb et al. 2009). Large spruce beetle killed forests were located in much of the Chakina Fire burn area. Spruce beetle damage, mapped from 1987 to 2007 in forest damage surveys, totaled 16,322.87 acres or 28.7 % of the Chakina burn perimeter area.

Non-native invasive plant species can alter fire regimes and burned areas can provide sites for invasive plant establishment. Invasive plants that alter fire regimes are widely recognized as some of the most important ecosystem-altering species on the planet, causing changes in frequency, intensity, extent, type, and seasonality of fires through modification of fuel properties (Brooks et al. 2004). Invasive plants can reproduce better in burned soils, according to a study looking at burn susceptibility to non-native plant invasions in Alaska (Villano 2008). Invasive plants, however, actually respond better in burns of low severity, whereas native plants rapidly re-establish in sites of high severity burns (Villano 2008).

Direct human activities can change natural landscape processes and affect species composition. Logging and land clearing is an example of this and occurs on non-federal lands within WRST and on lands adjacent to WRST. The extent and potential effects of these activities represents a data gap for the park; however, a beetle and vegetation study in WRST did document clear-cuts, occurring during the 1990s of approximately 4,244 ha (10,448 acres) on non-NPS lands within the administrative boundaries of WRST (NPS PDS 2009e). In addition to logging, human caused fires and the suppression of natural fires can alter the natural fire regime‘s extent and distribution.

Data needs

A better understanding of the stressors of natural fire regimes and a more thorough investigation of reference condition for fire regime are necessary for WRST. For example, in boreal ecosystems, the interaction of climate, vegetation composition and the fire regime, and the natural variability of fire regimes remains poorly understood (Hu et al. 2006). Understanding how fire disturbance regimes vary across time and space is also a data need (Chapin et al. 2006).

Additional information about historic (Holocene) fire regimes (fire frequency, extent, and intensity) and insect disturbance regimes in WRST is important to help understand the reference condition. The paleo-ecological approach is particularly useful in understanding fuel dynamics and climate (Lynch et al. 2004).

Fire studies involving charcoal may shed more light on the historic fire return intervals in other portions of WRST. Extents of historic fires throughout Alaska are being constructed through anecdotal accounts and will hopefully contribute to a better understanding of reference condition. Finally, the interactions between spruce beetle infestations and the fire regime in WRST represents an important knowledge gap.

While extent, location, and frequency are readily available and easy to report using fire history records, the identification, quantification, and mapping of burn severity has only recently been undertaken. Burn severity is an important measure for understanding fire regime because it influences post-fire vegetation succession, soil erosion, and wildlife populations in fire-adapted boreal forest ecosystems (Allen & Sorbel 2008).Fires burn under varying weather conditions, topography and vegetation types, thus, their behavior and effects can vary dramatically. In fact, within the same fire perimeter, some areas can be intensely scorched and others completely untouched during the same fire event (Allen and Sorbel 2005).

Allen and Sorbel (2008) assessed burn severity using a satellite-derived measure called differenced Normalized Burn Ratio (dNBR) and found that it can be used as an effective way to map burn severity in boreal forest ecosystems. Burn severity maps provide baseline information that can be useful for management, monitoring, modeling, and research, and may be particularly important to the park staff that monitor vegetation, wildlife, water quality, and permafrost (Allen & Sorbel 2008). Burn severity mapping using satellite imagery will be conducted for all fires larger than 500 acres in Alaska national parks (Allen 2005), and the recent 2009 Chakina Fire has been mapped (Barnes pers. comm.).

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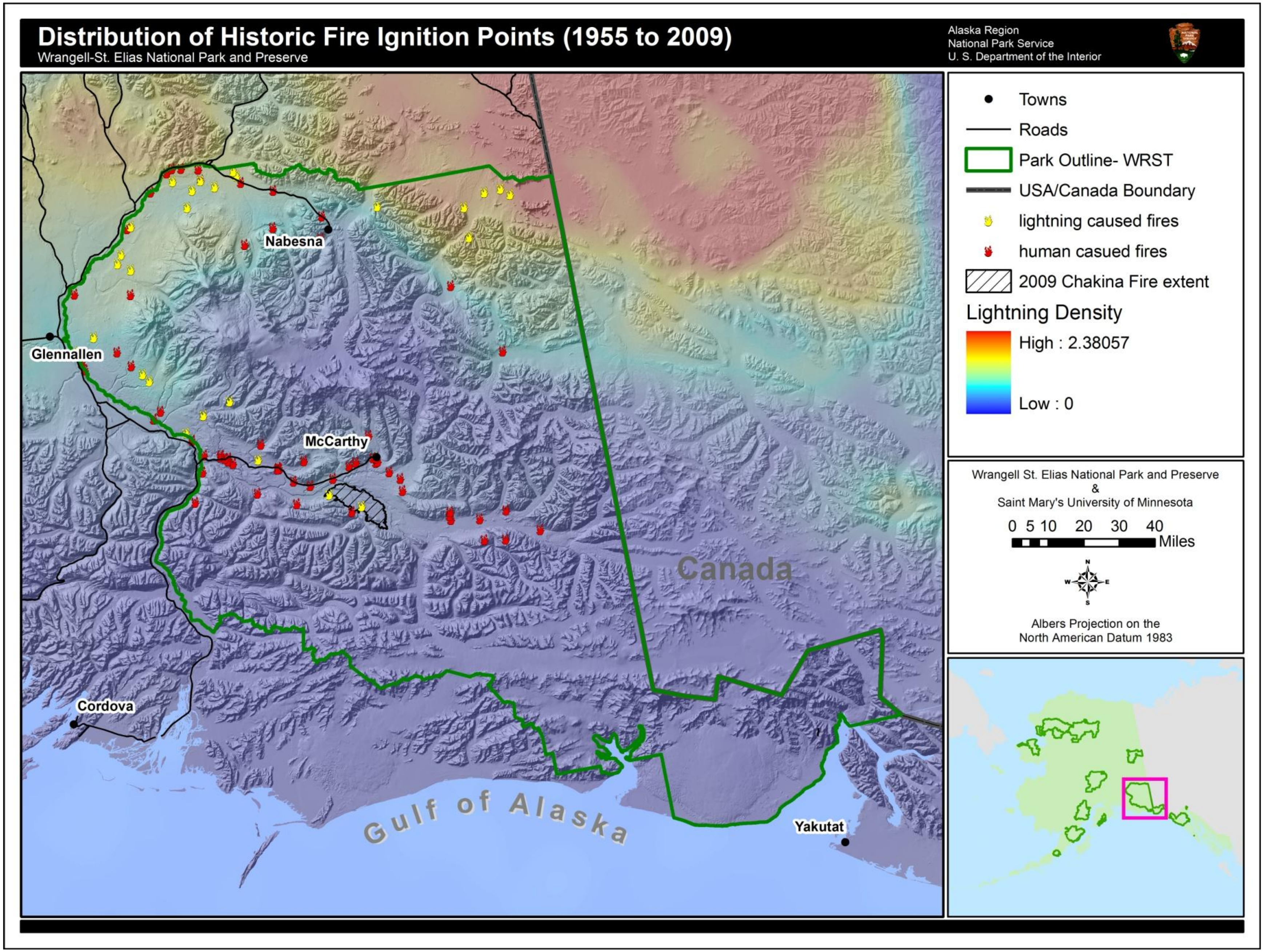


Plate 3. Historic fire ignition points, WRST, 1955-2009. (NPS PDS 2009a, AICC 2009)

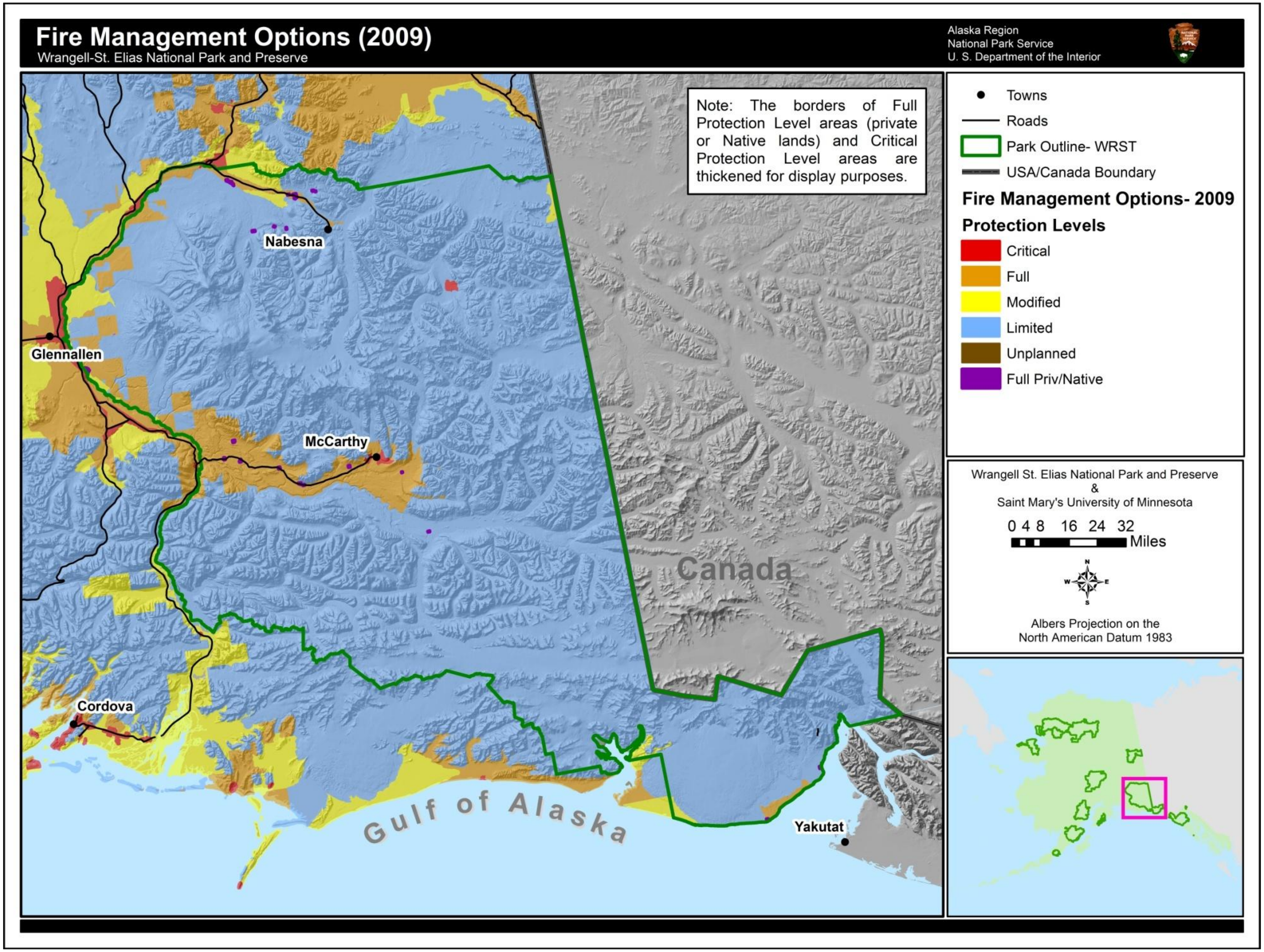
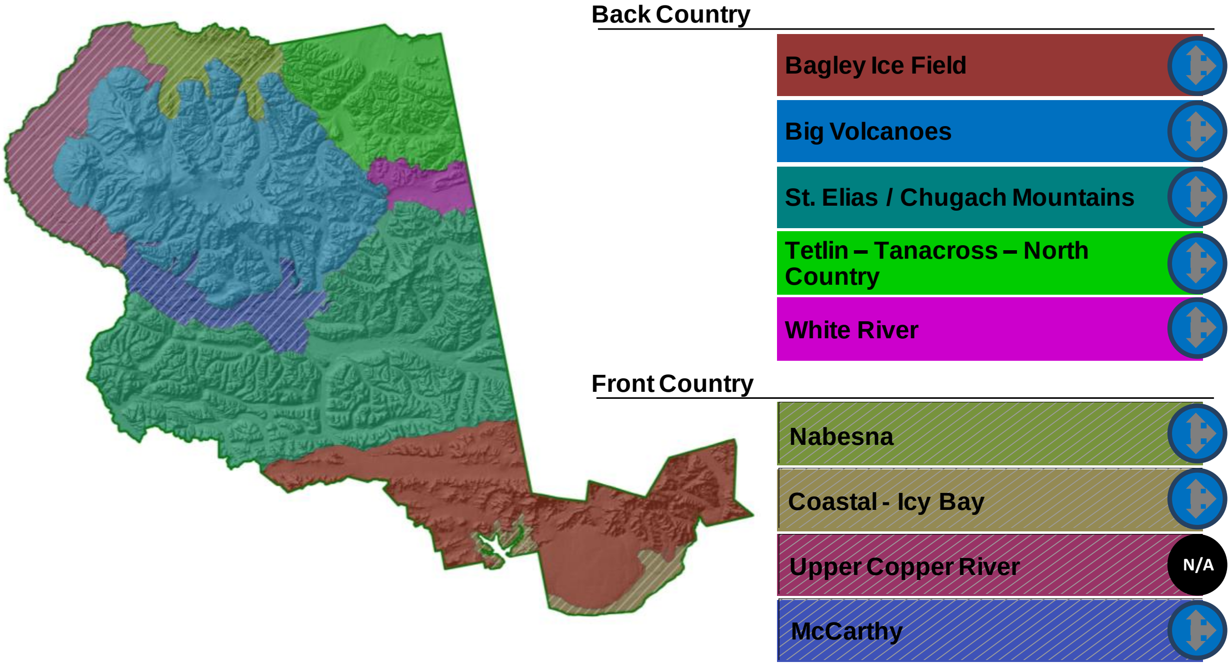


Plate 4. Fire management options, WRST, 2009. (NPS PDS 2009a)

4.3 Ecosystem and Communities

Indicators and Measures

Plant Phenology



Condition

Due to climate change concerns, plant phenology is an area of interest to WRST NPS staff; however, current condition or recent trend is unknown due to the limits of available data. The plant phenology data analyzed by Markon (2001) are more than ten years old and therefore not necessarily indicative of the current condition, however, Markon's (2001) results are useful as baseline measures of plant phenology to which future plant phenology data could be compared. The ongoing aspen and Exotic Plant Management Team (EPMT) phenology monitoring projects in the park are developing data sets that will be useful for future determination of trends in plant phenology.

Background

Changes in ecosystem and community dynamics potentially affect all ecological components, from individual species to large, broad-scale processes. One important dynamic of ecosystems and communities is phenology: the recurring life cycle events of plants and animals (USA National Phenology Network 2010). Phenology affects the number, diversity, and behavior of organisms, interactions between organisms, and food webs (USA National Phenology Network 2010). Changes in timing of phenophases have been observed globally, but changes are not all occurring at the same rate. These varying rates of change are altering ecosystem processes and interactions between organisms (USA National Phenology Network 2010).

Detection of changes in plant phenology is important for understanding climate change and its effects, including resulting changes in habitat. Changes in phenology are a particularly sensitive indicator of climate change (USA National Phenology Network 2010). Plants provide the energetic foundation of ecosystems and provide habitat for other living organisms (Central Alaska Network 2007) Quantity and timing of snowfall, quantity of useable moisture for plant growth, and extent of permafrost are additional climate effects that can be reflected in plant phenology, which could in turn affect an organism that relies on the plant for its food supply.. Due to its importance, plant phenology has been selected as a vital sign for the Central Alaska Network Inventory and Monitoring program (MacCluskie and Oakley 2005).

Reference Condition

The reference condition for plant phenology is "the range of natural variability." Due to the many natural factors that affect plant phenology from year to year, a long data record is necessary to determine the range of natural variability. Phenology data published in a study by Markon (2001) contributes to an understanding of natural and healthy plant phenology, but due to its limited time-frame and large scale approach, it is not sufficient to define the full range of natural plant phenology variability for WRST.

Markon (2001) calculated plant phenology statistics for nineteen ecoregions across Alaska using an advanced very high resolution radiometer (AVHRR) and derived normalized difference vegetation index (NDVI) data. Plate 5 depicts the ecoregions used for analysis. The ecoregions completely or partially within Wrangell-St. Elias National Park and Preserve are the Copper Plateau, Wrangell Mountains, Pacific Coastal Mountains, Coastal Western Hemlock–Sitka Spruce Forests, Alaska Range, and Interior Highlands. The following plant phenology measurements reported in Markon (2001) are summarized for the ecoregions that overlay the park in Table 10 and Figure 15:

Date of Initial Greenness: Earliest recorded date of measurable photosynthesis or spring leaf-out

Date of Initial Senescence: Latest recorded date of measurable photosynthesis or fall senescence

Date of Maximum Greenness: Recorded date of maximum measurable (MJD) photosynthesis or peak of green

It is important to remember that error may exist in the data because sensors are affected by such factors as resolution, means of measurement, atmospheric conditions, and reflectance. Dates may not be precise, because data for the study were composited every 14 to 16 days (Markon 2001).

In general, the latest dates for initial greenness, initial senescence, and maximum greenness occurred in 1992 (Markon 2001). One possible reason for these later dates is the eruption of Mt. Pinatubo in 1991 and the resulting increase in atmospheric haze. An increase in atmospheric haze reduces the amount of sunlight available to plants and reduces solar heating of the Earth‘s surface (Markon 2001). The impression of a trend toward earlier dates of initial greenness from 1993-1997 may be a result of the dissipation of the atmospheric haze from Mt. Pinatubo (Markon 2001). Each year the date of initial greenness tended to occur earlier in the Copper Plateau, Coastal Western Hemlock-Sitka Spruce Forests, and Interior Highlands ecoregions compared to the Wrangell Mountains, Pacific Coastal Mountains, and Alaska Range ecoregions (Figure 15).

Table 10. Average date (Julian day) and standard deviation (SD) of initial greenness, initial senescence, and maximum greenness (1991-1997) for ecoregions partly or entirely within WRST. (Markon 2001)

	Date of Initial Greenness		Date of Initial Senescence		Date of Maximum Greenness	
Ecoregion	**Average**	**SD**	**Average**	**SD**	**Average**	**SD**
Copper Plateau	122	11.9	274	13.6	242	16.8
Wrangell Mountains	135	10.5	268	11.1	240	16.5
Pacific Coastal Mountains	147	9.8	267	11.2	245	10.7
Coastal Western Hemlock - Sitka Spruce Forests	116	8.8	270	12.8	251	14.5
Interior Highlands	126	9.5	272	14.5	238	21.4
Alaska Range	142	9.7	269	12.5	242	11.7

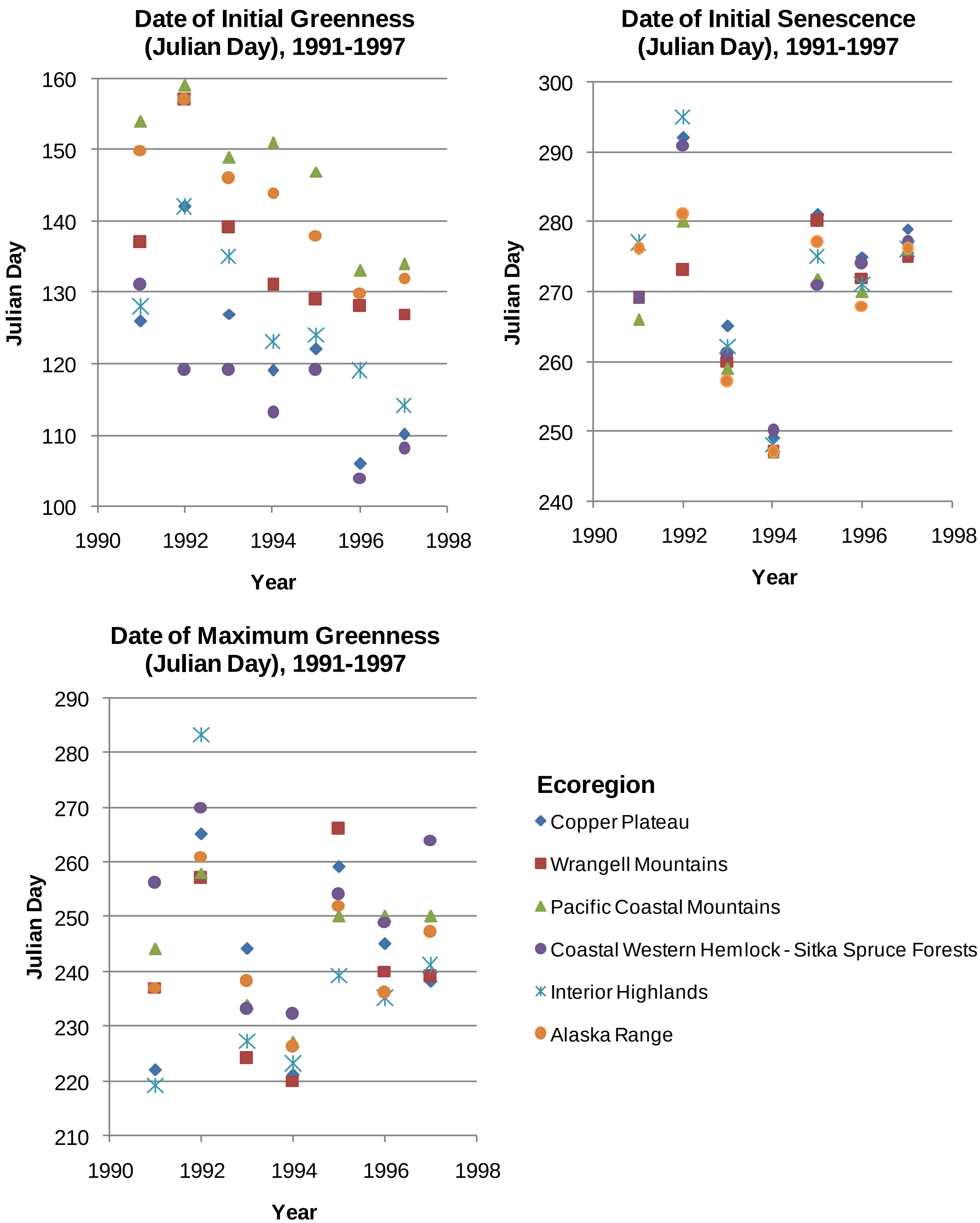


Figure 15. Date of initial greenness, date of initial senescence, and date of maximum greenness for ecoregions partly or entirely within WRST, 1991-1997. (Markon 2001)

Indicator Status

Two recent and ongoing projects monitor plant phenology in Wrangell-St. Elias National Park and Preserve. Neither study has sufficient data recorded and/or analyzed that would allow conclusions about the condition of plant phenology throughout the park; however, each project is capturing important data that will inform future condition assessments.

Central Alaska Network Aspen Phenology

The Central Alaska Network (CAKN) began monitoring the yearly phenology of aspen (*Populus tremuloides*) in 2005 (Roland 2010 draft). Aspen is an advantageous plant to study because of its wide distribution and popularity as a study species in other phenology networks. The ability to place CAKN aspen phenology in regional, national, and international contexts will result in more meaningful interpretation of data. The two initial monitoring sites were located in Denali National Park. In 2008, new sites were added at Eagle in Yukon Charley Rivers National Preserve (YUCH) and at Copper Center in WRST.

Park staff record soil temperature, snow cover, weather, presence of pathogens, and phenophases multiple times a week in the spring. Observations are also recorded in the fall. Recorded phenophases include: catkins evident, catkins open, catkins ripe, leaf buds bursting, leaves unfurled, leaves full-sized, leaves turning yellow, and tree girth. Initial data suggest there are differences in aspen phenology related to climatic conditions between the three park sites (Roland 2010 draft). Figure 16 depicts leaf phenophases for the Copper Center plot in 2008 and 2009.

Exotic Plant Management Team

In 2006, the Exotic Plant Management Team (EPMT) operating in WRST began recording phenology of plant species encountered during their activities in order to better time their work. The focus of this work is non-native invasive plants, but not every plant listed in the phenology database is non-native. Dates of first flower and seed set are recorded due to their importance for management of non-native species. Data exist for the Copper Basin site from 2006 to present and for the McCarthy/Kennecott and Slana sites from 2007 to present. Date of first flower and seed set for each species are depicted in Figure 16, Figure 17, and Figure 18. The data illustrate the variable nature of plant phenology.

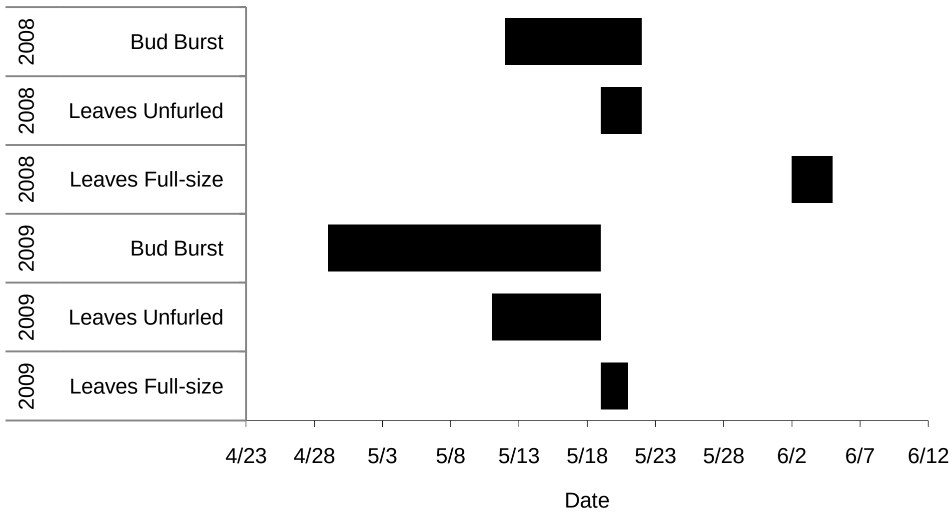


Figure 16. Aspen leaf phenophases at the Copper Center plot. Boxes mark the time period between the first date each phase was observed in the plot and the date on which the phase was observed for every tree in the plot. (CAKN 2010)

Stressors

Both natural and anthropogenic factors affect plant phenology. Natural factors include the species of plants comprising the community, insect damage, disease, climate events, nutrient availability, water supply, and natural disturbance such as fire, floods, and volcanoes (Markon 2001). Anthropogenic stressors of plant phenology include non-native species, insects, and disease introduced by humans. In addition, changes in atmospheric composition caused by humans or natural events (e.g. volcanoes) can lead to changes in air quality and climate, both of which can change plant phenology.

Climate and natural disturbances such as fires and volcanoes are the most important drivers of change in plant communities (Central Alaska Network 2007). Climate change and the effects of climate change, including changes in temperature and precipitation patterns, snow cover, permafrost, and available moisture for plant growth, can cause changes in plant phenology. Snow cover is of particular importance to spring plant phenology in WRST. There is concern that variability in timing of snow melt and temperature could result in plants greening up earlier and then becoming injured by cold temperatures (M. Terwilliger pers. comm.).

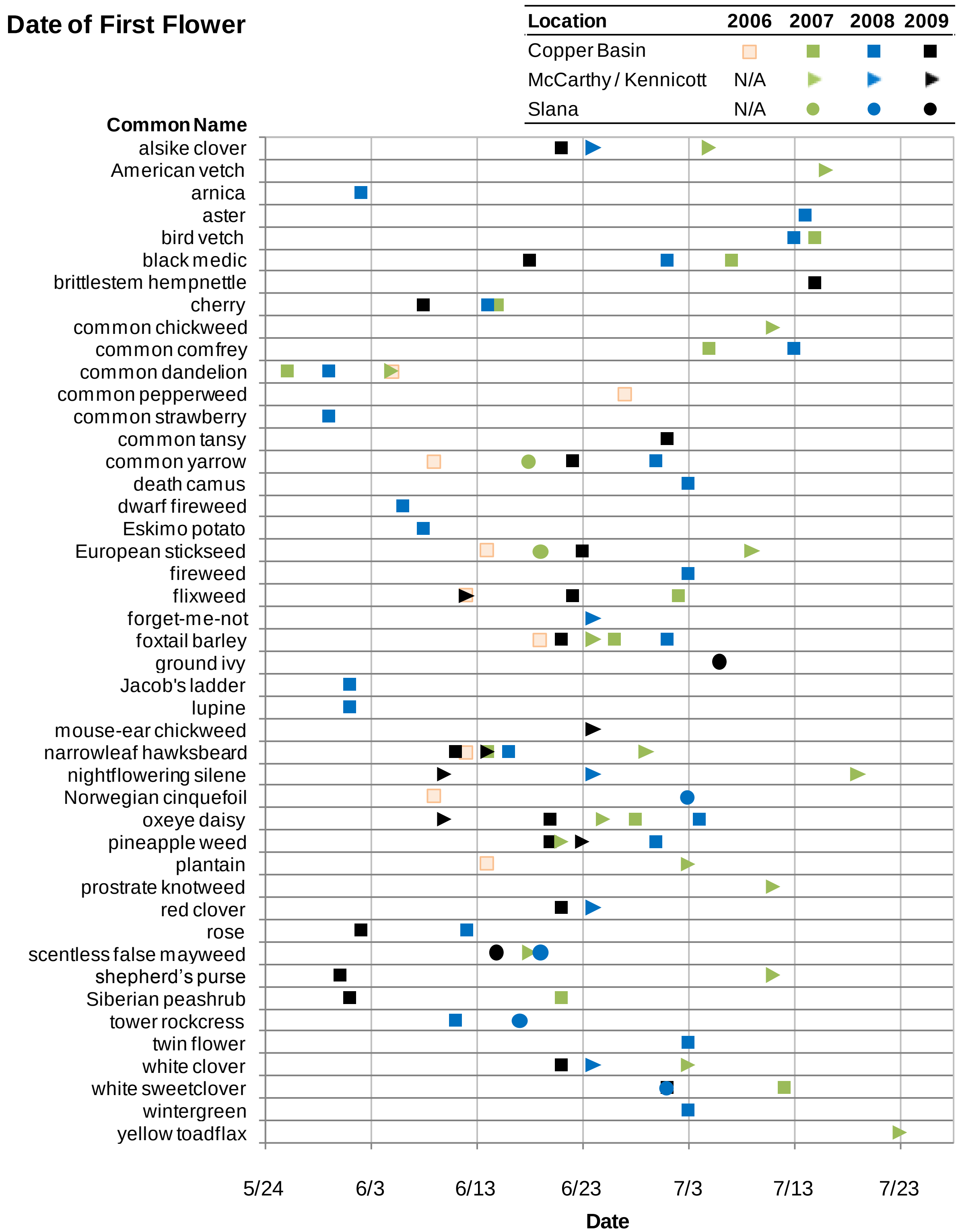


Figure 17. Date of first flower for plant species at three locations in WRST, 2006-2009. (WRST 2010)

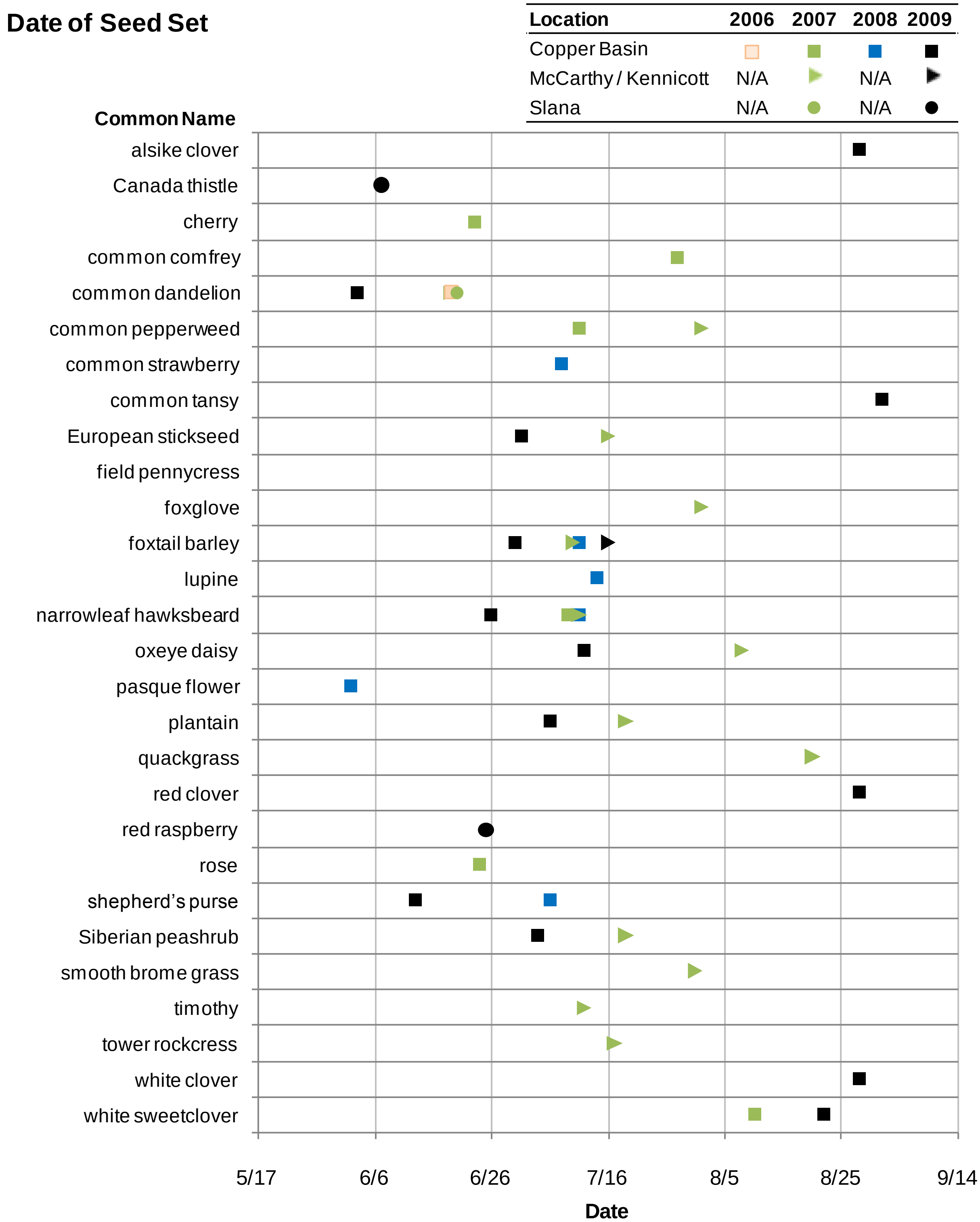


Figure 18. Date of seed set for plant species at three locations in WRST, 2006-2009. (WRST 2010)

Reporting Zones

Plant phenology is relevant for all RZs. The aspen phenology plot is located in the Upper Copper River RZ. The plant phenology data collected by the EPMT are obtained from small portions of the Upper Copper River, McCarthy, and Nabesna RZs. Table 11 reports the ecoregions used in Markon's (2001) study that are present in each RZ. See Plate 5 for a spatial representation of the overlap between RZs and ecoregions.

Table 11. Dominant and other ecoregions within WRST reporting zones.

Reporting Zone	Dominant Ecoregion	Other Ecoregions Within Zone
Bagley Icefield – Malaspina	Pacific Coastal Mountains	Coastal Western Hemlock – Sitka Spruce Forests
Big Volcanoes	Wrangell Mountains	Copper Plateau
Coastal – Icy Bay	Pacific Coastal Mountains	Coastal Western Hemlock-Sitka Spruce Forests
Upper Copper River	Copper Plateau	Alaska Range; Wrangell Mountains
McCarthy	Copper Plateau	Wrangell Mountains; Pacific Coastal Mountains
Nabesna	Wrangell Mountains	Copper Plateau; Alaska Range
St. Elias/ Chugach Mountains	Pacific Coastal Mountains	Wrangell Mountains (substantial portion); Copper Plateau
Tetlin-Tanacross-North Country	Wrangell Mountains	Interior Highlands
White River	Wrangell Mountains	(none)

Data Needs

The last park-wide study was published in 2001 and reported on data for years 1991-1997 (Markon 2001). Ongoing monitoring of the dates of initial greenness, initial senescence, and maximum greenness is needed to be able to report on the condition of this component. Ongoing projects monitoring and analyzing the phenology of individual plant species such as aspen, will also be useful for the assessment of ecosystem and community dynamics.

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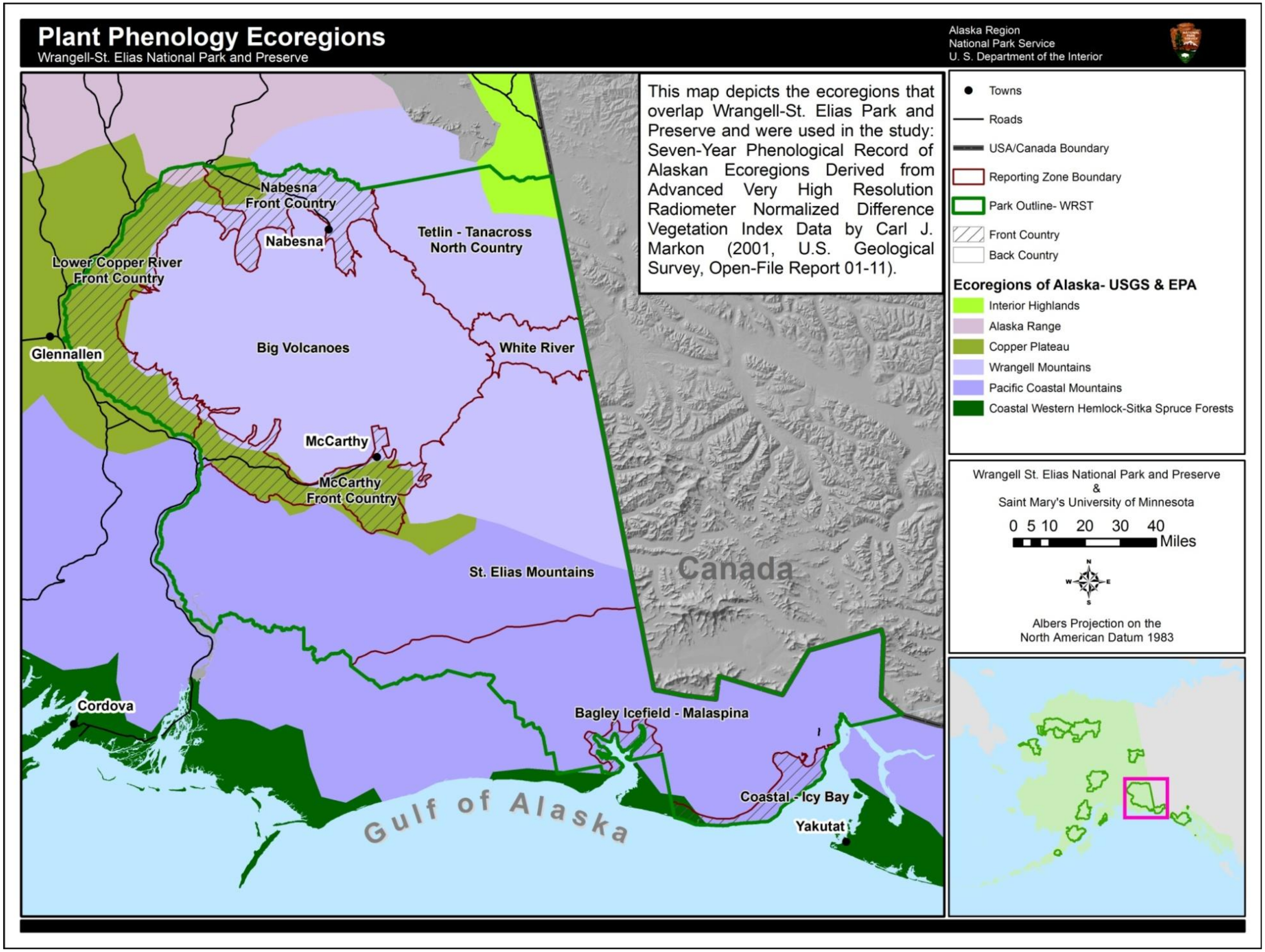
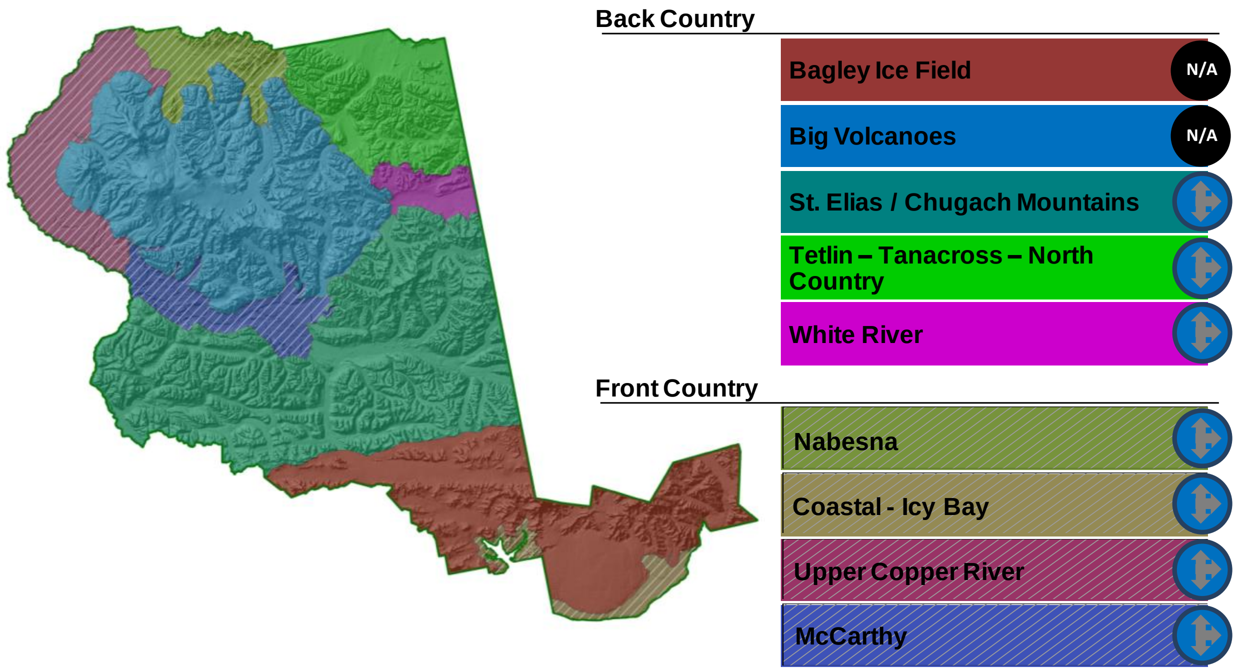


Plate 5. Plant phenology ecoregions, WRST.

4.4 Trumpeter Swans

Indicators and Measures:
Population and Nesting Status and Trends



Condition
Trumpeter swan populations within WRST are considered to be in good condition. However, because the last population survey was conducted in 2005, the trend is currently unknown. Analysis by Kozie (1996) concluded that populations increased significantly between 1968 and 1995. Since 1995, no evidence suggests changes in the population. Additional information on productivity within the park would assist future management decisions regarding this species.

Distribution and Background

The historic breeding range of trumpeter swans (*Cygnus buccinators*) extended in a wide band east from the Bering Sea through most of Canada and south to Missouri, Illinois, and Indiana. In the early 1900s, the trumpeter swan was nearly hunted to extinction by market hunters for its skin, feathers, meat, and eggs. By the end of this period, only about 70 known birds existed, in and around Yellowstone National Park. The trumpeter swan was considered for the Endangered Species List, but was removed from consideration when a nesting population was discovered in the Copper River Basin (Hansen et al. 1971). Conservation efforts, implemented in the 1960s and 1970s, lead to a quick turnaround in the swan population. The 2005 North American Trumpeter Swan Survey showed the population had rebounded to 34,803 swans within the continental United States (USFWS 2006).

There are three populations of trumpeter swan in North America: Rocky Mountain; Interior; and Pacific Coast. Birds of the Pacific Coast population nest in Alaska and winter near coastal waters from Cordova to the west coast of British Columbia, and Washington. The 2005 Pacific Coast population, estimated at 23,692 individuals, represents approximately 70% of the world population of trumpeter swans (Conant et al. 2007). In WRST, trumpeter swans occur in the Bremner, Tana, Chitina, Copper, and Chisana River Basins. USFWS and WRST staffs have observed trumpeter swans in all RZs except Bagley Ice Field and Big Volcanoes (Plate 6).

Named after its trumpet-like call, the trumpeter swan is one of two native swans in North America. Their habitat consists of shallow lakes, slow-moving rivers, and ponds that contain abundant vegetation. The average weight of an adult is approximately 30 pounds and they are five feet long with a seven to nine foot wingspan. They are distinguishable by their white plumage, dark legs, and a large black beak, with black coloration that extends around the eye. Sexual maturity is reached around age four or five, but they may pair off with a lifetime mate after their second year. Nesting generally initiates in late April through early May. Clutch size ranges from two to nine with an average of five eggs. Incubation occurs for 33 to 37 days and hatchlings emerge near the end of June in South Alaska. Fledging occurs at 100 to 120 days. Young swans, or cygnets, will remain with adults until the following spring, but siblings may remain together for several years (NatureServe 2009).

Reference Condition

Parameters that define the ―natural and healthy" reference condition are unknown. The earliest available trumpeter swan data are from 1968, well after the decline of trumpeter swans due to market hunting.

Demographics

The first extensive survey of Alaska's trumpeter swan population occurred in 1968, and estimated the population at 2,847 individuals (Conant et al. 2007). Since 1975, the USFWS, in cooperation with other land management agencies, conducts statewide-standardized aerial surveys every five years. With the knowledge of additional breeding locations, the number of surveyed units has increased from 176 sample units in 1975 to 780 sample units in 2005. The USFWS surveys, conducted between August 15 and 31, record the number, location, and age composition of observed swans. Since 1968, the number of observed trumpeter swans in WRST has increased (Figure 19).

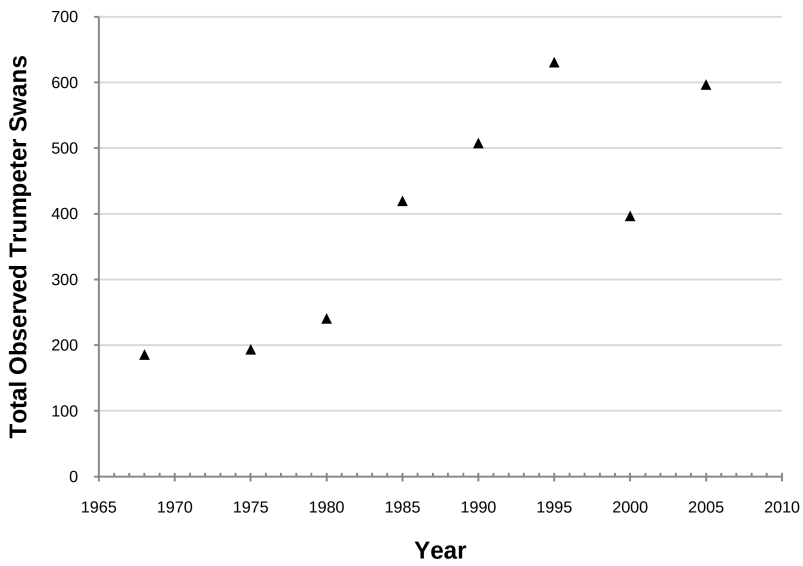


Figure 19. Total number of trumpeter swans observed in WRST during U.S. Fish and Wildlife Service Censuses, 1968-2005.

In the mid 1980s, WRST biologists determined that the five-year USFWS survey interval was inadequate to detect population trends in a timely manner. Consequently, trumpeter swan surveys were initiated by the WRST biologist in 1984. WRST surveys were conducted in 1984, 1986, and 1988, as well as annually, from 1989 to 1997 (Mullen 1984, 1986, Christophersen 1988, Faer 1989, Kozie 1991, 1992, 1994, 1995, 1996, Mitchell, C.D. 1997). Before 1992, swans were monitored throughout WRST by park resource staff. Between 1992 and 1997, annual productivity surveys in WRST were limited to the Lower Copper, Bremner and Tana Rivers and their associated wetlands. Surveys were standardized in 1992, and a trumpeter swan monitoring protocol was developed in 1994 (Kozie 1994).

The objectives of the swan monitoring protocol was to track population trends, assess productivity of nesting birds, and opportunistically document fall staging areas within WRST. Productivity surveys required one flight in June to locate nests and a second in August to document reproductive success. This allowed population and productivity data to be compared between years, and supported the determination of population trends. In 1996, Kozie summarized all swan monitoring data prior to 1997. Kozie (1996) reached two major conclusions: the population of trumpeter swans within WRST had increased significantly from 1968 to 1995 and trumpeter swan productivity in WRST was similar to productivity across the entire Copper River Delta for the years 1993 to 1995.

Mitchell (1997) summarized all annual survey and productivity data from 1992 to 1997. Mitchell concluded that it was unlikely that every trumpeter swan pair or nest was observed with only two sampling flights. Additionally, Mitchell (1997) concluded that there was no trend in population size or reproductive parameters from 1992 to 1997. He also noted that expanding the survey effort (beyond two days of flying) was too costly in terms of funds or personnel, but the five year survey interval, for USFWS surveys, is too lengthy to monitor all biological and ecological phenomena associated with trumpeter swan populations (Mitchell 1997). Annual trumpeter swan surveys in WRST ceased in 1997.

In 2005, trumpeter swans numbered 23,692 individuals in Alaska, a 38% increase from the 2000 statewide survey (Conant et. al. 2005). Cygnets accounted for 27% of the population compared to 19% in 2000, and average brood size increased from 2.8 in 2000 to 3.1 in 2005. The number of adult birds has increased by 5.9 % annually and the number of cygnets by 5.3% annually between 1968 and 2005 (Schmidt 2008, Conant et al. 2007). Conant et al. (2007) suggests the density of swan use in some of the best habitat is still increasing and that peripheral habitat is being utilized in several statewide units including the upper Tanana.

Stressors
Schmidt et al. (2009) indicates that transportation infrastructure in proximity to Tetlin National Wildlife Refuge has a negative effect on local trumpeter swan broods. Trumpeter swans are sensitive to a variety of human disturbances. Potential threats to nesting swans include disturbance from recreational activities and modes of access into the park, such as aircraft (including float planes), watercraft, and off-road vehicles (OHVs). Other threats or potential disturbances include development of private lands, new road construction, or coastal tourism development.

Pond shrinkage within WRST results in loss of breeding, foraging, and nesting grounds. Since the 1950s there has been an overall decrease in size and numbers of water bodies within Alaska (Riordan 2005). Trumpeter swans seldom breed in high densities (Schmidt et al. 2009) and with an increasing population and loss of water bodies, overcrowding could pose a threat to birds within the park.

Data Needs
Annual standardized trumpeter swan population and nesting surveys should continue until population and productivity trends are understood. Additionally, a more complete breakdown of the USFWS data, allowing for analysis of productivity measures would be beneficial to management.

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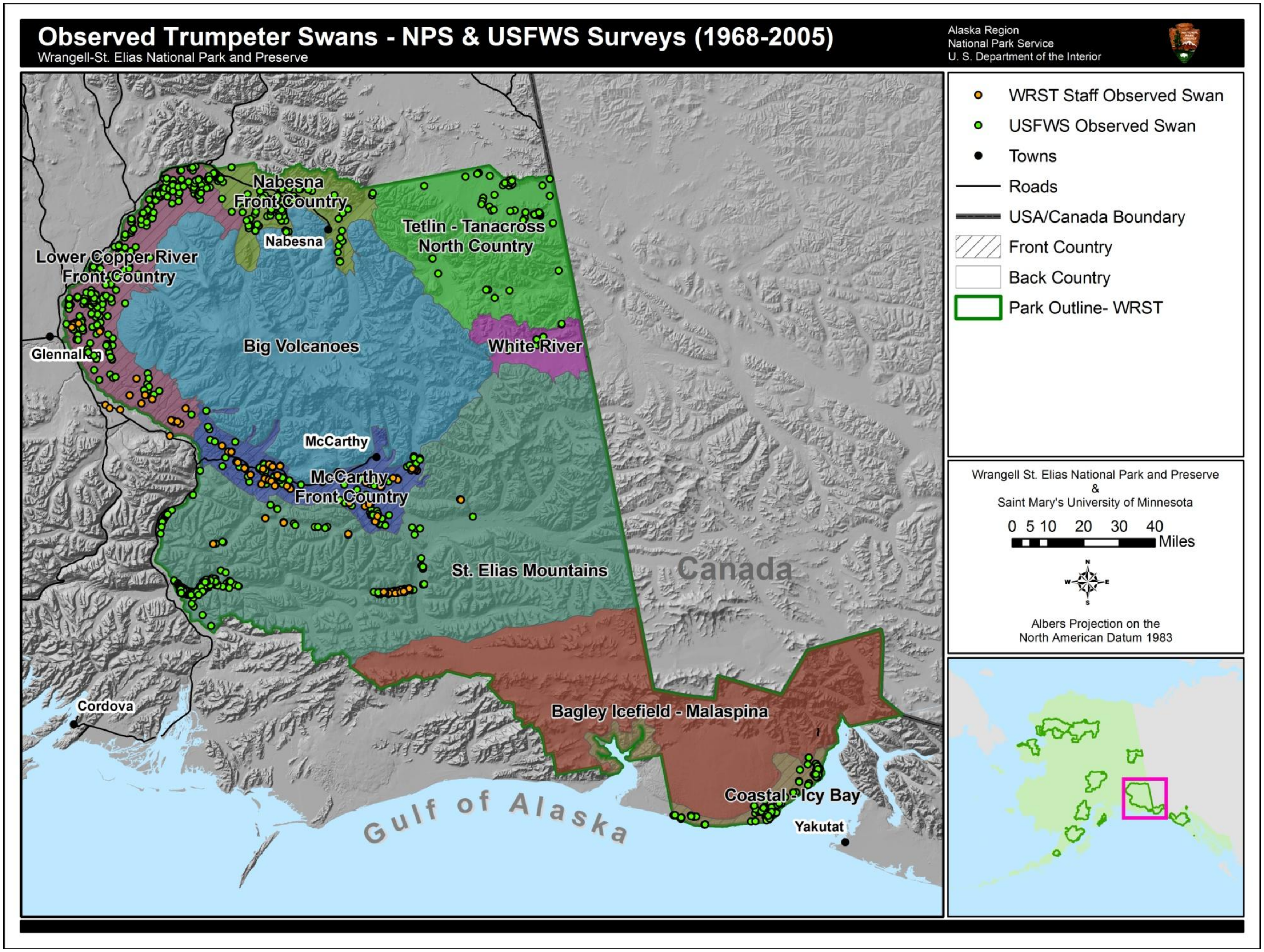
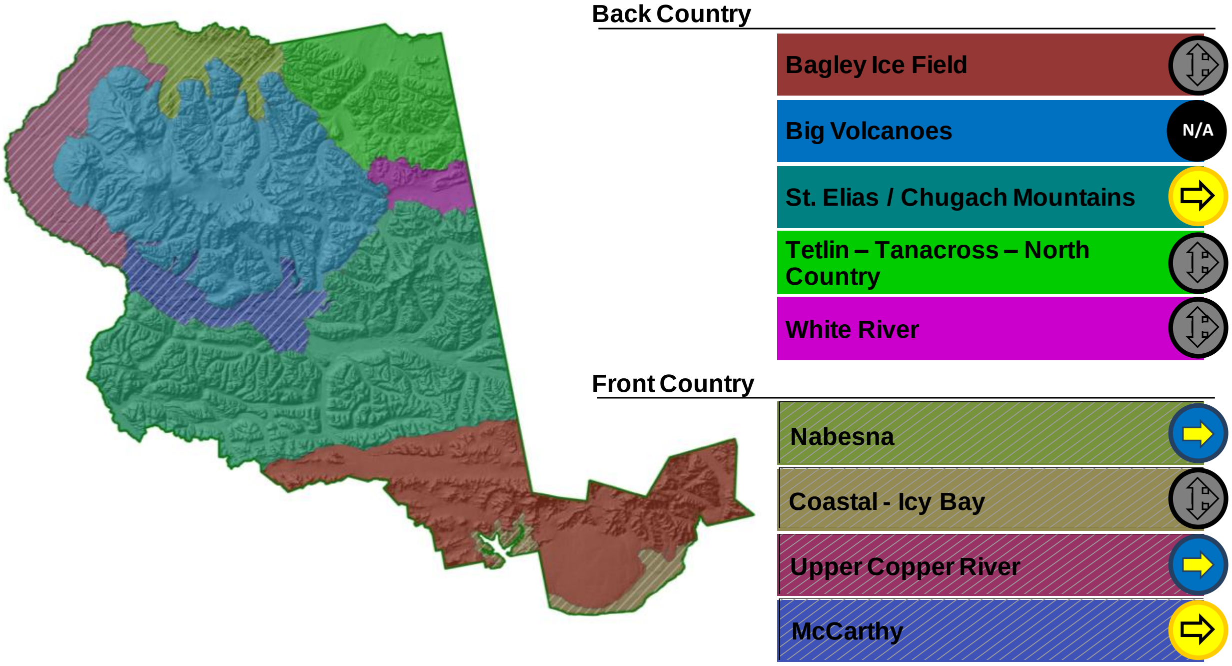


Plate 6. Observed Trumpeter Swan from NPS and USFWS surveys, 1968-2005. (NPS PDS 2009a, b)

4.5 Bald Eagle

Indicators and Measures

Nesting Territory Occupancy, Nesting Success, Mean Brood Size



Condition

Overall, bald eagle nest occupancy, nest success, and productivity in WRST have increased each year between 2006 and 2009. An accepted indicator of bald eagle population stability is nest success greater than 50% and productivity of at least 0.70 young per occupied nest. Between 2006 and 2009, this threshold was only met once, in 2009, for the entire survey area. Nest success and productivity within the Nabesna RZ has consistently been above 60% and 0.90 young, respectively. The most recent nest surveys in the Coastal-Icy Bay RZ, conducted between 1992 and 1995, displayed an average nest success and productivity of 27% and 0.32 young per occupied, respectively. Current condition on the coast is unknown.

Background and Distribution

Range
Bald eagles (*Haliaeetus leucocephalus*) are found across the United States and Canada with their range extending into the northern parts of Mexico. A majority of bald eagles breed in Alaska and British Columbia. In Alaska, bald eagles are usually found along the coast, around offshore islands, and on interior lakes and rivers. While not well understood, Alaska‘s interior bald eagles are thought to winter in the Intermountain West and Pacific Northwest. Coastal bald eagles in Alaska remain in these areas throughout the year. Though this species is only known to nest within the Nabesna, Upper Copper River, McCarthy, St. Elias/ Chugach Mountains, and Coastal-Icy Bay RZs, bald eagles are likely present throughout most of WRST.

Life History & Biological Characteristics
Mature adults have a yellow beak and dark plumage with white feathers covering their tail and head. They are around 89-94 cm (35-37 in) tall and their wingspan ranges from 182-240 cm (72-96 in) in length. Immature bald eagles are dark with light markings on the bodies, under wing, tail base, and flight feathers.

Bald eagles reach sexual maturity at 4-5 years of age. Clutch size ranges from 1-3 eggs, and the second hatchling normally dies. Incubation lasts about 35 days, both adults tend the nest, and surviving young leave the nest after approximately 75 days (NatureServe, 2009).

Population History
The Alaska bald eagle population is approximately 30,000 individuals and is considered secure; this accounts for approximately 30% of the worldwide population (100,000 individuals) (NatureServe 2009). In 1978, the bald eagle was federally listed as Endangered for the lower 48 states because of population declines resulting from illegal hunting, habitat destruction, and contaminant poisoning (DDT). The Migratory Bird Treaty Act, Bald Eagle Protection Act, and Endangered Species Act all provided protection for population recovery. In 2007, the bald eagle was removed from the Endangered Species List.

Reference Condition

Measures related to the reference condition of natural and healthy populations are unknown. There is no historical evidence or accounts of this species‘ distribution or health prior to modern human occupation in WRST.

Surveys

The U.S. Fish and Wildlife Service began monitoring bald eagles along a portion of the Copper River in 1987, and initiated annual (July) bald eagle productivity surveys along sections of the Copper River. In 1989, May occupancy surveys were added, and two surveys per year were continued on various segments of the Copper River and its tributaries until 1997. In 1992, coastal surveys along the Malaspina Forelands were initiated and continued through 1995. No surveys were conducted in WRST between 1998 and 2003. In 2004, surveys were again conducted along one section of the Copper River from the Chistochina River to Chitina, and in 2005 the surveys were extended to Miles Lake on the lower Copper River. In 2006, the CAKN included the bald eagle as a vital sign for long term monitoring in WRST. Consequently, nest surveys were expanded in 2006 to include the entire Copper River from its source at Copper Lake to Miles Lake, and the lower Chitina and Bremner Rivers.

Annual nest surveys are conducted using slow fixed-winged aircraft with one observer. All known nests are checked during the early occupancy survey, and new nests and territories are recorded. Location, tree species holding the nest, whether the tree is dead or alive, and nest integrity are recorded for each nest. Occupancy surveys are conducted in mid-May, before eggs hatch, and before most failures occur. Occupancy is defined as an adult in the nest in incubating posture or two adult birds at the nest or in the nest tree. Only occupied nests are checked during productivity surveys which are conducted in late July or early August, after most nestlings are ≥80% of their fledging age.

Kozie (1993) defined five areas along the current bald eagle survey area that are used to compare bald eagle productivity within WRST. The Upper Copper River area is 80 km and runs along the Copper River from Copper and Tanada lakes to the confluence of the Chistochina River. The Middle Copper River area is 179 km and extends from the Chistochina River south along the Copper River to the confluence of the Chitina River. The Lower Copper River area is 188 km and continues from the Chitina River to Miles Lake. The Bremner River survey area encompasses 45 km of that river between its confluence with the Copper River and Threemile Canyon. The Chitina River Survey area is 116 km and extends from the Chitina River and Copper River confluence to the braided section of the Chitina River above the Tana River.

Bald Eagle Survey Results

Consistent bald eagle surveys, covering the same area and using the same methodology, were conducted from 2006 to 2009 in the Copper River Drainage. Overall nest success increased each year from 30 to 51% between 2006 and 2009, with a corresponding increase in productivity each year of 0.41 to 0.74 young produced per occupied nest (Table 12). Percent nest success and productivity has been consistently high each year along the Upper Copper River segment (Nabesna and upper portion of Upper Copper River RZ‘s) and consistently low along the Chitina River segment (McCarthy RZ) (Table 13). Success improved along the Lower Copper and Bremner River segments (St. Elias/Chugach Mountains RZ), but decreased along the Middle Copper River segment (lower portion of Upper Copper River RZ). Average nest success and productivity in the Coastal-Icy Bay RZ was 27% and 0.32 young per occupied nest between 1992 and 1995, respectively. There was a complete nest failure in 1993. Plate 7 shows recent observed nest locations.

Sprunt et al. (1973) found that nesting territory success greater than 50% and minimum productivity of 0.70 young per occupied nest were required to maintain stable bald eagle populations. Overall nest success and productivity were above the minimum level in 2009 and within the Upper Copper River segment each year. Overall nest success during 2008 was just below the minimum level of 50%, while productivity was above the minimum required to maintain a stable population.

Nest success and productivity are quite variable among the survey segments, probably reflecting the availability of prey such as salmon. The highest productivity is consistently found in the Upper Copper River segment, which is clear and shallow, providing lots of opportunity to catch salmon. Nest trees are limited along this segment, which exceeds 900m in elevation. The Middle

Copper and Chitina River segments, which generally have low success and productivity, are fast-flowing, deep, and silt laden, which likely reduces the availability of salmon. The Lower Copper and Bremner River segments contain a considerable coastal influence, with an abundance of larger nest trees, and large quantities of salmon soon after they leave the ocean. However, nest success and productivity are generally lower than expected in this area.

Table 12. Results of bald eagle occupancy and productivity surveys, 2006-2009.

Year	Occupied Nests	Successful Nests	% Nest Succes s	No. of Young	Young/Occupied Nest	Young/Success Nest
2006[1]	101	29	30	39	0.41	1.35
2007[1]	110	40	39	54	0.52	1.35
2008[2]	99	42	48	65	0.74	1.56
2009[2]	134	56	51	79	0.72	1.41

[1] Occupancy was defined by the presence of an incubating bird or 2 adult birds at the nest.
[2] Occupied nests not found or checked during productivity surveys.

Table 13. Bald eagle percent occupied nest success/productivity (young per occupied nest) by river segment, WRST, 2006-2009.

Year	Upper Copper River	Middle Copper River	Chitina River	Bremner River	Upper Copper River
2006[1]	70 / 1.12	26 / 0.39	14 / 0.14	50 / 0.50	25 / 0.36
2007[1]	79 / 1.07	22 / 0.24	17 / 0.25	70 / 0.60	35 / 0.52
2008[2]	60 / 0.93	53 / 0.84	33 / 0.44	40 / 0.60	38 / 0.57
2009[2]	64 / 0.91	43 / 0.59	-	44 / 0.67	56 / 0.79

[1] Occupancy was defined by the presence of an incubating bird or 2 adult birds at the nest.
[2] Occupied nests not found or checked during productivity surveys.

Stressors

Specific stressors to bald eagle populations in WRST include development and timber harvest on private lands along rivers, lakes, and coastal areas; potential increases in commercial and recreational fishing on the Copper River and its tributaries; camping or other recreational or subsistence access/use activities (including use of OHVs, jet boats, and low flying aircraft) in sensitive breeding areas; potential highway construction on an old railway bed between Cordova and Chitina; and environmental contamination. The TransAlaska Pipeline and Richardson highway, transportation routes for petroleum products, cross three major tributaries of the Copper River. Should oil leaks occur at these sites, there is a potential for contamination of downstream areas and bioaccumulation of toxins in fish consumed by eagles.

The impact of human activities on bald eagles depends on the timing of disturbance in the breeding cycle, type of disturbance, proximity, intensity, degree of previous exposure, and environmental condition. Eagles are most sensitive to human disturbance during the courtship and nest building phase, which can lead to nest abandonment. Adults are less likely to abandon nests during incubation and hatching. However, flushed adults leave eggs and young unattended making eggs susceptible to thermal stress and predation while newly hatched young are vulnerable to predation and weather. Older nestlings may not receive adequate food or may prematurely leave the nest due to disruption if adults are excessively flushed from nests. The U.S. Fish and Wildlife Service recommend guidelines to minimize disturbance to bald eagles. During the breeding season, both non-motorized and motorized activities should occur at least 330 ft. from the nest while aircraft should not come within 1000 ft of the nest.

With current trends showing the lengthening of growing seasons and less severe winters, changes in the latitudinal or elevational ranges of insects can be expected (Schrader and Hennon 2005). Monitoring and control of invasive insects (e.g. spruce beetles, sawflies, spruce aphids, etc.), which can contribute to mortality of large expanses of forest, is vital for maintaining adequate bald eagle nesting habitat.

Data Needs

No quantitative data on food consumption by bald eagles in WRST exists. Anecdotal information on diet has been collected during visits to nest trees along the Copper River in 1987-1988, 1991, and 1993 (Kozie 1993). Prey remains included salmon, other avian species, and snowshoe hare and Dall‘s sheep lamb. Prey availability in early spring may be critical to nesting eagles since salmon are not available in the Copper River or its tributaries until about mid-June. Steidl et al (2000) suggests that most nest failures occur before hatching, making prey levels before and during incubation most critical. Hooligan (*Thaleichtys pacificus*) runs along the Copper River Delta may be very important in late winter and early spring to bald eagles breeding along the Copper River and other interior areas. Alternate prey sources, including snowshoe hare, migrating birds, and winter killed ungulates, are likely also critical in spring prior to ice out. Spring food sources should be identified, monitored, and protected. Contaminant levels in bald eagles and their primary prey species should also be monitored.

Bald eagle nest occupancy, success, and productivity in WRST coastal habitats need further documentation. Very low nest success and productivity documented in 1992-1995 was of concern because productivity in coastal areas is typically much higher. Evidence suggests that coastal bald eagles are consuming Kittlitz‘s murrelets in the Icy Bay region. Research will begin in 2010 to quantify predation by bald eagles and peregrine falcons on the local population of Kittlitz‘s murrelets in Icy Bay (NPS, Judy Putera WRST Wildlife Biologist, pers. comm.).

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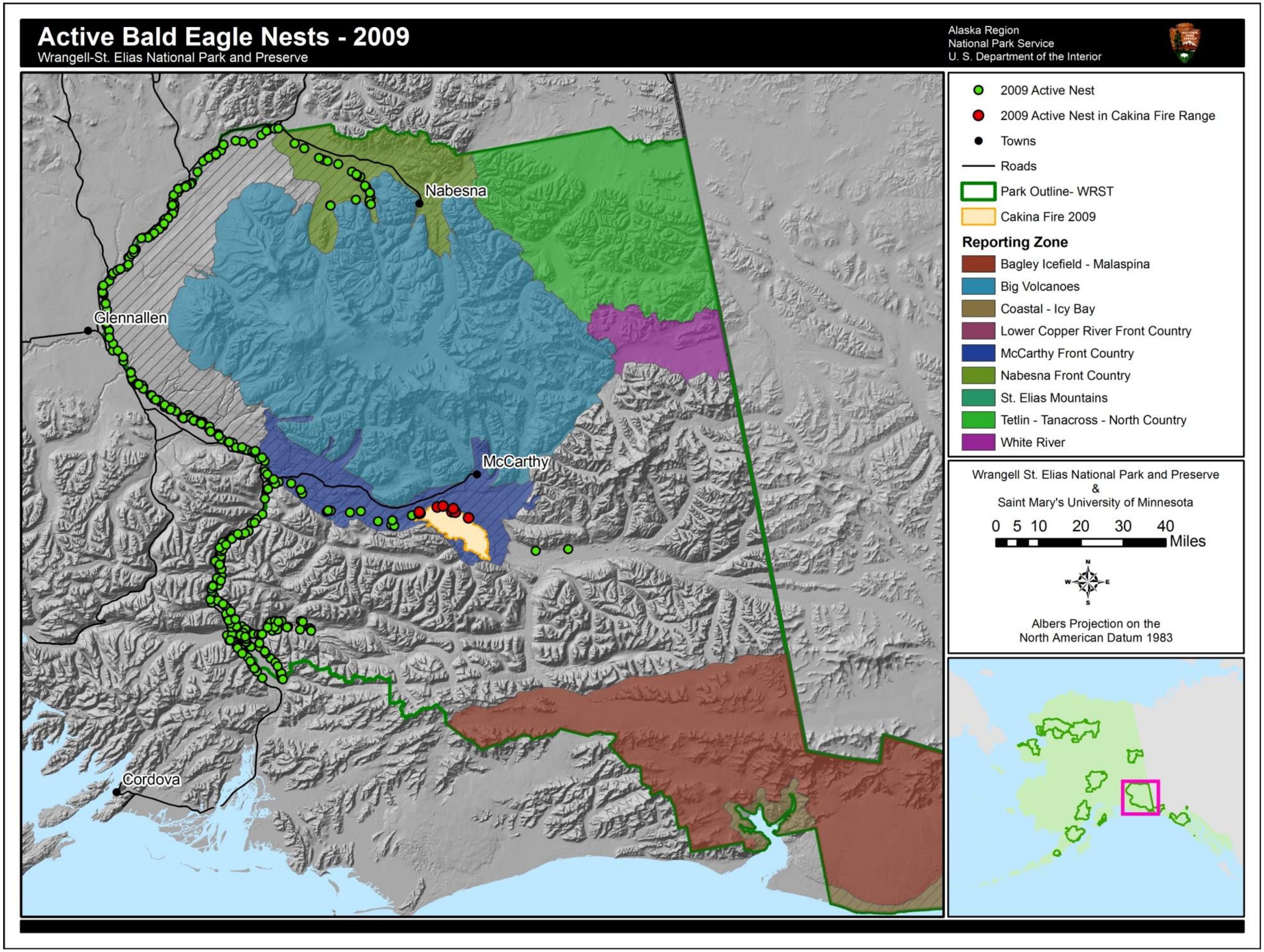
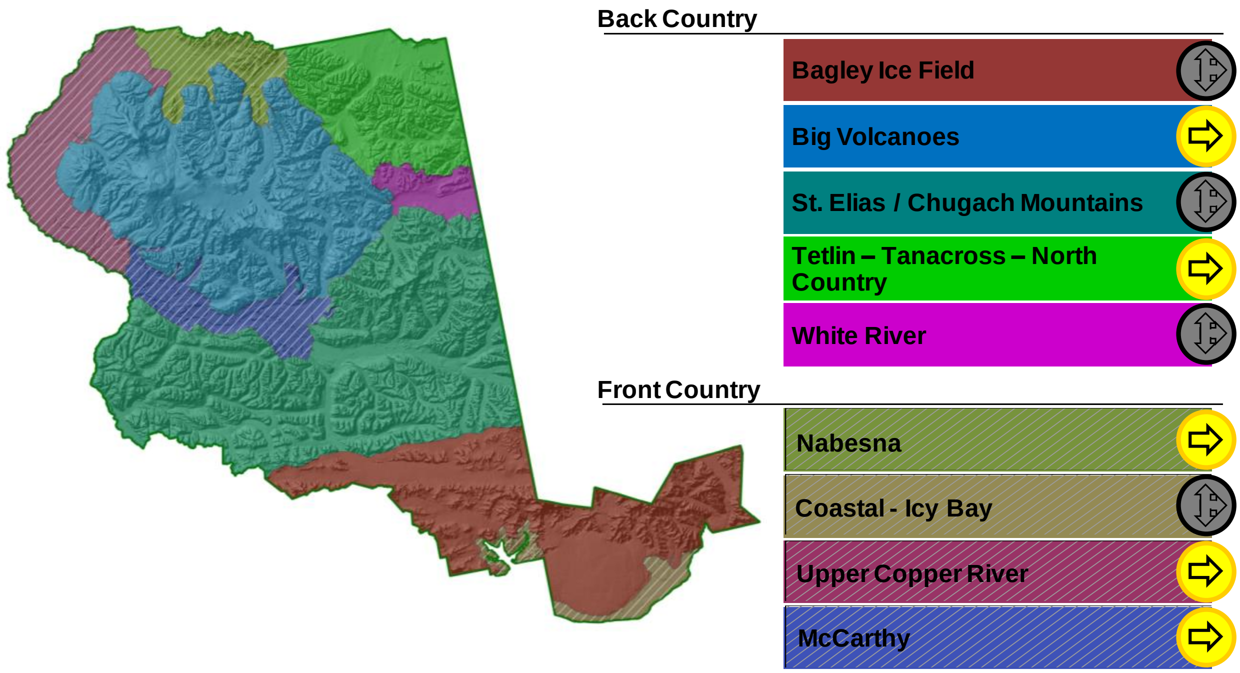


Plate 7. Active bald eagle nest sites in WRST, 2009. (NPS PDS 2009a, b)

4.6 Moose

Indicators and Measures
Population Size and Distribution, Age and Sex Composition



Condition
Moose (*Alces alces*) densities in WRST are typical of many of the low-density populations across Alaska. During the 1990s, four moose population surveys were conducted in different areas of WRST. Results revealed that moose densities ranged from 0.23-0.54 moose/km^2 (0.6-1.38 moose/mi^2). In 2007, an 8,210 km^2 (3,170 mi^2) area was identified for long-term monitoring of the harvested moose population. This area included large portions of the Big Volcanoes, Nabesna, Upper Copper River, and McCarthy RZs. Results from this effort indicate an overall moose density of 0.19 moose/km^2 (0.5 moose/mi^2) in those areas (Reid 2008). Tetlin National Wildlife Refuge, adjacent to the northeast boundary, reported similar densities, from 0.11-0.24 moose/km^2 (0.28-0.62 moose/mi^2) based on surveys conducted between 1990 and 2008 (Keller et al. 2009).

The ratio of bulls to cows varies widely depending on year-to-year harvest pressure. The ratio of bulls to cows to calves from the 2007 survey was 52:100:19. The 2007 Mt. Drum analysis/trend count area, which receives little harvest pressure, showed higher ratios (118 bulls:100 cows) than other areas, consistent with ADF&G historical trend counts where bull to cow ratios around parity (mean 99.8:100, 1980-2006) were commonly observed. In contrast, the Upper Copper River analysis/trend count area shows consistently lower bull to cow ratios, constant with trend count surveys (mean 44.5:100, 1991-2007), and is reflective of higher hunting pressure due to road and off road vehicle access. Calf to cow ratios are of concern in WRST, particularly in the Upper Copper River and Mt. Drum/Mt. Sanford trend count areas. The 2007 GeoSpatial Population Estimator (GSPE) survey identified calf to cow ratios below 20:100 in these areas, a value that represents the threshold of concern for moose populations in WRST.

Background and Distribution

Moose are herbivorous, consuming a vast assortment of plants. During fall and winter, moose primarily feed on willow, birch, and aspen; this often results in browse lines 6 to 8 feet above the ground. During the spring, moose will graze on a variety of plant species, including sedges, horsetail, various pond weeds, and grasses. During the summer, moose feed on aquatic vegetation and birches, willows and aspens (Rausch et al. 2008).

Cows typically begin breeding at 28 months, with peak rutting behavior exhibited by bulls in late September and early October. Bulls will exhibit aggressive behavior in order to secure mates. Jousting between males is common but serious injuries are a rare occurrence. Calves are born between mid May and early June and stay with their mother until just before the birth of subsequent calves (Rausch et al. 2008).

Moose are present in all RZs within WRST (Putera pers. comm.), and point locations of documented moose from surveys are available for the following RZs: Upper Copper River, Nabesna, McCarthy, Tetlin - Tanacross - North Country, White River, and Big Volcanoes (Plate 8).

Reference Condition

Parameters defining the reference condition, natural and healthy, are unknown for moose in WRST. The earliest modern survey data available estimated the density of moose in the northwestern Wrangell Mountains as 0.23 moose/km^2 (0.60 moose/mi^2) in 1993 (Route and Dale 1994). One historical account, in 1919, estimated the moose population in the Ladue Creek/White River area as 20,000 to 50,000 animals (Simeone 2006). Oral tradition also suggests that moose were scarce in the Copper River Basin, compared to today (Simeone 2006). One account stated that, before 1950, moose were so rare that ―if you saw tracks, you were obliged to run the animal down and harvest it" (Simeone 2006). Today, moose are considered the most important mammal in the Copper River Basin because, for subsistence hunters, one moose provides much more meat than is provided by other game species (Simeone 2006).

Management

ADF&G and NPS cooperatively monitor moose in WRST. ADF&G moose population goals vary across the park depending on the game management unit (GMU). ADF&G expresses moose management objectives in terms of the fall (post-harvest) ratio of bulls per 100 cows. The ADF&G target bull to cow ratios for the two GMUs (11 and 12), which comprise most of the park, are 30:100, and 20-40:100, respectively. NPS considers fall calf to cow ratios of 35:100 as adequate to maintain stable moose populations, while a ratio less than 20:100 cows indicates concern (Putera pers. comm.).

Park Habitat Use

GPS points acquired during surveys spanning 1997 to 2007 were used in habitat analyses for this project. Surveys are performed in early winter, after snow is present, to maximize visibility of moose. Because of survey timing, these data are only applicable to the survey season, late November to early December. Vegetation class at moose location sites was determined by comparing location points with detailed landcover raster data (NPS PDS 2009a, b, c). Moose were most often associated with the open lowland or mixed shrub vegetation class (36.73%). The second and third most frequently associated vegetation classes included woodland conifers (13.99%) and closed tall shrubs (12.44%) (**Figure 20**).

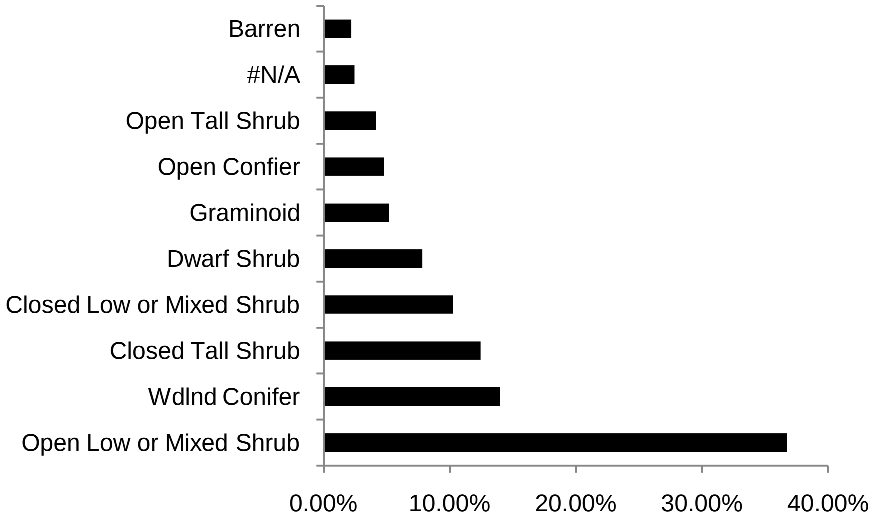
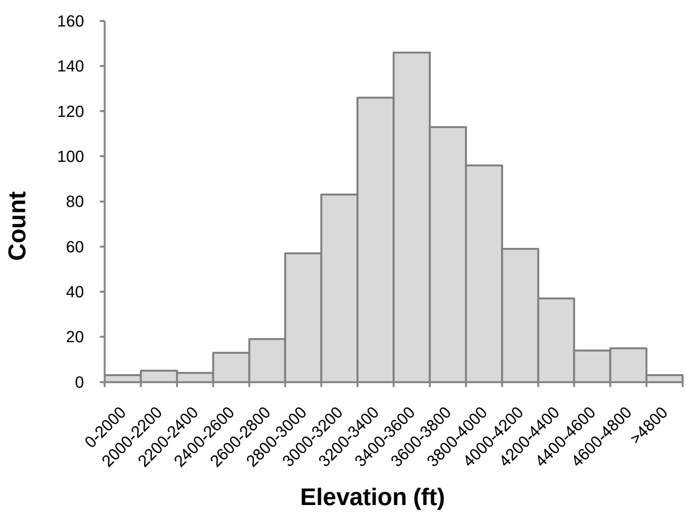


Figure 20. Moose habitat associations, 1997-2007, No Data was defined as #N/A in dataset. (NPS PDS 2009a, b, c)

Figure 21 shows the distribution of moose elevations from surveys spanning 1997 to 2007. Documented locations of moose at different elevations, developed by extracting elevations from a 30m digital elevation model, follow a relatively normal distribution ($\bar{x} = 3535$ ft, $\sigma = 492.4$ ft). Plate 9 shows the locations of surveyed moose along with a green zone representing the mean elevation ± one standard deviation for the entire park.



$\bar{x}$	3535.073
σ	492.4356
Median	3509
Mode	3300
Min.	1448
Max.	4867

Figure 21. Elevations at documented moose locations from WRST fall moose surveys spanning 1997-2007. (NPS PDS 2009 a, b, d)

Demographics

In 2005, CAKN Inventory and Monitoring developed moose monitoring objectives for WRST, DENA, and YUCH. The objectives are to determine changes in abundance, distribution, and composition of moose in each CAKN unit every three years, as well as to annually estimate calf survival, recruitment success, and human harvest (MacCluskie and Oakley 2005).

Moose population surveys in WRST, conducted periodically for the last 30 years, utilized many different survey methods. Those methods include the Gasaway method, the No-Strat Gasaway Method, and the Geospatial Population Estimator Method (GSPE) (Table 14). A reference list of moose surveys in WRST and methodologies used is highlighted in Table 14.

Table 14. Summary of moose surveys in WRST, 1993-2007.

Survey Year	Date	Survey Method	Moose / km^2	Bull:Cow:Calf Ratio	Survey Area	Reference
1993	Nov. 17-21	Stratified Gasaway	0.23	36.2:100: 20.6	3589 km^2 area in the northwestern portion of WRST	Route and Dale 1994
1994	Nov. 25, 27,28	No-Strat Gasaway	0.25	59.5:100:28.9	1025 km^2 area north of the Chitina River	Route 1994
1997	Nov. 5,6, 8	No-Strat Gasaway	0.53	75.6:100:21	334 km^2 around the Crystalline Hills	Mitchell 1997
1998	Oct. 29-31	No-Strat Gasaway	0.32	65:100:34.3	912 km^2 near Chisana	Mitchell 1998
2007	Nov. 12-26	Geospatial Population Estimator	0.19	52:100:19	8210 km^2 area in the northwestern portion of WRST	Reid 2008

The most recent survey conducted in WRST, in 2007, utilized the GSPE method (Kellie and DeLong 2006, DeLong 2006). This survey calculated a study-site population estimate of 1,576$\pm$244 moose across 8210 km^2 (3170 $mi^{2)}$ in northwest portion of WRST (90% C.I.), resulting in a density of 0.19 moose/km^2 (0.5 moose/mi^2). The estimated bull to cow to calf ratio was 52:100:19 (Reid 2008). The density value and bull to calf to cow ratio from the 2007 survey is comparable with previous surveys completed in the park (Reid 2008). Additionally, Reid (2007) examined population parameters in four analysis areas within the 2007 survey area that correspond to previous ADF&G trend count areas.

WRST moose trend counts began in 1955. Plate 10 displays three of the moose trend count areas in WRST: Nabesna/Chisana, Mt. Sanford/Mt. Drum, and Upper Copper River. Table 15 summarizes the data from all trend counts performed in WRST to date, by trend count area. Reid (2008) compared two of the trend count areas in the park, Mt. Drum and Upper Copper River, to the 2007 GSPE survey results. The Nabesna/Chisana trend count area was not included in the 2007 GSPE survey and the Crystalline Hills area has only one trend count on record, which made comparative analysis of these areas invalid (Reid 2008).

The 2007 GSPE survey resulted in fewer bulls and more calves than the long-term average for the Upper Copper River area. The calculated bull to cow to calf ratio for the Upper Copper River area in 2007 was 38:100:16 (Reid 2008). In 2007, the calf to cow ratio in the Mt. Drum area was roughly half of the long-term average at 11:100. The bull to cow ratio for the same area was slightly higher than the long-term average at 118:100. (Reid 2008). Reid (2008) attributes the high bull to cow ratio in the Mt. Drum area to lower hunting pressure.

Table 15. Summary of moose trend counts by analysis area in WRST, 1955-2008. (NPS 2010)

	Mt. Drum		**Upper Copper River**		**Nabesna/Chisana**		**Crystalline Hills**	
	Bulls/ 100 Cow	Calves/ 100 Cow	Bulls/ 100 Cow	Calves/ 100 Cow	Bulls/ 100 Cow	Calves/ 100 Cow	Bulls/ 100 Cow	Calves/ 100 Cow
Mean	88.5	21.9	47.5	13.5	78.9	32.3	56.4	23.7
Min	45.5	4.0	36.8	6.0	10.8	11.0	56.4	23.7
Max	156.8	55.0	68.3	19.7	142.0	69.0	56.4	23.7
Dates	1955-2003		1991-2008		1965-1997		1991	
# of Surveys	34		8		24		1	

Harvest Information

Moose harvest data came from three primary sources: the ADF&G harvest database, the Federal subsistence permit harvest database, and the community harvest survey (CHS) database. The CHS database was developed through comparative analysis of harvest and sealing records (ADF&G and NPS) and a community harvest survey from 1987 (Moderow 2006). Using the ratios of harvest records to community survey records, Moderow (2006) developed coefficients that, when applied to reported harvest records, provide an estimate of actual harvest. In the case of moose, it is estimated that 1.47 moose are harvested per record in the ADF&G harvest database (Moderow 2006). Sources of potential error in Moderow‘s coefficients include false reporting and confusion of community definition by individuals surveyed (Moderow 2006).

From 1983 to 2007, estimated yearly harvest has remained stable (Figure 22). The average harvest over this time span was 104.3 moose per year. The largest estimated harvest was 129.5 moose in 1985 and the lowest estimated harvest was 78.39 in 1992. Over the same time interval the number of hunters per year ($\bar{x}$ = 614.9, σ = 103.1) and their success rates ($\bar{x}$ = 0.173, σ = 0.029) were relatively constant (Figure 23). No literature exists that explains whether moose mortality from human take in WRST is additive or compensatory.

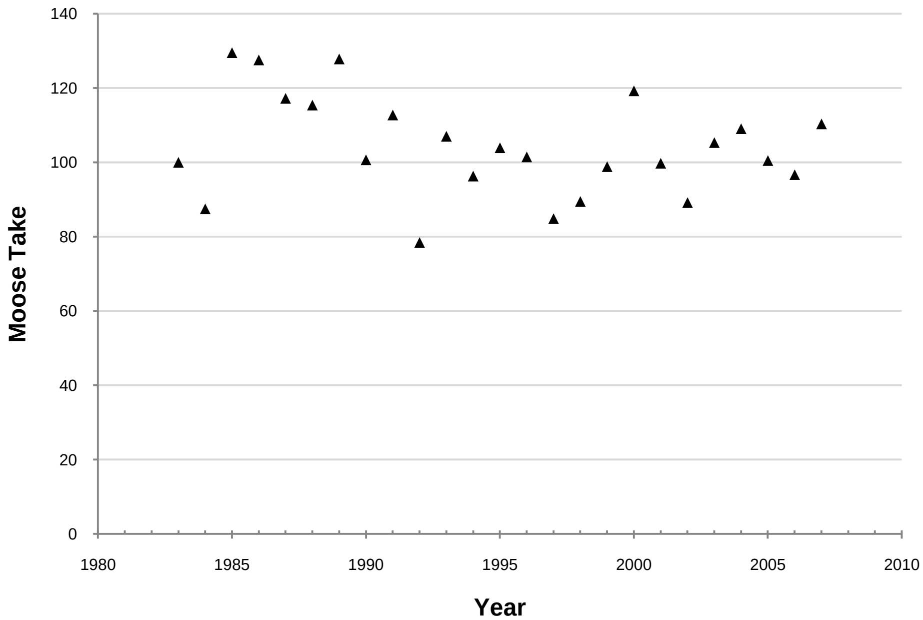


Figure 22. Moose take vs. year, WRST, 1983-2005. Data were collected from ADF&G harvest database and adjusted using Estimated Take coefficients. (Moderow 2006)

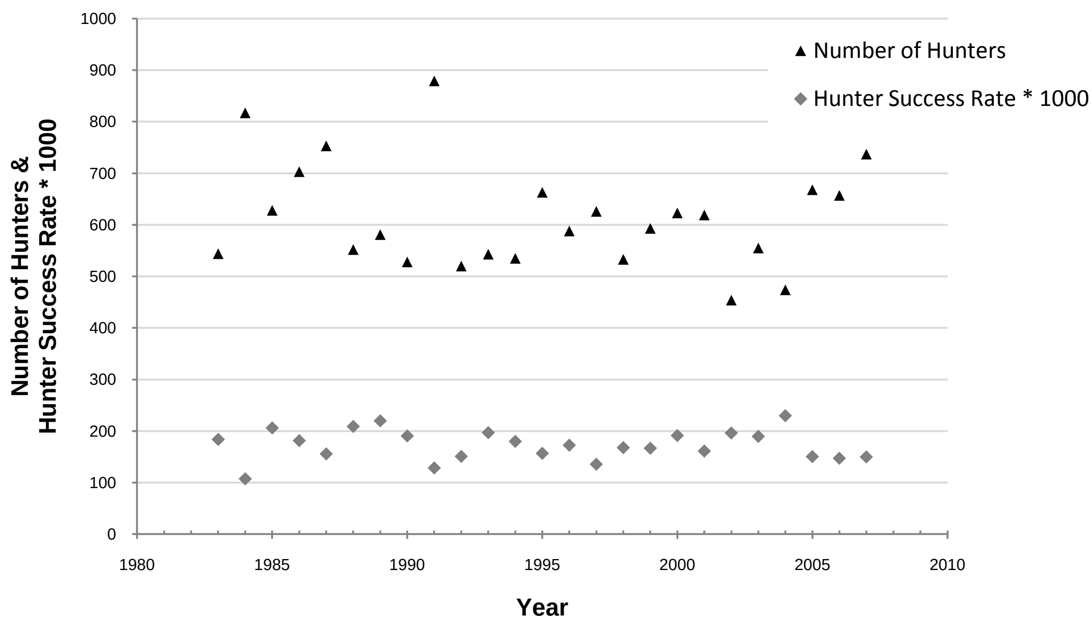


Figure 23. Number of hunters and hunter success rate * 1000 vs. Year, WRST, 1983-2007. (Moderow 2006)

Stressors

Stressors identified by NPS staff included climate change, landcover composition change, disease, hunting pressure, habitat fragmentation, bison, and increased road and trail development. In addition to these stressors, Gasaway et al. (1991) explained five factors that could limit the size of an Alaskan moose population: nutrition, snow, harvest, disease, and predation.

There is little existing data regarding the effects that these stressors have on moose populations in WRST. Harvest pressure is the only stressor that has been well documented in the park. Harvest levels have decreased in recent years, as the number of hunters in the area seeking out moose has decreased (Moderow 2006). Thus, the effects of hunter pressure as a stressor on moose populations should be alleviated to a degree.

Many studies have documented the effects of malnutrition on moose populations. Poor nutrition results in low reproductive rates, reduced recruitment, and retarded body growth (Gasaway et al. 1991, Lohuis 2008). Malnutrition also makes moose more vulnerable to predation, harsh weather, and disease (Gasaway et al. 1991). Periodic forest fires, prescribed or wild, prove beneficial to reestablishing primary food sources for moose in Alaska (Boertje et al. 2007).

To date, predation on moose in WRST is unquantified. ADF&G states that wolves and brown bears are abundant in GMU 11, but accurate population estimates do not exist (Tobey 2008). Wolves (*Canis lupus*) and Brown bears (*Ursus arctos*) are the primary predators of moose in Alaska, with brown bears killing a high percentage of neo-natal calves and wolves being responsible for the majority of other kills (Gasaway et al. 1991).

Early studies of moose health in Alaska have shown that they are relatively free of infectious diseases and parasites (Kocan et al. 1986, Lankester 1987, Zarnke 1988). There is no literature on the status of disease in moose found within WRST.

Data Needs
Disparity between survey methodologies makes survey comparisons difficult, but current inventory and monitoring efforts will alleviate comparison difficulty. The 2007 survey, which utilized the GSPE method, will act as baseline data for future comparison of population density and age and sex composition. This area will be surveyed every 3 years with the next survey scheduled for November/December 2010. In addition, basic research to understand movements, reproduction, survival, predation rates, and habitat quality would be beneficial (Putera pers. comm.).

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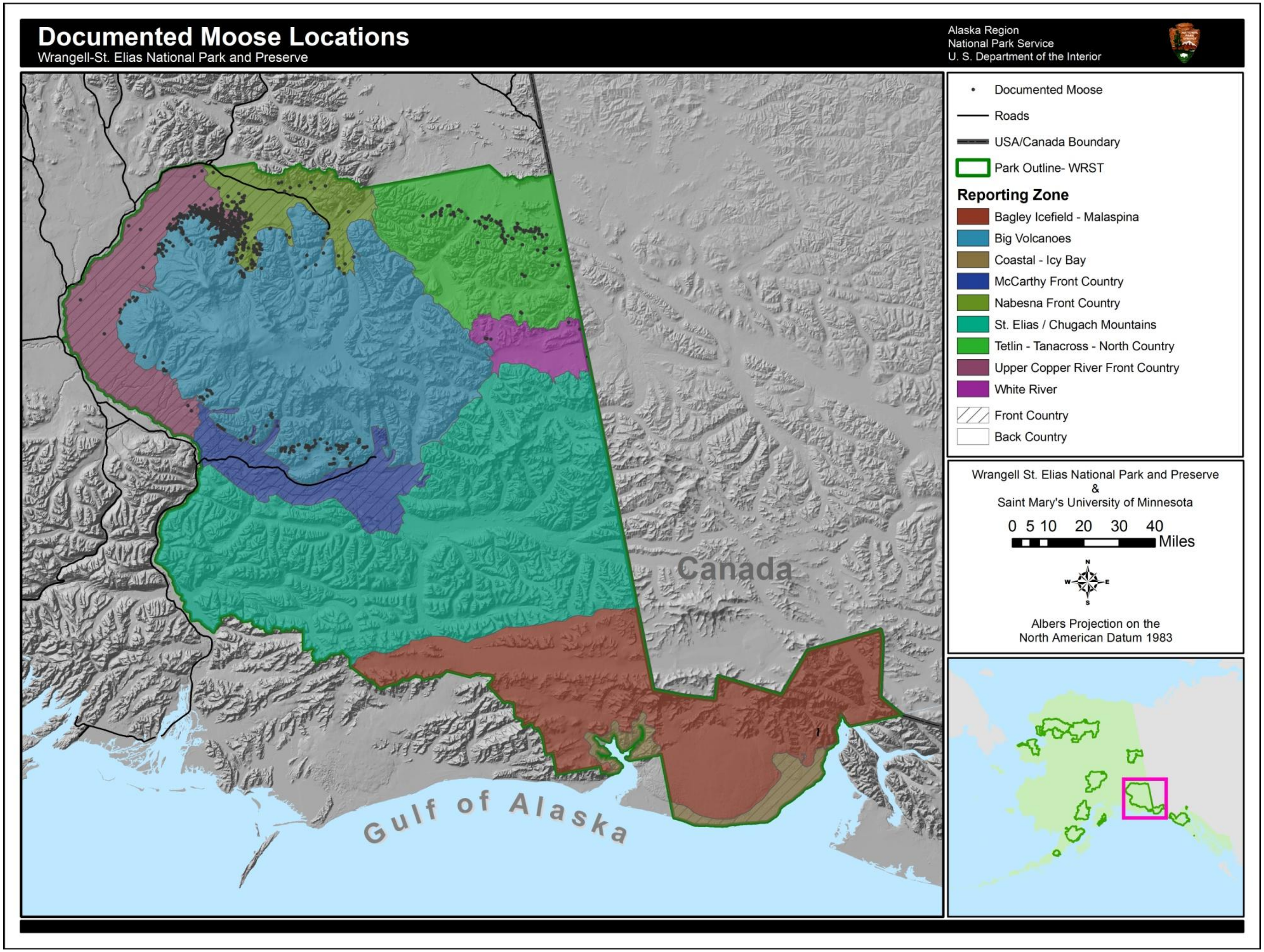


Plate 8. Documented moose locations, from surveys spanning 1997-2007. (NPS PDS 2009a, b)

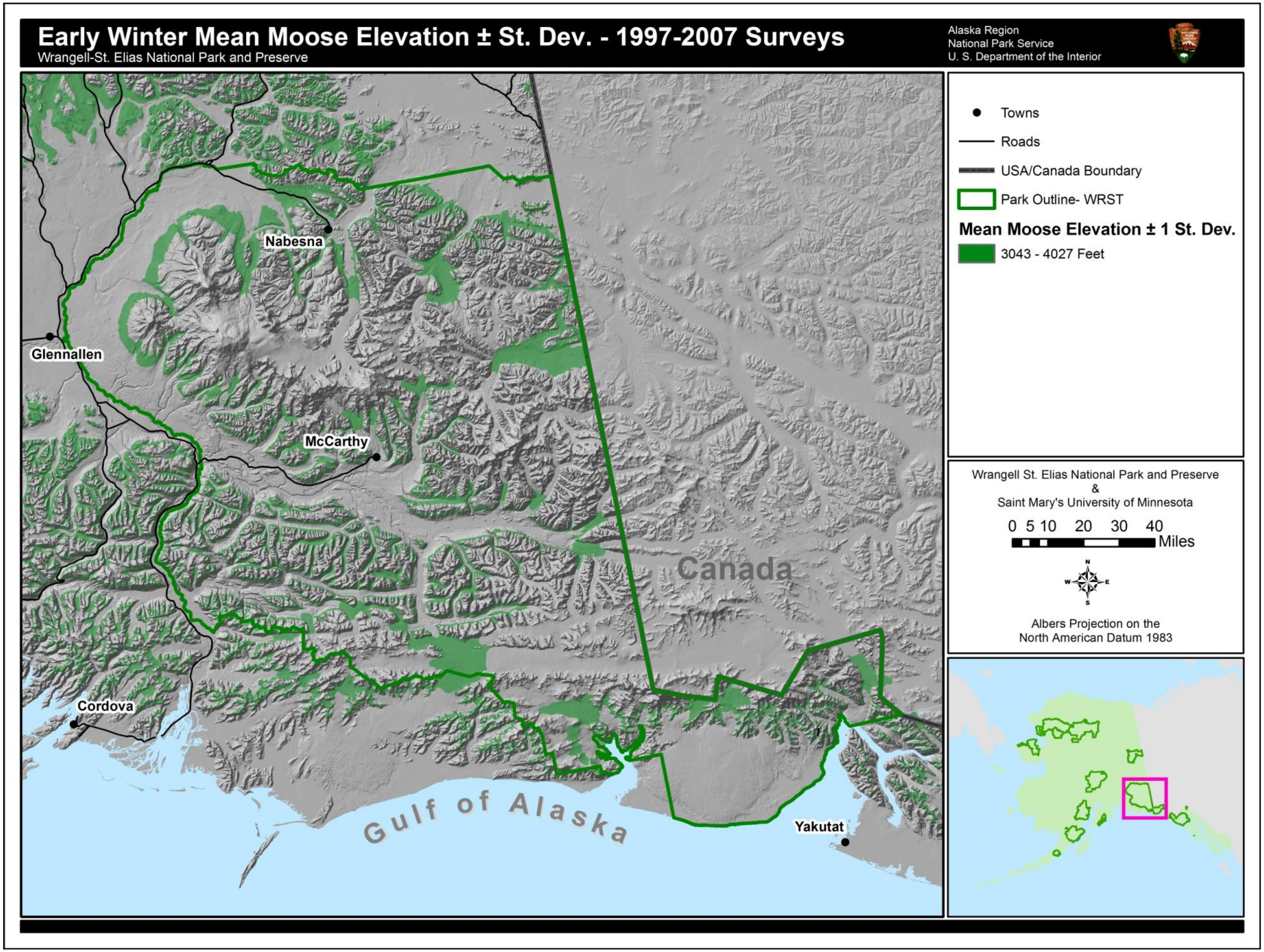


Plate 9. Early winter mean moose elevation, from surveys spanning 1997-2007. (NPS PDS 2009c, d)

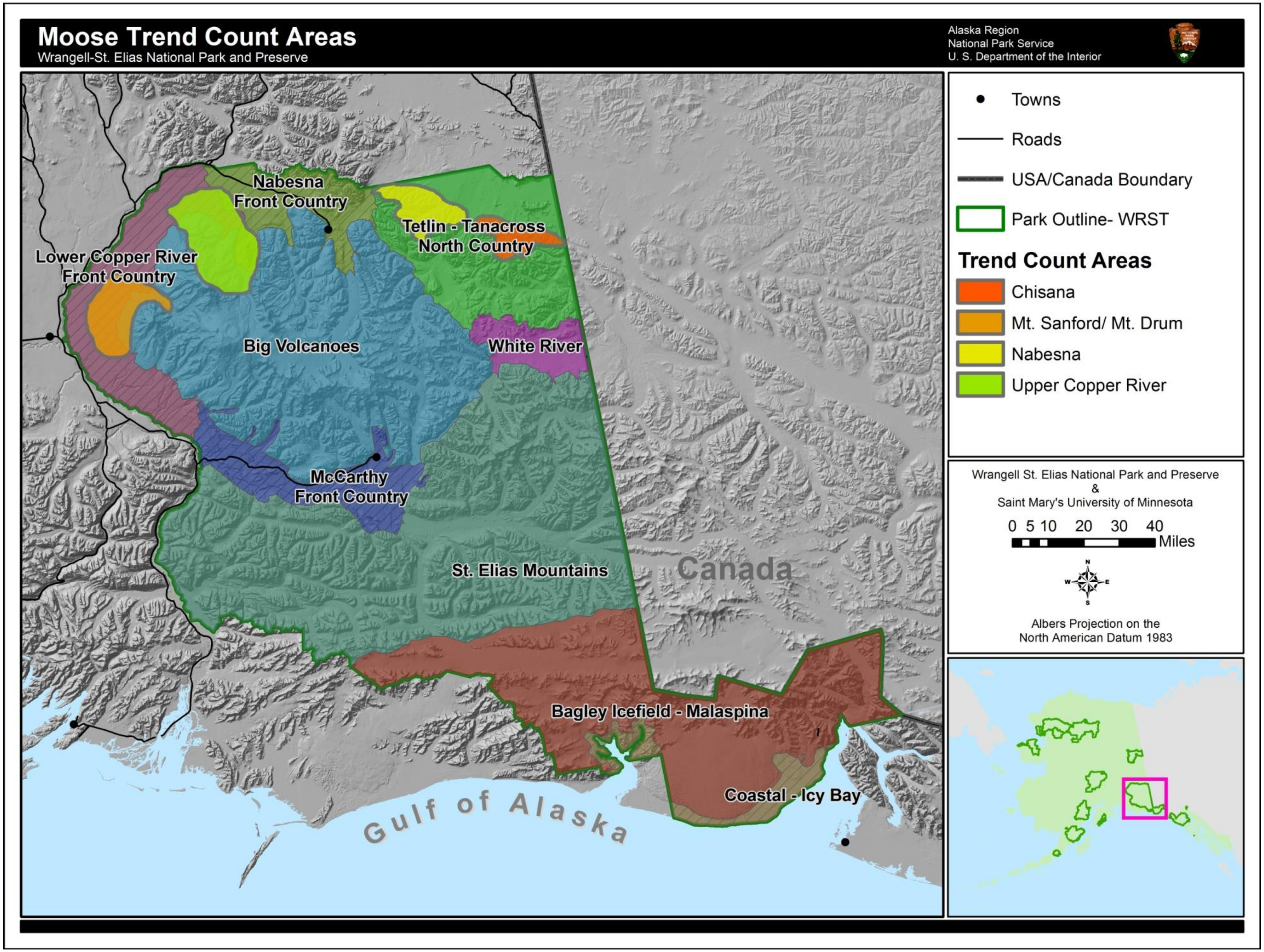
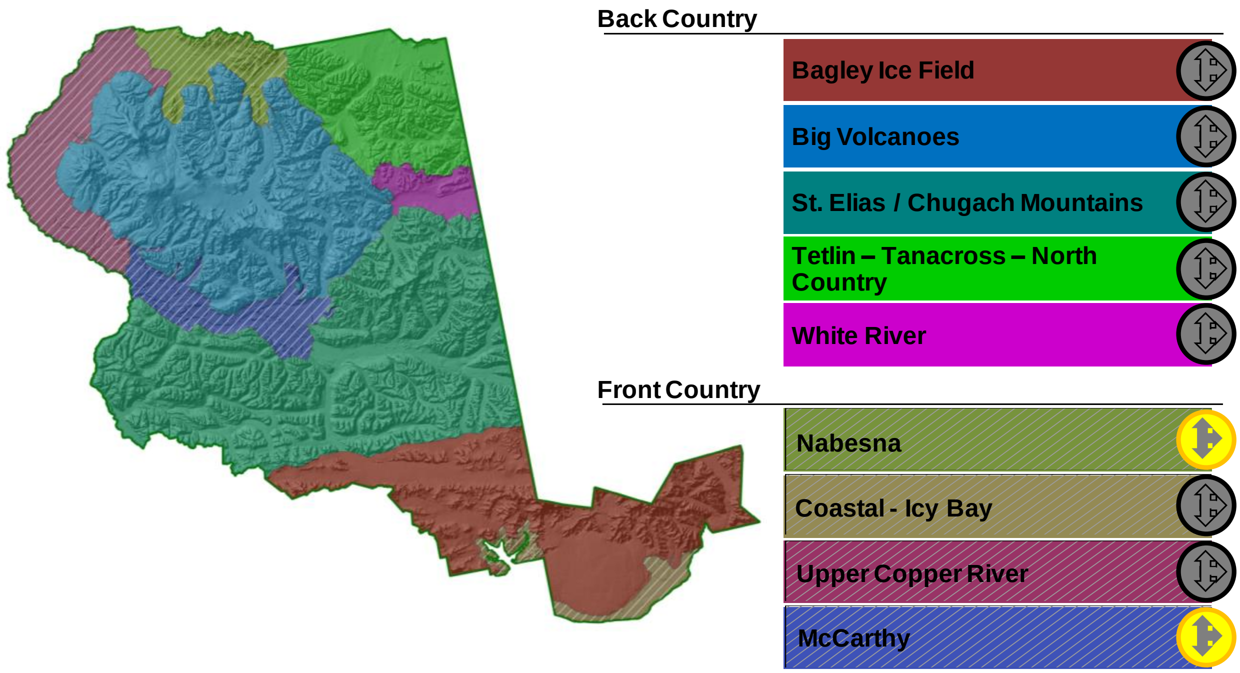


Plate 10. Moose Trend Count Areas, WRST. (NPS PDS 2009e)

4.7 Brown Bear

Indicators and Measures

Population Size and Distribution, Age and Sex Distribution



Condition

The condition of brown bear in WRST is unknown. The absence of reference condition and sound population data make it difficult to assess condition for this species. Harvest data for the park suggest that bear populations are stable, but this is not sufficient to assess condition. Brown bear populations in areas unpopulated by humans within the park are most likely stable, but without accurate population data this is not certain. Brown bear populations in the areas that are populated by humans, specifically the Nabesna and McCarthy areas, are more susceptible to defense of life and property (DLP) kills and more knowledge of human-bear interactions in the park would be helpful to management. Evidence from Wilder (2003) and NPS (2009b) suggest that the condition of brown bear populations in the McCarthy and Nabesna RZs is of moderate concern, even though little is known about the population size and distribution of bears in those areas. The condition and trend of brown bear populations in the other RZs is unknown.

Distribution and Background

Currently, no population or distribution surveys are completed or available for WRST. ADF&G states; ―Frequent sightings by ADF&G staff and the public suggest a relatively abundant and well-distributed population of brown bears in (Game Management) Unit 11" (ADF&G 2007). In addition, brown bears are acknowledged as present in all other Game Management Units (GMU) within WRST (12Z, 05B, 06A, 13C), with harvest numbers reaffirming these claims (ADF&G 2007). GMU 11Z, which encompasses 60% of WRST, also has many recorded human-bear interactions, of which most occurred in the McCarthy Front Country RZ (RZ) (Plate 11).

Reference Condition

Reference condition for brown bear in WRST is unknown. No historical population data are available for this species. Interviews with area natives suggest that current aboriginal harvest of brown bear is less than historical values; however, this is not due to a decrease in population size, but rather a shift in desirable game species (Thornton 1992).

Demographics

Brown bear population surveys have not been conducted in WRST.

Harvest Information

ADF&G harvest data, described at the GMU level in the 2006 ADF&G brown bear management report, are the best source of brown bear harvest information for WRST. Only three of the five GMUs that comprise WRST were used in this analysis, GMU 11Z, GMU 12Z and GMU 05, which represent 60%, 23.8% and 12.8% of the park‘s area, respectively. GMU 13C was excluded because it covers less than 1% of WRST. GMU 06A, which makes up 3.2% of the park, was excluded because it encompasses the Bagley Ice Field, which is difficult to access and is sub-optimal brown bear habitat.

Combined average annual sport harvest in GMUs 5, 11, and 12 is 63.6 brown bears per year (Table 16). Of these GMUs, 97.2% of GMU 11Z, 48.9% of unit 12Z, and 38.1% of GMU 05 are located within WRST. Assuming that brown bear harvest for these GMUs in WRST is proportional to the area of these units in the park, an average of 35.5 brown bears are harvested for sport in WRST each year. However, the proportional harvest value is likely high, as much of GMU 05 in WRST is inaccessible, with only limited logging roads, a few airstrips, and virtually no accommodations for hunters (ADF&G 2007).

Subsistence hunting makes up a small percentage of brown bear harvest in WRST. Eight brown bears have been harvested under Federal subsistence rules from 2003-2008 (NPS 2009a).

Non-hunting kills are also an important aspect of brown bear take in WRST. This includes research mortalities, defense of life and property (DLP) kills, illegal kills, and human-caused accidental mortality. There is concern that many non-hunting kills go unreported in Alaska, resulting in a percentage of take not accounted for in currently reported numbers (Wilder 2003).

Table 16. ADF&G recorded Brown bear harvest for GMUs 11, 5, 12.

Year	Male	Female	Unknown	Total
GMU 11				
2001-2002	5	4	0	9
2002-2003	7	4	0	11
2003-2004	11	4	0	15
2004-2005	14	19	0	24
2005-2006	11	6	0	17
GMU5				
1996	23	14	1	38
1997	18	9	0	27
1998	28	7	0	35
1999	23	8	0	31
2000	25	8	0	33
2001	18	12	1	31
2002	15	6	0	21
2003	28	3	0	31
2004	24	9	0	33
2005	25	8	0	33
GMU 12				
1991-1992	7	5	0	12
1992-1993	15	9	0	24
1993-1994	11	7	0	18
1994-1995	7	7	0	14
1995-1996	6	3	0	9
1996-1997	12	9	0	21
1997-1998	10	1	0	11
1998-1999	8	8	0	16
1999-2000	8	9	0	17
2000-2001	21	12	0	33
2001-2002	8	7	0	15
2002-2003	5	7	0	12
2003-2004	5	3	0	8
2004-2005	14	10	0	24
2005-2006	11	11	0	22

From 2001 through 2006, only two non-hunting kills were reported to ADF&G in GMU 11Z (ADF&G 2007). Between 1996 and 2005, ADF&G received reports of 35 non-hunting kills in GMU 05. Twelve non-hunting kills in GMU 12Z were reported to ADF&G from 1991 to 2006 (ADF&G 2007).

A study of the Kennicott Valley, located in the McCarthy Front Country RZ, noted 157 human-bear interactions during the summers of 2000 and 2001 (Wilder 2003). The same study reported at least seven bears (black and brown) killed in the McCarthy area in 1999, at least 5 brown bears in 2000, and at least 1 brown bear in 2001. Wilder also suggested that the actual number of unreported bear kills in the Kennicott Valley could be twice as many as observed over the duration of the study, resulting in a brown bear population sink in the McCarthy area. A population sink is a part of a larger metapopulation that requires immigration to maintain population size due to a death rate that exceeds the birth rate.

Bears in populated park areas, both black and brown, are subjected to more stress than populations in more remote areas (Putera pers. comm.). Bears in populated park areas are more likely to encounter and utilize human food sources from both park residents and visitors, typically because of improperly sealed food and garbage. In some cases, bear exposure to human food sources can ultimately result in the need to euthanize bears to avoid any risk to humans (Putera pers. comm.).

To gain a better understanding of problem bears and DLP take in Alaska's National Parks, NPS developed the Bear/Human Information Management System (BHIMS) (NPS 2009b). BHIMS was intended to be a continuously updated database of reported human-bear interactions that could assist park management staffs in Alaska bear management. The BHIMS database structure was updated in 2009 and redistributed to Alaska parks for data entry. WRST originally entered 67 bear incidents recorded from 1967 to 2003 as part of a pilot project for the database (NPS 2009b). Of the 67 records in the BHIMS database, 47 occurred in the McCarthy RZ, nine in the Big Volcanoes RZ, seven in the St. Elias/ Chugach Mountains RZ, and four in the Nabesna RZ (**Plate 12**). WRST is currently in the process of entering all bear-human encounters and incidents into the BHIMS database.

Stressors

NPS identified a number of stressor to the brown bear population in WRST, including interactions/conflicts with humans, hunting pressure, habitat fragmentation, increased human access to bear fishing and habitat areas, climate change, and subsistence harvest. No information is available for WRST regarding the effects of habitat fragmentation, climate change, and increased human access on brown bears. Human and bear conflicts undoubtedly affect brown bear mortality. As indicated by Wilder (2003), many unreported bear deaths are unaccounted for in bear management decisions. In addition, it is likely that hunting affects bear populations in WRST, the extent of which is unclear. Subsistence harvest levels for brown bears in southeast Alaska are lower than historical values, confirmed by the small numbers of Federal subsistence take that are reported (NPS 2009a). In addition, many historical subsistence users have shifted harvest emphasis to other species (Thorton 1992).

Data Needs

The primary data needs for brown bear include an accurate estimate of population and precise distribution information, predation rates on ungulates, and distribution of bear-human interactions. A comprehensive bear survey has not been performed in WRST, limiting managers' ability to make informed bear management decisions. Documentation of hunter and sport harvest in WRST seems complete, but other forms of harvest are not as clearly documented. Wilder (2003) suggests that actual non-hunting bear kills could be twice the reported total, providing justification for further investigations in WRST.

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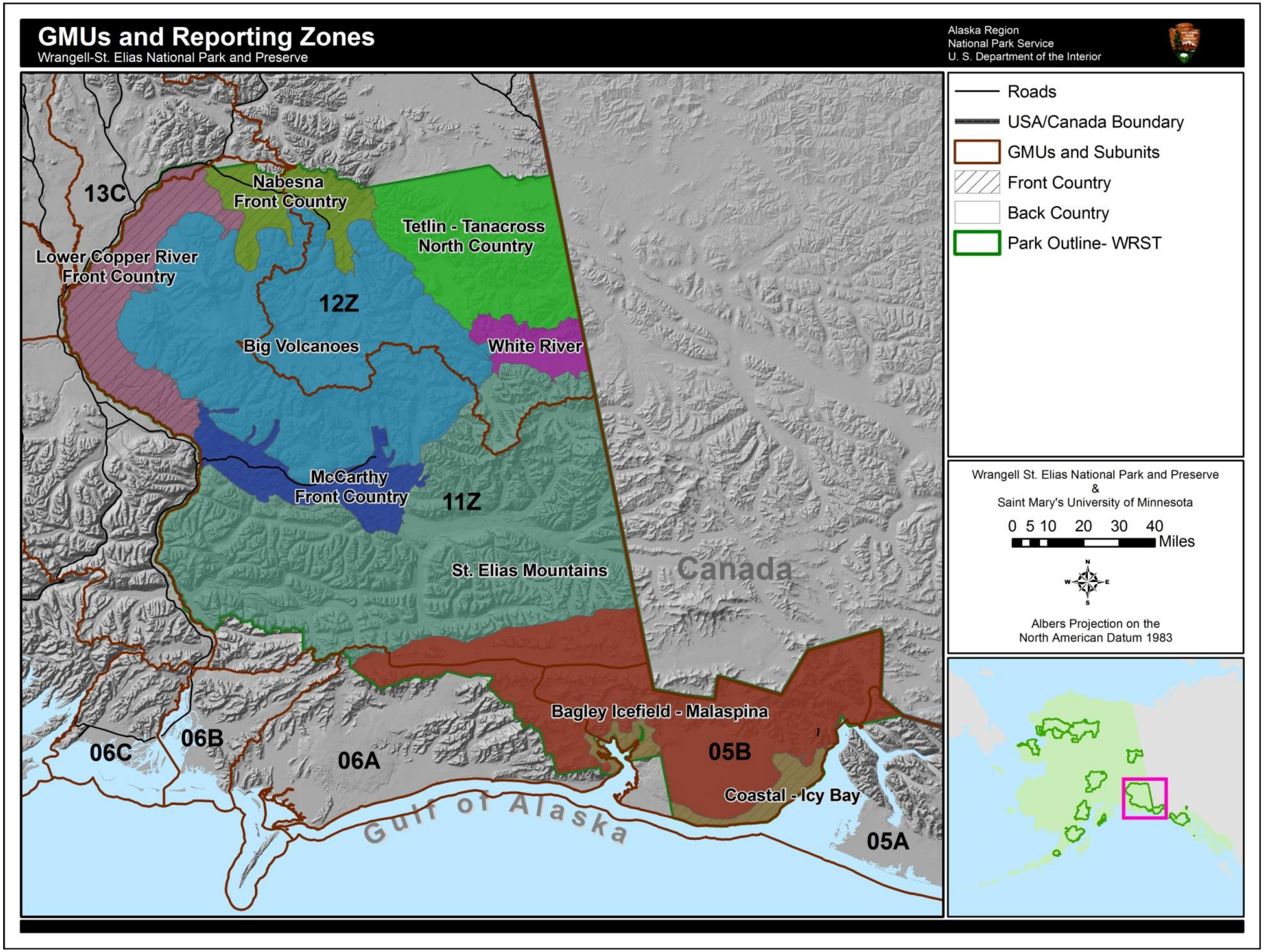


Plate 11. ADF&G Game Management Units (GMUs) and WRST NRCA Reporting Zones. (NPS PDS, 2009a)

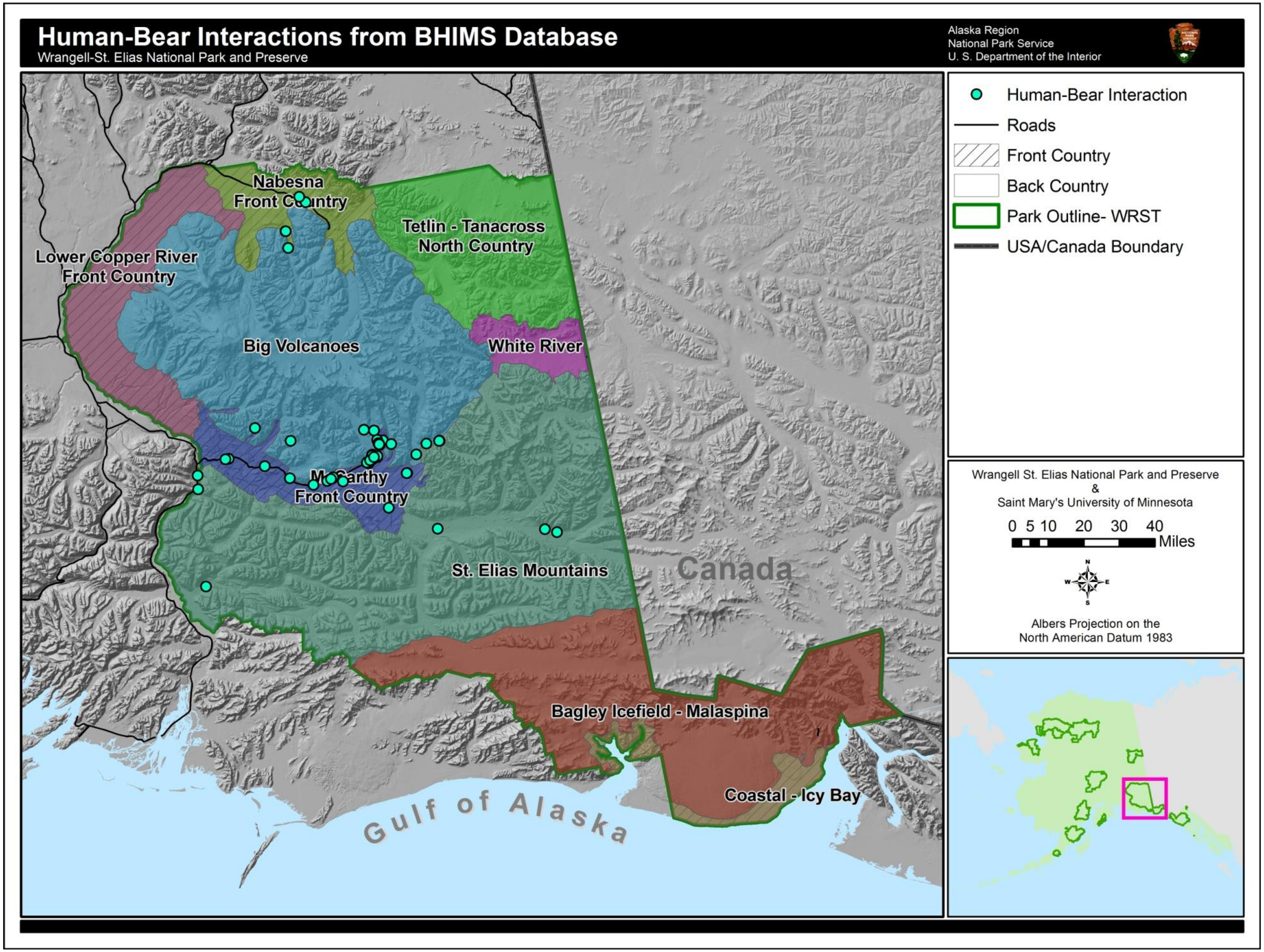
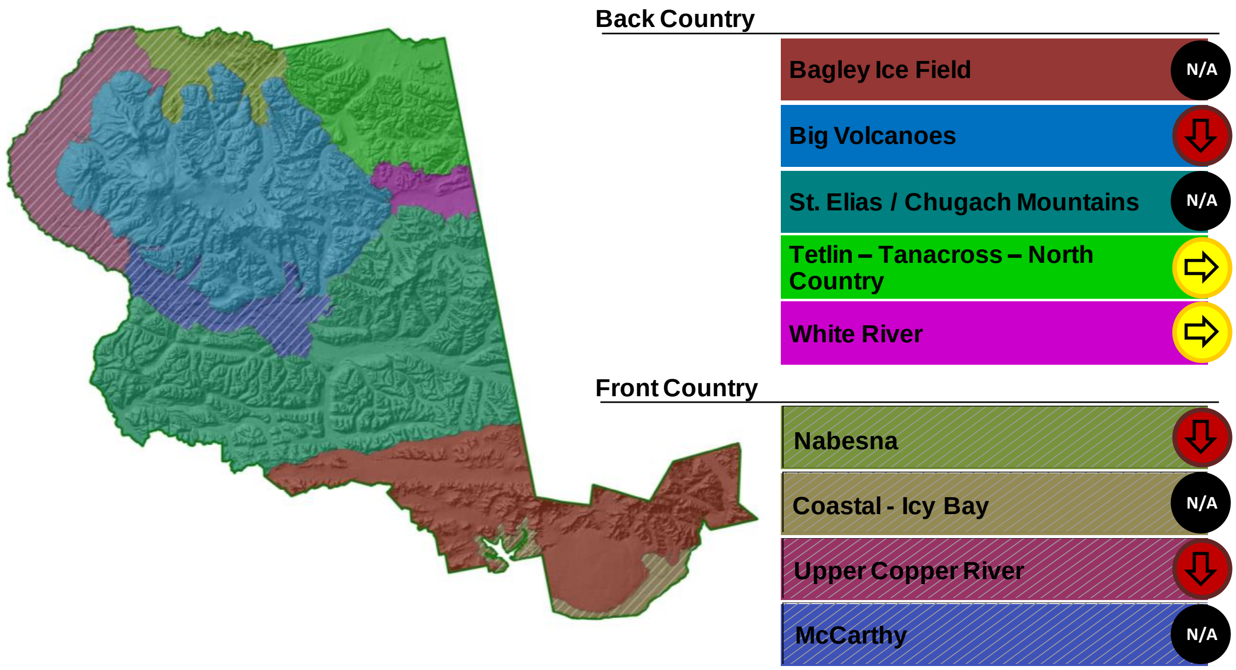


Plate 12. Human-Bear interation points from NPS BHIMS database. (NPS PDS 2009b)

4.8 Caribou

Indicators and Measures
Population Size, Herd Size, Geographic Distribution, Age and Sex Composition



Condition
Two caribou herds, the Chisana and the Mentasta, reside primarily within WRST. The Chisana herd is an international herd occurring in Alaska and Yukon, Canada. In Alaska, the Chisana herd is predominantly located in the Tetlin-Tanacross-North Country and White River RZs. The Mentasta herd's primary range occurs in the Big Volcanoes, Upper Copper River, and Nabesna RZs. Both herds, along with other small herds in interior Alaska, experienced significant declines in the early 1990s following severe winters in 1988-89 and 1989-90, summer drought in 1989 and 1990, and a severe snowstorm during the calving season in late May 1990 (Jenkins and Barten 2005). With an estimated population of 1680 animals in 1990, the Chisana herd experienced a long and steady decline in population, reaching an estimated 315 animals in 2002. However, the 2003 population estimate was more than twice the number recorded the previous year, indicating that the population was significantly underestimated in 2002 (Putera pers. comm). The Chisana Caribou Herd Working Group (CCHWG) comprised of NPS, ADF&G, USFWS, White River First Nation, Kluane First Nation, and the Yukon Department of the Environment, came together following the decline of the Chisana herd in the late 1990s. The CCHWG has directed research and monitoring of the Chisana herd along with taking part in an active management captive rearing program in the Yukon from 2003-2005. Currently, the condition of the Chisana herd is of moderate concern (Putera pers. comm.) and survey data suggest that the Chisana herd is stable between 694 and 766 animals, possibly a result of the captive rearing program (CCHWG 2009).

The condition of the Mentasta herd is of significant concern as is evidenced by a declining trend in population numbers (Putera pers. comm.). The Mentasta herd, estimated to have 3,160 animals in 1987, began to sharply and steadily decline in the early 1990s, where it reached an estimated 445 animals in 2008. As a result of the decline, the ADF&G, USFWS, and NPS developed a Mentasta Caribou Herd Cooperative Management Plan in 1995. The Mentasta herd has remained relatively stable the last 5 years, but evidence suggests that this herd is at low-density equilibrium, regulated by predation (Jenkins and Barten 2005).

Distribution and Background

WRST is host to two of the four caribou herds in the Central Alaska Network: the Chisana and Mentasta. The Chisana herd is unique because it is the only woodland caribou (*Rangifer tarandus caribou*) herd in Alaska. Woodland caribou are slightly larger than the more common barren ground caribou (*Rangifer tarandus granti*). The NPS states that caribou are considered a keystone species in interior Alaska, playing a critical role in the maintenance of ecological communities (NPS 2008).

Caribou have been an important source of food and raw materials for humans in Alaska for hundreds of years (NPS 2008). In the 18th and 19th centuries, the Ahtna depended so heavily on caribou that starvation would occur during years the animals did not arrive (Simeone 2006). Fall caribou hunts provided the necessary food and clothing materials for the Ahtna to survive harsh winters (Haynes and Simeone 2007). The Ahtna's system for harvesting caribou was complex but efficient; they developed drift fences to aid harvest, and relay systems to transport the fresh meat to base camps (Haynes and Simeone 2007).

Today, five of the RZs in WRST host caribou at some time over the course of a typical year. The Chisana herd is found primarily in the White River RZ and the Tetlin-Tanacross-North Country RZ (NPS PDS 2009a, b, Plate 13). During summer, the Chisana herd is located almost entirely within WRST, but during winter the herd resides mostly within the Kluane Wildlife Sanctuary and the Asi Keyi Natural Environmental Park in the Yukon Territory of Canada. The range of the Chisana herd covers territory that consists of rugged and glaciated mountains, with many peaks higher than 2,500 m (8202 ft). This area is characterized by a dry, cold, continental climate, which receives less than 32 cm of rainfall per year. This is primarily due to the rain shadow from the St. Elias/ Chugach Mountains (Farnell and Gardner 2002).

The range of the Mentasta herd includes the Big Volcanoes RZ, Upper Copper River RZ, Nabesna RZ, and the Tetlin-Tanacross-North Country RZ. The Mentasta herd spends its summers in the northwestern portion of WRST, near Mt. Drum and Mt. Sanford. During winter, a portion of the herd migrates with the Nelchina caribou herd to the winter range north of the park, near the US-Canada border (Jenkins and Barten 2005). While in the park the Mentasta herd occupies a wide range of elevations (600-2200 m [1968-7217 ft]) and varying vegetation regimes, including wetlands, tussock tundra, shrub tundra, and sedge tundra (Jenkins and Barten 2005).

Reference Condition

Parameters defining the ―natural and healthy" reference condition are unknown for the Chisana and Mentasta herds. The earliest caribou population estimate for the WRST area was in a 1919 letter from the Governor to the Secretary of Agriculture, indicating that 2,000 non-migratory caribou were located on the northern side of the Nutzotin Mountains (Simeone 2006). The 1919 estimate, possibly focused on the modern day Chisana herd, includes no methodology, causing concern about accuracy. Traditional ecological knowledge (TEK) offers several accounts about the historic condition of caribou in the WRST area (Simeone 2006); however, these accounts vary and lack sufficient detail to be able to derive a reference condition.

Demographics

Mentasta Herd

The fall season population estimates for the Mentasta caribou herd are based on June post-calving censuses, as well as fall sex and age composition counts (Putera pers. comm). Population counts are facilitated by maintaining approximately 40 radio-collared cows in the herd (Putera pers. comm.). Recent population estimates are adjusted for radio-collared animals missed during surveys. The highest recorded population estimate of the Mentasta caribou herd was 3,160 animals in 1987 (NPS 2009). From 1989 to 1993, the Mentasta caribou herd experienced a severe population decline, losing 63% of its total population, primarily due to poor adult female and juvenile survival during severe winters and summer drought (Figure 24) (Jenkins and Barten 2005). After 1993, the Mentasta herd's population continued to decline to an estimated 445 animals in 2008. Jenkins and Barten (2005) predicted that the Mentasta herd would decline until reaching a low-density equilibrium, sustained by density-dependent changes in the functional response of predators.

From 1973 to 1985, the average calf to cow ratio was 34.2:100 for the Mentasta herd (NPS 2009). Since 1985, the mean calf to cow ratio is 12.7:100. Population growth will occur when an average calf to cow ratio of 18:100 in the fall is realized (Putera pers. comm). The 2007 and 2008 calf to cow ratios were 29:100 and 20:100 cows, respectively. The bull to cow ratio has been stable since 1973, with a mean of 47.6:100 (NPS 2009).

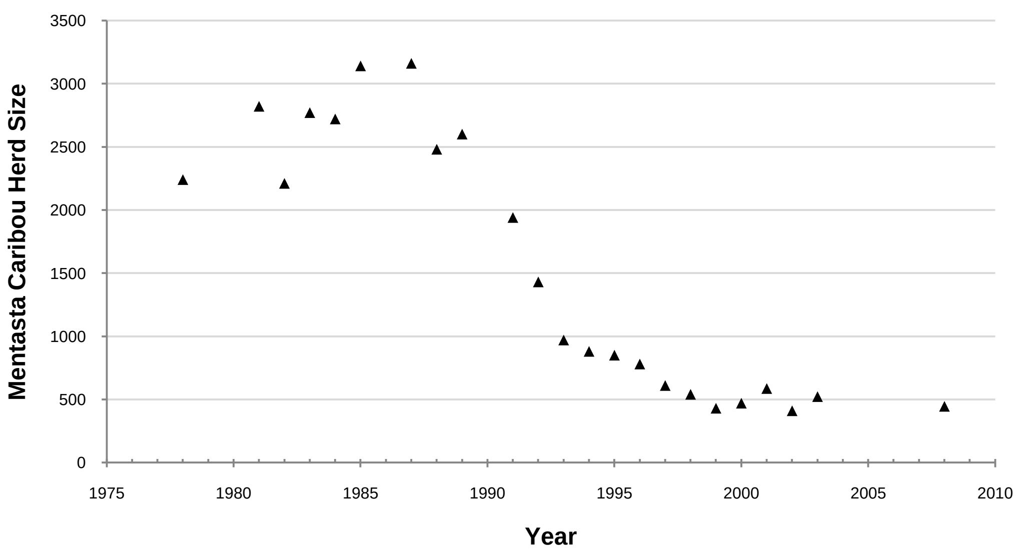


Figure 24. Mentasta caribou fall population estimates, 1978-2008. (NPS 2009)

Chisana Herd

Chisana caribou herd fall composition surveys, first performed in 1977, have continued annually since 1986 (NPS 2009). In 1987, 15 adult female caribou were radio-collared to monitor movements and to help facilitate spring and fall census and composition surveys. Between 1987 and 2002, fall population estimates were derived from June post-calving surveys, fall sex and age composition counts, and mortality data (Gross 2005). Population estimates between 1987 and 1992 ranged between 1270 and 1882 individuals (Gross 2005). Following yearly declines, ADF&G believe the herd size declined to an estimated 315 caribou in 2002, which prompted the initiation of a captive rearing program in the Yukon the following year. However, following a more intense population survey by the USGS in October 2003, the population was estimated at 720 caribou; this estimate was significantly higher than estimates generated from previous surveys. Numerous caribou were likely missed during previous fall surveys because of the small number of radio-collared individuals, patchy aggregations of caribou, and the tendency of the Chisana herd to use timbered habitat in the fall when surveys were conducted (Adams and Roffler 2007).

Population estimates derived in 2003, 2005, and 2007 are based on a mark-resight procedure that used 39, 98, and 138 radio-collared cows, respectively, to correct for sightability bias related to group size, as well as to provide a measure of precision. These estimates were also supplemented by captive reared calves, many of which would have died due to predation (Putera pers. comm.). The 2007 Chisana herd population estimate was 766 individuals (90% Confindence Interval (CI) - 719-823) (Adams and Roffler 2007). Farnell and Gardner (2002) expressed concern that the Chisana herd would become functionally extirpated by 2016, due to poor age structure and recruitment; however, recent increases in population estimates have alleviated that concern (Putera 2009).

The long-term average (1977-2009) calf to cow ratio for the Chisana Herd is 15.0:100 (NPS 2009). From 1998 to 2002, when the Chisana herd was declining most rapidly, the calf to cow ratio ranged from 3.9:100 to 14:100 (Gross 2005). During the last five surveys, calf to cow ratios have been closer to the long-term average, ranging from 13:100 to 23:100, with a most recent value of 15:100 in 2009 (NPS 2009). Typically, the calf to cow ratios of woodland caribou herds in Yukon, Canada are 20-25:100 (Putera pers. comm).

The long-term average bull to cow ratio for the Chisana Herd is 33.28:100 (1977-2009) (NPS 2009). Of all surveys, the lowest bull to cow ratio was 17:100, in 1999 (NPS 2009). The three most recent bull to cow ratios are 50:100 in 2007, 39:100 in 2008, and 49:100 in 2009 (NPS 2009).

Stressors
NPS identified stressors for caribou in WRST include hunting pressure/harvest, incidental harvest on winter range, predation, conflicting management objectives, and habitat decline.

Between 1981 and 1994, the average yearly harvest of Chisana caribou was 31 (range 16-65 individuals). Licensed harvest of the Chisana herd has not taken place in Alaska or the Yukon since 1994 (Gross 2007). At this time, the White River First Nation also issued a voluntary ban resulting in zero subsistence harvesting of the Chisana herd. In 2002, the herd was listed as a ―Specially Protected" population under the Yukon's Wildlife Act resulting in a formal ban on all licensed hunting. From 1974 to 1989, a mean of 100 Mentasta caribou (range: 45-236 individuals) were harvested per year under state regulations, while a mean annual harvest of 31 caribou (range: 17-67 individuals) were taken under subsistence regulations between 1985 and 1992. State general harvest and federal subsistence harvest of Mentasta caribou were closed in

1989 and 1992, respectively. Currently, no legal federal subsistence or state sport hunting of either the Mentasta or Chisana caribou herds takes place in Alaska or Canada (FSMP 2010). .

Jenkins and Barten (2005) confirmed that low reproductive rates following severe winter weather and summer drought, combined with ongoing predation-related mortality, was the primary proximate cause of population decline in the Mentasta herd. The same study also revealed that wolves and bears are the primary sources of juvenile predation on the Mentasta herd, with wolves accounting for 57% of juvenile mortality and bears accounting for 38%. Grizzly bears in particular are responsible for a disproportionate amount of mortality in 0- to 1-week-old caribou neonates when compared to older juveniles (Jenkins and Barten 2005).

Evidence also suggests that the population levels of caribou do not affect wolf populations when alternate sources of prey are available, in particular moose and Dall‘s sheep (Jenkins and Barten 2005). Farnell and Gardner (2002) stated that, ―The presence of alternate prey has meant that caribou as prey are not as critical to wolf demography as wolf predation is to caribou demography.” This supports Jenkins and Barten‘s (2005) speculation that the Mentasta herd will continue to decline until a low-density equilibrium is reached.

Research has shown that, morphologically, the Chisana herd is in good health, which supports the idea that predation is the primary factor influencing low calf survivorship for the population (Farnell and Gardner 2002). Wolf density in the Chisana herd‘s range has not changed since the late 1980s, indicating a lack of wolf numerical response to decreasing caribou populations (Farnell and Gardner 2002). Wolf density is also well below the average for that geographical area (Farnell and Gardner 2002). In summary, predation and periodic extreme weather events seem to be the limiting factor for growth of both the Chisana and Mentasta herds. Additionally, the high proportion of moss, compared to lichens, raises questions about the adequacy of winter forage quality within the Chisana herd's range (CCHWG 2009).

Climate change has the potential to affect population dynamics of caribou in WRST by altering the primary sources of forage for caribou (Lenart et al. 2002). In addition to declines in forage quality and abundance, other potential influences from climate change may include increased insect harassment in summer due to warmer temperatures, variability of snow conditions in winter, and changes in the timing of spring onset (Lenart et al. 2002).

Fire on the landscape also plays an important role in quality of caribou habitat. In particular, whether or not an area has burned recently may influence how caribou herds use habitat during winter months. For instance, the Nelchina caribou herd, which shares its winter range with the Mentasta herd, prefers climax lichen communities as opposed to areas that have burned within the last 50 years (Joly et al. 2003). How climate change could affect the frequency and intensity of wild fires in the ranges of the Mentasta and Chisana herds is currently unexplored.

A multi-agency cooperative management plan has been in place for the Mentasta herd since 1995, while a management plan for the Chisana herd is near completion. Each plan sets conservative population targets, including sex and age ratios, that must be met before any harvest of caribou can be resumed. It also provides conservative sex and age ratio thresholds below which harvest would be immediately closed. These targets and thresholds should minimize adverse affects on the caribou populations.

Data Needs

Mentasta Herd

The condition of winter range and the prevalence of incidental harvest in that range are both unknown (Putera pers. comm.). Throughout winter, lichens are the primary food source for the Mentasta herd. Many factors affect the lichen communities, including fire frequency, shrub encroachment, and snow cover. Incidental harvest is a concern because the Mentasta herd shares its wintering range with the Nelchina herd, just north of WRST. Some cows captured and radio-collared during early September on Mentasta herd summer range have subsequently been located on Nelchina calving grounds, indicating the possibility that some Mentasta cows may permanently join the Nelchina herd (Putera pers. comm.). Research into these areas would help management of the Mentasta herd.

Chisana Herd

The following is an excerpt from the Chisana Caribou Herd Working Group ―Draft Chisana Management Plan" (2009) that addresses the data needs for the Chisana caribou herd:

"A number of observations have been made in recent years that highlight opportunities for further research in the (Chisana herd) region. This research could advance the ability of managers to make better decisions for the benefit of the CCH. There are potential sources of funding available within and outside each of the management authorities.

Little information exists with respect to habitat quality or habitat use and availability. The high ratio of moss to lichens within the core winter range suggests that this may be low quality caribou habitat. Altered tree lines and increased shrub growth have been observed throughout the Chisana range; however, the effects to Chisana caribou are unknown.

To understand the limiting effect of predation on Chisana caribou, current information is needed on wolf and bear numbers in the region. This will help managers evaluate effects to the Herd so that appropriate management decisions can be made more strategically."

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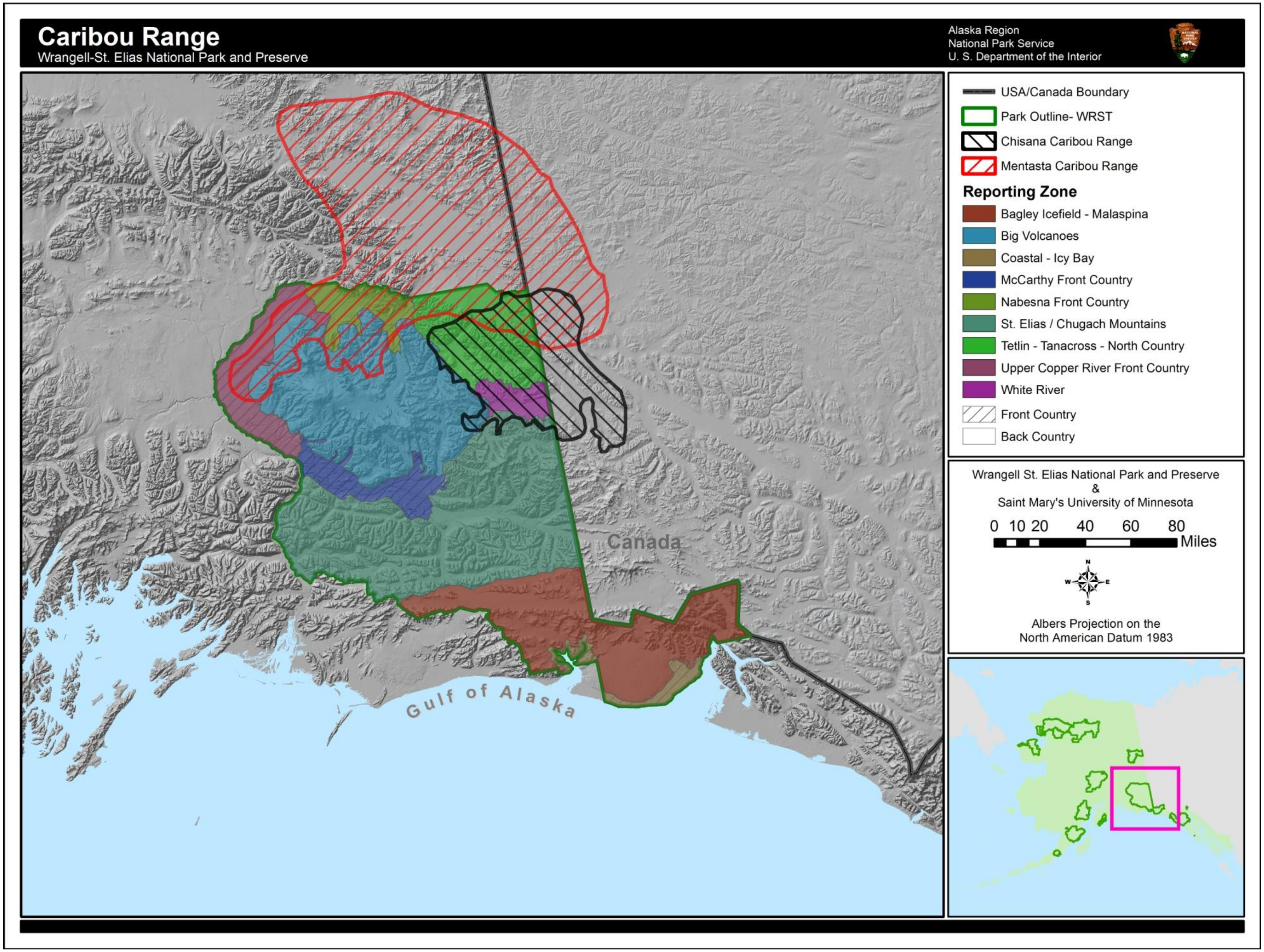
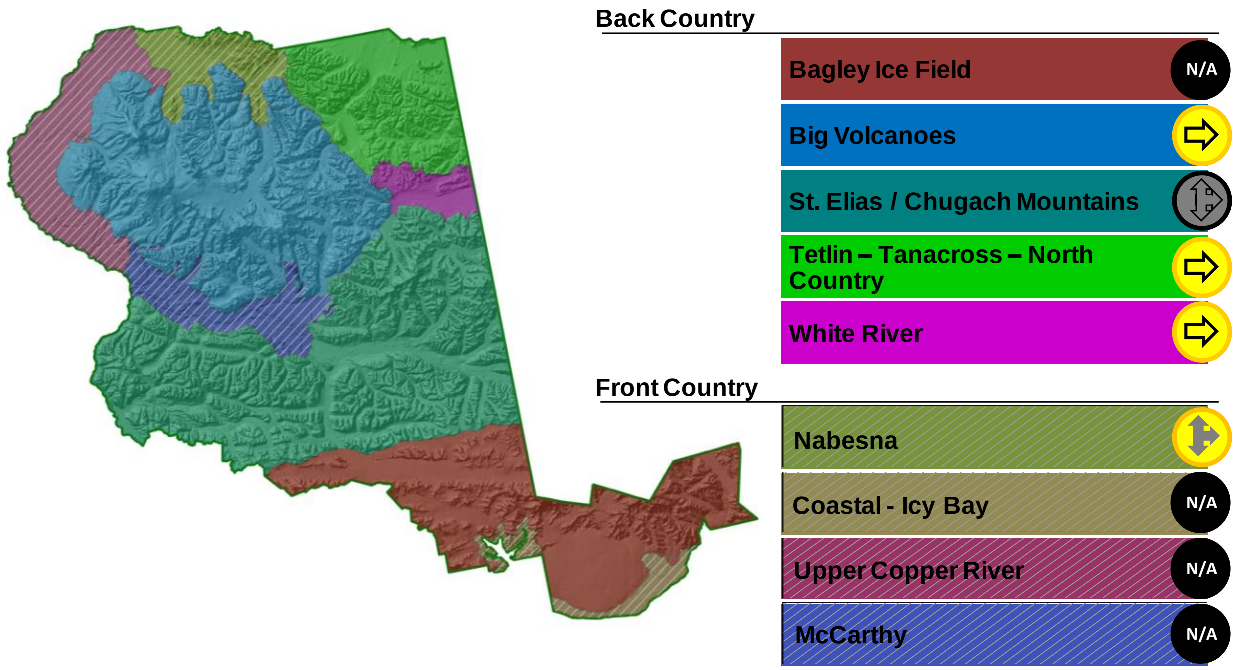


Plate 13. Mentasta and Chisana Caribou herd ranges. (NPS PDS 2009a,b)

4.9 Dall’s Sheep

Indicators and Measures
Population Size and Distribution, Age and Sex Composition



Condition
Due to the lack of an accurate reference condition for Dall‘s sheep (*Ovis dalli dalli*) populations in WRST, the most appropriate way to determine the condition of this species is to compare current lamb to ewe to ram (LER) ratios against long-term averages from the duration of available data (NPS, Judy Putera WRST Wildlife Biologist, pers. comm., NPS, Miranda Terwilliger Park WRST Ecologist, pers. comm.). To help facilitate analysis of Dall‘s sheep for this assessment, Sheep Survey Units (SSU) (Plate 14) were grouped, based on location within RZ, into seven areas called sheep reporting regions (SRR) (Plate 15). The condition graphic above shows the overall condition of Dall‘s sheep to the RZ level. Four of the RZs are designated ―not applicable” because Dall‘s sheep do not inhabit those regions.

The condition of Dall‘s sheep in the Big Volcanoes RZ is moderate and stable. The Big Volcanoes RZ holds 13 SSUs, which are encompassed in three distinct SRRs (North, Southeast, and Southwest SRRs). In the north region of the Big Volcanoes RZ, most recent surveys have shown above average lamb to ewe ratios, indicating a good and stable condition for that SRR. The condition of the southeast region is unknown primarily because the most recent surveys were completed in 1999 and 1992. The southwest region of the Big Volcanoes RZ, comprised of SSUs 10-14, is one of the only SRRs with long-term population data (SSU 11 and 12). The most recent survey in SSU 11 (2009) showed a very low ewe to lamb ratio for the region, and the most recent surveys in four of the five SSUs that comprise the southwest region have shown below average lamb to ewe ratios. However, surveys from the previous several years returned normal ratios. The most recent survey in SSU 12 (2006) showed an above average ram to ewe ratio and a slightly below average lamb to ewe ratio. The condition of Dall‘s sheep in the Big Volcanoes Southwest SRR is of moderate concern with a stable trend.

The condition of Dall‘s sheep in the Nabesna RZ, comprised of only SSU01, is moderate. The southern half of this SSU is located within the preserve adjacent to the Nabesna road and receives heavy state sport and subsistence harvesting pressure. The northern half is located outside of the WRST boundary, where sport harvest occurs regularly. The most recent survey, conducted in 2002, showed a below average lamb to ewe ratio. However, there has been variation in the range of lamb to ewe ratios in previous surveys for this unit. As a result, the trend for this unit is quite unclear.

The St. Elias/ Chugach Mountains RZ is comprised of three SRRs (east, south, and west), and encompasses 15 total SSUs. There is very little existing survey information for the south and west SRRs of the St. Elias/ Chugach Mountains, making the condition of Dall‘s sheep in these unknown. All four SSU‘s (25, 26, 27, and 28) in the west portion of the SRR were surveyed in 1973, during which 192 sheep were recorded, and 1983-84 during which 155 sheep were recorded. SSU 26 was surveyed most recently in 2002, during which no sheep were observed. This is consistent with the past two surveys for this SSU. SSUs 29, 30, and 31 in the southern region were surveyed once in 1973, during which 78 sheep were observed, and in 1983 during which 195 sheep were observed. The St. Elias/ Chugach Mountains south and west SRRs are located in the eastern Chugach Mountain Range. The Chugach Range is heavily glaciated and has a maritime climate, which is typified by heavy snowfall, warm winters, and cool summers. Consequently, this does not support substantial sheep populations (Mullen and Cella 1984).

The condition of Dall‘s sheep in the east region of the St. Elias/ Chugach Mountains RZ (SSUs 19, 20, 21, 22, 23, and 24) is good and stable. SSUs 20, 21, 22, and the west half of 23 are located within the preserve; a popular area for state sport harvest and federal subsistence harvest. Consequently, SSUs 21 and 22 have long-term survey data. Three surveys of the St. Elias/ Chugach Mountains East SSR in 2002 returned above average lamb to ewe and ram to ewe ratios.

The Tetlin-Tanacross-North Country RZ and SRR is comprised of five SSUs (05e, 05w, 07e, 07w, 09) that are located in the Tetlin-Tanacross-North Country RZ and the White River RZ. This SRR is located entirely within GMU 12, and both state sport and subsistence harvest occurs. The most recent surveys, conducted in SSUs 07w and 09 in 2005, resulted in below average lamb to ewe ratios and above average ram to ewe ratios. The condition of Dall‘s sheep in Tetlin-Tanacross-North Country RZ and White River RZ is of moderate concern with a stable trend, assuming no change since the last surveys in 2005.

Distribution and Background

Dall‘s sheep are found within most of the mountainous terrain, north of the Bagley Ice Field, in WRST. The sheep in WRST use four types of habitat: smoothly contoured, open, graminoid covered slopes; steep, broken cliffs; sparsely vegetated talus slopes; and ridges at high elevations (Geist 1971). Due to large tracts of suitable habitat, most Dall‘s sheep in WRST are located in the St. Elias, Big Volcanoes, and Tetlin-Tanacross-North Country RZs (RZ). Aerial surveys have also documented Dall‘s sheep in portions of the Nabesna RZ and White River RZ.

Reference Condition

Parameters defining the —natural and healthy" reference condition for Dall's sheep in WRST are unknown due to insufficient data. The annual Governor's Report to the Secretary of Agriculture from 1919 provides the earliest Dall's sheep population estimate in the WRST area (Simeone 2006). This report estimated 10,000 Dall's sheep were located in the Nutzotin Mountains of the present day WRST (Simeone 2006). It also estimated that 1,000 sheep were located in the Wrangell-Mountains, including near the White River, and 3,000 sheep occupied the south side of Mt. Natazhat and the Klutina Glacier (Simeone 2006). Based on current knowledge of Dall's sheep, it seems unlikely that these numbers represent a true estimate of reference condition. For example, a population of 10,000 sheep in the Nutzotin Mountains corresponds to a density of greater than 5 sheep/km^2 (13.2 sheep/mi^2) across roughly 1,900 km^2 (733 mi^2), using the Nutzotin subsection of the Ecological Subsection map of WRST developed in 2001 (NPS PDS 2009b). The highest recorded sheep density in the Nutzotin Mountains, from modern survey data provided by NPS (2010), is 1.14 sheep/km^2 (3 sheep/mi^2) in 1974. The only complete sheep population survey in WRST was conducted in the early 1990's and resulted in an estimate of 17,455 ± 3883 sheep for all of WRST (95% CI) (Strickland et al. 1993).

Demographics

Dall's sheep surveys in WRST began in 1949. In 1967, ADF&G established 30 sheep survey units (SSU) within the park, designed to accommodate fixed-wing aerial surveys with 4-6 hours of effort. Most of the SSUs in WRST are located in the Big Volcanoes RZ (13 units) and St. Elias/ Chugach Mountains RZ (15 units). Four additional SSUs fall entirely in the Tetlin-Tanacross-North Country RZ, and the final two SSUs are located partially in the Nabesna, Tetlin-Tanacross-North Country, and White River RZs (Plate 14).

In 2005, all available Dall's sheep survey data from WRST were compiled and summarized in cooperation with the Alaska Cooperative Fish and Wildlife Research Unit (Terwilliger 2005). Mean adult density per SSU from 1949 through 2005 was 0.45 adults/km^2 (1.16 adults/mi^2) with a mean lamb density of 0.09 lambs/km^2 (0.23 lambs/mi^2). The mean observed lamb to ewe ratio over the same period was 27.6:100. Most SSUs in WRST did not show significant changes in density from the 1970s to 2005, and those that did change had low rates of population change (<0.01 sheep/km^2/year) . Terwilliger (2005) concluded, —There was no strong evidence for a net change in sheep density throughout WRST, even though there has been some variance within individual survey units."

Sheep populations in SSUs 11, 12, 20, 21 and 22 are of particular concern, due to relatively easy access and higher hunting pressure compared to most other units in WRST (Putera pers. comm.). Of the previously listed SSUs, 11 and 12 have long-running, current sheep survey data (Figure 25, Figure 26). These units have shown substantial declines in the surveyed sheep since the early 1990s. Sheep populations in SSUs 20, 21, and 22 appeared stable as of the last surveys conducted in 2002 and 2004.

Only one comprehensive, full-park sheep survey has been conducted in WRST (Strickland et al. 1993). Yearly SSU counts do provide insight into sheep population health; however, there are some issues with available count data for WRST. Sampling protocols have varied significantly over the years and contain procedural inconsistencies because of weather, aircraft type, and observer bias. Due to budget constraints, only a few survey units are completed each year.

Survey results are limited in their application due to unknown emigration and immigration into and out of each count unit. This creates some questions about total count accuracy and population distribution. Finally, ADF&G surveys place more emphasis on assessing hunted areas of the park, particularly SSUs north of McCarthy road.

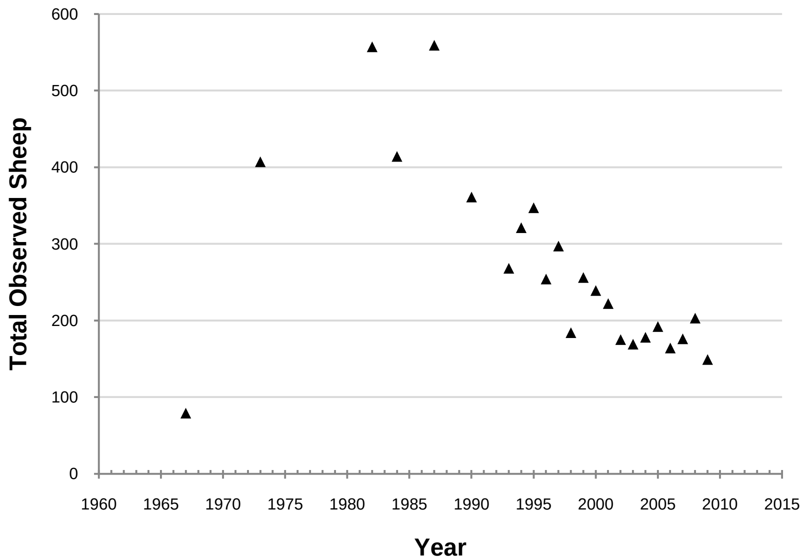


Figure 25. Observed Dall's sheep in SSU 11 surveys, 1967-2009. (Data compiled by NPS Staff from multiple sources)

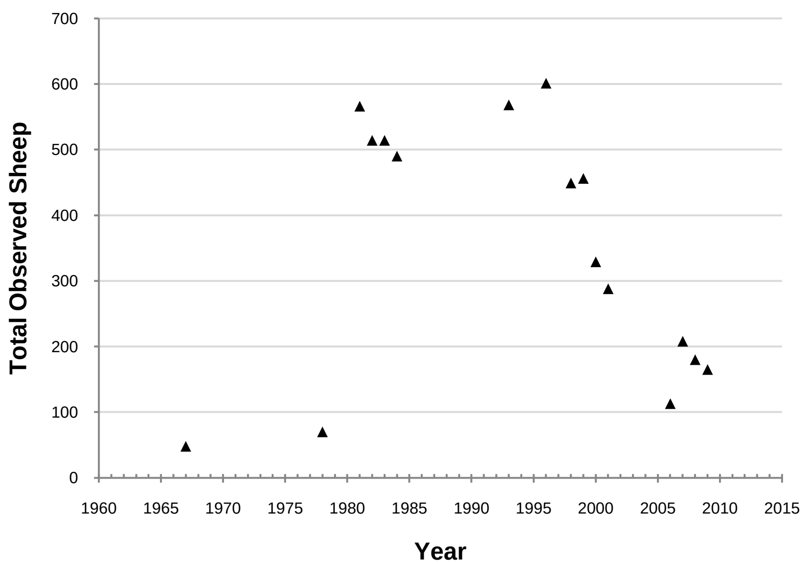


Figure 26. Observed Dall's sheep in SSU 12 surveys, 1978-2009. (Data compiled by NPS Staff from multiple sources)

In the absence of consistent and wide ranging Dall‘s sheep population surveys, lamb to ewe to ram ratios (LER) are a better descriptor of current sheep population health for WRST than count data (Putera pers. comm., Terwilliger pers. comm.). Because most surveys are conducted using fixed-wing aircraft, ‗ewes' consist of adult ewes, yearlings, and small rams that cannot be easily distinguished from ewes. LER ratios that are similar to the long-term average of a given area should reflect a stable population in that area, and those that vary from the long-term average likely indicate a change in population dynamics, and therefore population health (Putera pers. comm.)

Lamb: Ewe: Ram Ratio Analysis

For analysis of LER ratios, SSUs were broken down into sheep reporting regions (SRR) based on location within the larger RZs (Plate 15). Not all SSU's within a SRR are surveyed during any given year. Summary data from the following analysis, presented by SRR, are located in Appendix B and Appendix C.

Big Volcanoes North - SSUs 02, 03, 04e, 04w

There are data from thirteen sheep surveys for this SRR, spanning 1973 to 2006. The average LER ratio from 12 surveys in this unit is 24.7:100:35.1. LER ratios of most recent surveys in the Big Volcanoes North area exceed the all-survey average for the SRR with the exception of the 2009 survey of SSU 3. This unit displayed 8 fewer rams per 100 ewes than the all-survey average. The most recent surveys in SSU 03, 04E and 04W in 2006, returned lamb to ewe and ram to ewe ratios that were higher than the long-term average.

Big Volcanoes Southeast - SSUs 15, 16, 17, 18

Data from 14 of 25 sheep surveys conducted between 1950 and 1999 in the Big Volcanoes Southeast SRR resulted in average LER of 27.2:100:26.9. The most recent survey in this SRR is the 1999 survey of SSU 15 that documented an LER ratio of 26.3:100:24.2. Other than the 1999 survey of SSU 15, the most recent surveys in this SSR are 1992 (SSU 16) and 1983 (SSUs 17 and 18).

Big Volcanoes Southwest - SSUs 10, 11, 12, 13, 14

The Big Volcanoes Southwest SRR is the most surveyed region of WRST. Since 1973, 82 sheep surveys are on record for this SSR. The LER ratio from 52 surveys in this region is 26.86:100:341.

The most recent survey of SSU 11, in 2009, returned very low lamb to ewe and ram to ewe ratios, 132:100 and 17.5:100 respectively. 2009 was the first year that a survey of SSU 11 returned a lamb to ewe ratio lower than the SRR all-survey average since 2001 (8 total surveys); ram to ewe ratios in SSU 11 have been below the SSR all-survey average for the last six years.

In 2009, the observed LER ratio for SSU 12 was 24.7:100:79.0. The 2009 lamb to ewe ratio in SSU 12 was the lowest observed in that unit since 2001, although no surveys were performed in SSU 12 from 2002-2005. Ram to ewe ratios in SSU 12 are higher than the SRRs average for the last 11 surveys beginning in 1983.

The last survey in SSU 14, performed in 2006, resulted in an LER ratio of 38.5:100:47.7. The last survey in SSU 10 was 1990 and the last survey in SSU 13 was 1992.

Nabesna - SSU 01

There are five survey records for SSU 01 since 1973 with the most recent being in 2002. The all-survey average LER ratio for this unit is 36.5: 100: 27.7. The 2002 LER ratio was 54.9: 100:

21.4. Overall, total sheep numbers have remained stable in this SSU. Low ram to ewe ratios reflect heavy ram harvest.

St. Elias/ Chugach Mountains East - SSUs 19, 20, 21, 22, 23, 24
Sixty-one surveys have been performed in this SRR with the earliest being 1968. A 48 survey average LER ratio for this region is 27.4:100:36.1. The most recent surveys for this unit were in 2002 in SSUs 20, 21, 22. The LER ratios for the 2002 surveys showed above average rams and lambs per 100 ewes in all cases. The most current surveys for SSUs 19 and 24 are from 1983.

St. Elias/ Chugach Mountains South - SSUs 29, 30, 31
There are four survey records for this SRR, from the years 1973, 1983-84, 1990, and 1991. All SSU's were surveyed in 1973 and 1983-84, resulting in a total of 78 and 195 sheep, respectively. SSU 31 was surveyed in 1990 and 1991, where 24 and 27 sheep were observed, respectively.

St. Elias/ Chugach Mountains West - SSUs 25, 26, 27, 28
Only 12 surveys have been performed in this SRR between 1973 and 2002. All four SSU's were surveyed in 1973 and 1983-84, resulting in a total of 192 and 155 sheep, respectively. Only SSU 26 was surveyed in 2002, during which no sheep were observed. This is consistent with the past 2 surveys in this SSU.

The St. Elias/ Chugach Mountains South and West SRR's are located in the eastern Chugach Mountain Range. The Chugach Range is heavily glaciated and has a maritime climate, which is typified by heavy snowfall, warm winters, and cool summers, and thus, does not support substantial sheep populations (Mullen and Cella 1984).

Tetlin - Tanacross - North Country - SSUs 05e, 05w, 07e, 07w, 09
All SSUs are located within the preserve and are subject to state sport and subsistence harvest. Consequently, a significant number of surveys have recently been conducted in the Tetlin-Tanacross-North Country SRR. In total, there are 47 surveys on record for this region with 11 occurring since 2000. A 22 survey average LER ratio for this region is 28.1:100:49.4. The five most recent surveys in this region have returned above average ram to ewe ratios. Conversely, four of the same surveys returned below average lamb to ewe ratios.

Harvest Information
With the exception of the Elder and Junior/Senior Federal Registration Permit sheep hunts in GMU's 11 and 12, all federal (subsistence) and state sheep hunting is reported under the state harvest ticket system. Terwilliger (2005) summarized harvest data for Dall's sheep in WRST from 1983-2002. Over this time span, 6,672 total sheep were reported harvested. Seventy percent of harvested sheep over that time were rams, 3.3% were ewes, and 26.5% were of unreported sex. Terwilliger (2005) also reported that ram harvest was decreasing linearly through 2005 (r^2 = 0.93), but specific rates were not disclosed in this report. Moderow (2006) estimated that sheep harvest was decreasing as well, using coefficients developed from a community harvest survey that adjusts for unregistered harvest.

ADF&G (2008) reported that harvest levels for game management unit (GMU) 11, which is nearly completely encompassed within the WRST boundary, have decreased consistently from 1999 to 2007, with record lows in 2006 and 2007 (Figure 27). In GMU 12, of which roughly half is located in the northwestern portion of the park, there were also reported declines from 2005-2007 (Figure 28). The number of registered hunters and their success rates have also been declining in GMU 11, with record lows in 2007 (Figure 29, Figure 30). In GMU 12, the number of registered hunters has been decreasing, but success rates have remained relatively constant (Figure 31, Figure 32).

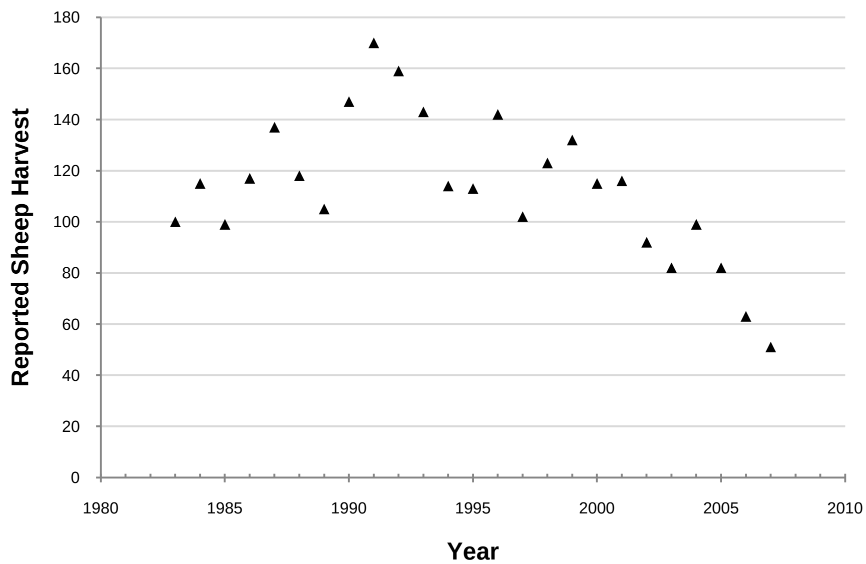


Figure 27. Dall's Sheep harvest in GMU 11, 1983-2007. (Moderow 2006)

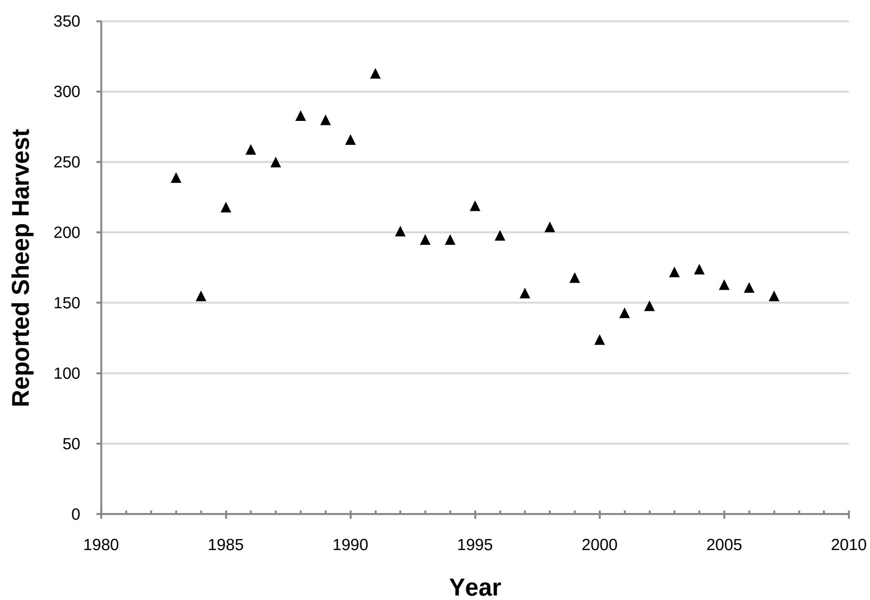


Figure 28. Dall's Sheep harvest in GMU 12, 1983-2007. (Moderow 2006)

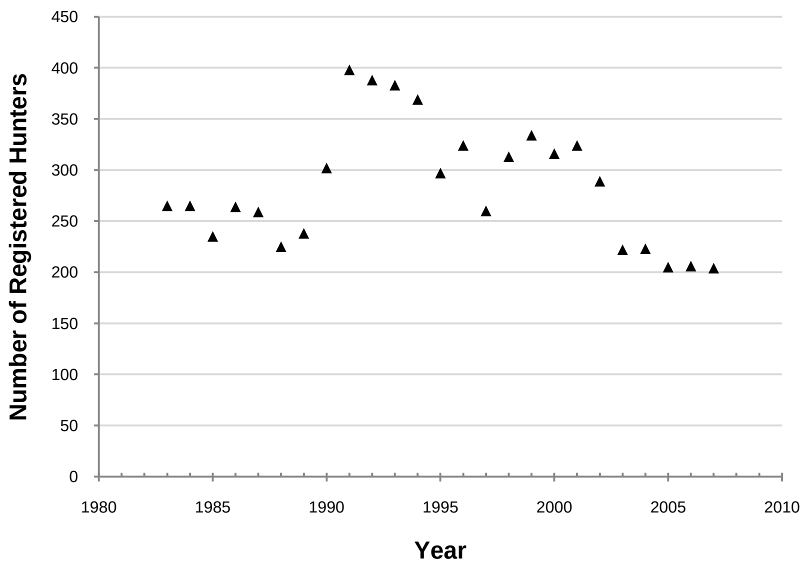


Figure 29. Registered Dall's sheep hunters in GMU 11, 1983-2007. (Moderow 2006)

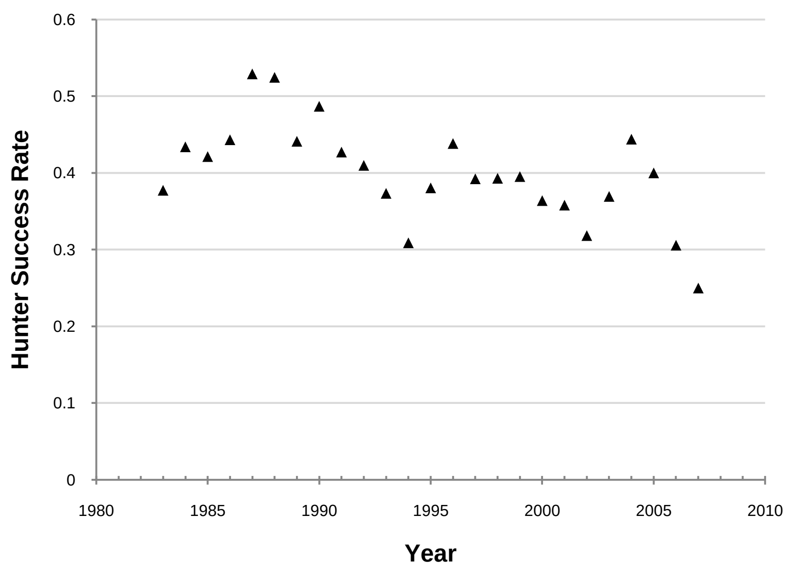


Figure 30. Dall's sheep hunter success rate in GMU 11, 1983-2007. (Moderow 2006)

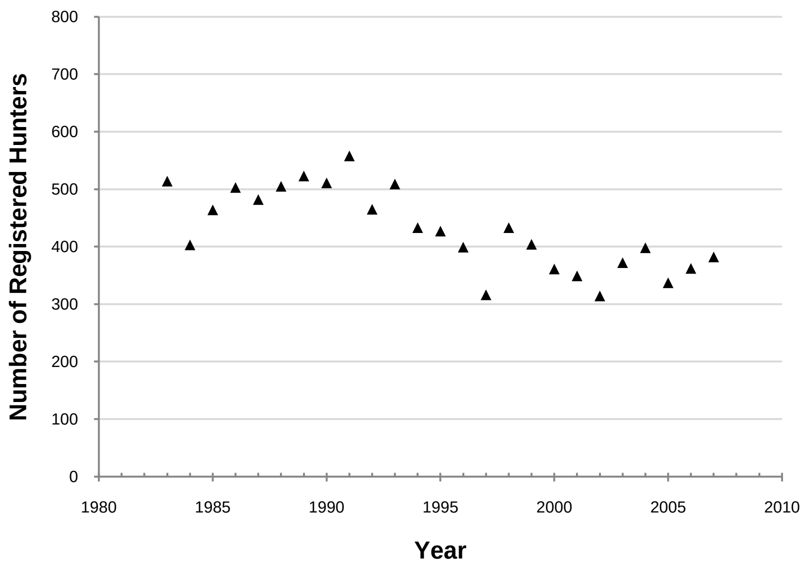


Figure 31. Registered Dall's sheep hunters in GMU 12, 1983-2007. (Moderow 2006)

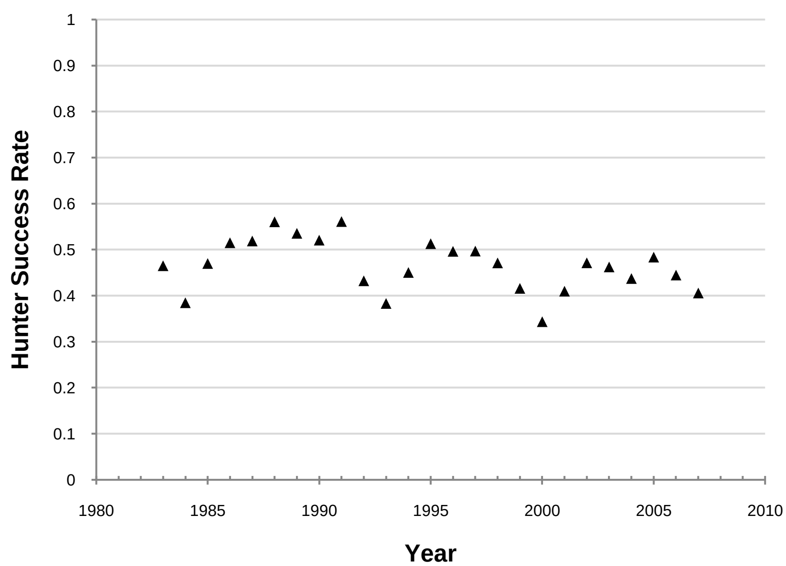


Figure 32. Dall's sheep hunter success rate in GMU 12, 1983-2007. (Moderow 2006)

Of the 94 permits issued in GMU 11 under Elder and Junior/Senior Federal subsistence from 2003 to 2008, only two sheep were harvested with 94% of permit holders reporting hunt results (NPS 2009). Similarly, of all 47 of the same Federal subsistence permits issued in GMU 12 from 2003 to 2008, 100% of hunters reported results and no sheep were harvested (NPS 2009).

Stressors

NPS identified several stressors to Dall‘s sheep populations in WRST, including hunting pressure, climate change, winter temperatures/snow depth, and subsistence harvest. Hunting pressure and success rates have been decreasing in recent history as indicated by the ADF&G (2008). The reason behind the decrease in Dall‘s sheep harvest in WRST has not been determined.

Climate change could affect Dall's sheep in WRST in many different ways. Climate change could result in an increase in the elevation at which shrubby plants grow best, thus decreasing the food availability in alpine tundra (Terwilliger pers. comm.). An increased number of thaw events followed by freezing could result in ice formation over winter forage. Climate change could also benefit Dall's sheep by exposing rugged terrain, which is a critical component of their habitat (Terwilliger 2005). Of all the climate change related stressors, altered levels of precipitation are likely the most significant threat to Dall's sheep. Years of unusually high snowfall typically result in a decrease in Dall's sheep numbers due to starvation, accidents, and predation. High snow levels impinge the mobility of Dall's sheep, decreasing their ability to escape predators and increasing the potential for slipping and falling off rocks.

Data Needs

A park-wide Dall's sheep survey method is needed to develop population estimates and to understand their condition within the park. The CAKN is developing survey methodology, with implementation to begin in 2010 (Putera pers. comm.). This survey will provide resource managers with a new baseline which may then be compared to estimates gathered in future surveys. To date, the majority of sheep surveys in the park have been in heavily hunted units (particularly SSU 11 and SSU 12), which may contribute to a misrepresentation of the overall population in the park. Additionally, past survey efforts do not account for range and movement patterns of sheep in the park.

Terwilliger (2005) explained that terrain ruggedness and vegetation regimes are two key components in modeling total sheep density within WRST. However, terrain ruggedness and Normalized Difference Vegetation Index (NDVI) only explain 50% of the variation in sheep density within studied units of the park (Terwilliger 2005). Additional data regarding snow cover in winter, wind scoring in relation to snow, climate, landcover, and predation risk would likely improve the ability to model sheep density in WRST (Terwilliger 2005).

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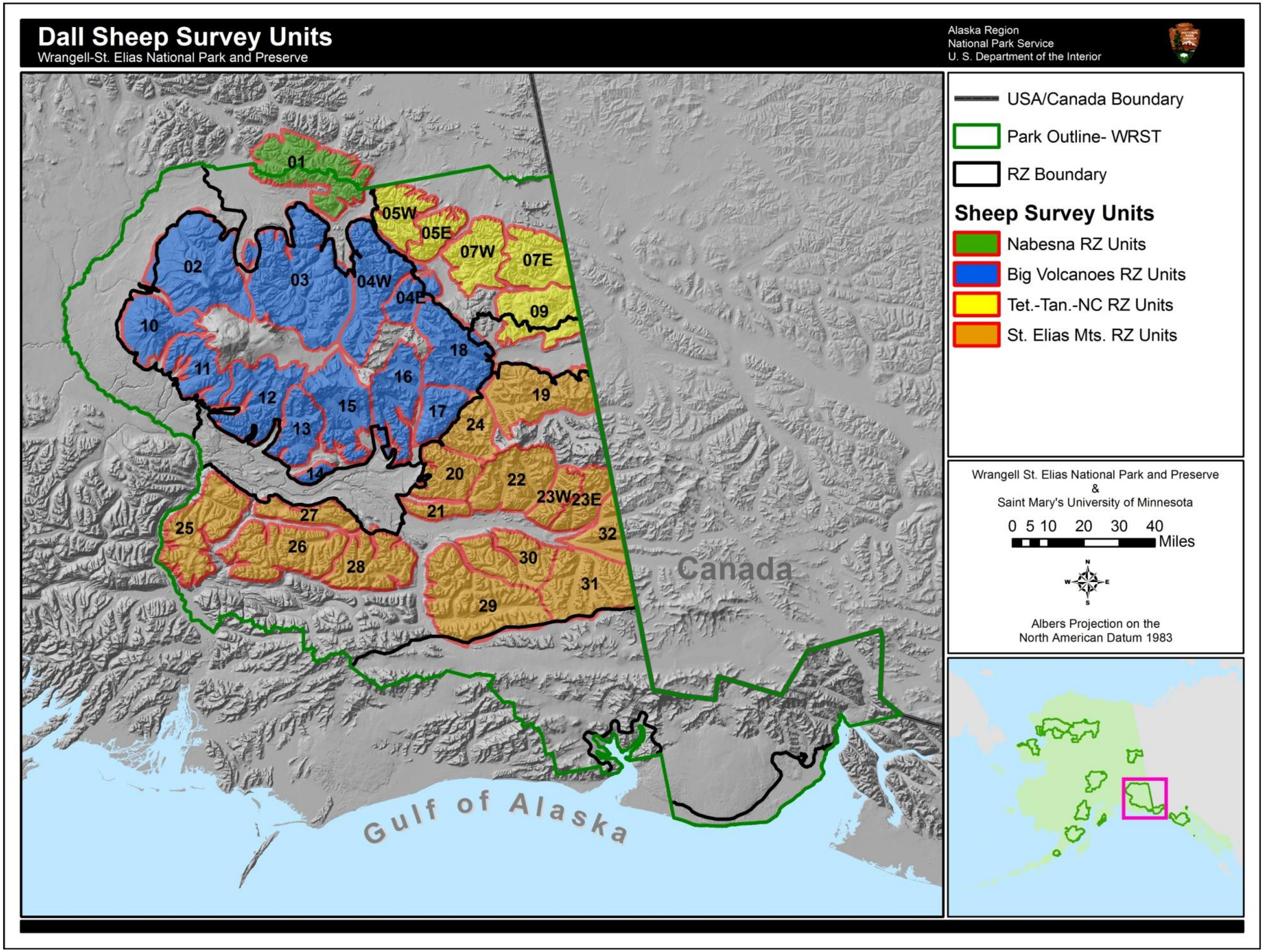


Plate 14. Dall’s sheep survey units in WRST. (NPS PDS 2009a)

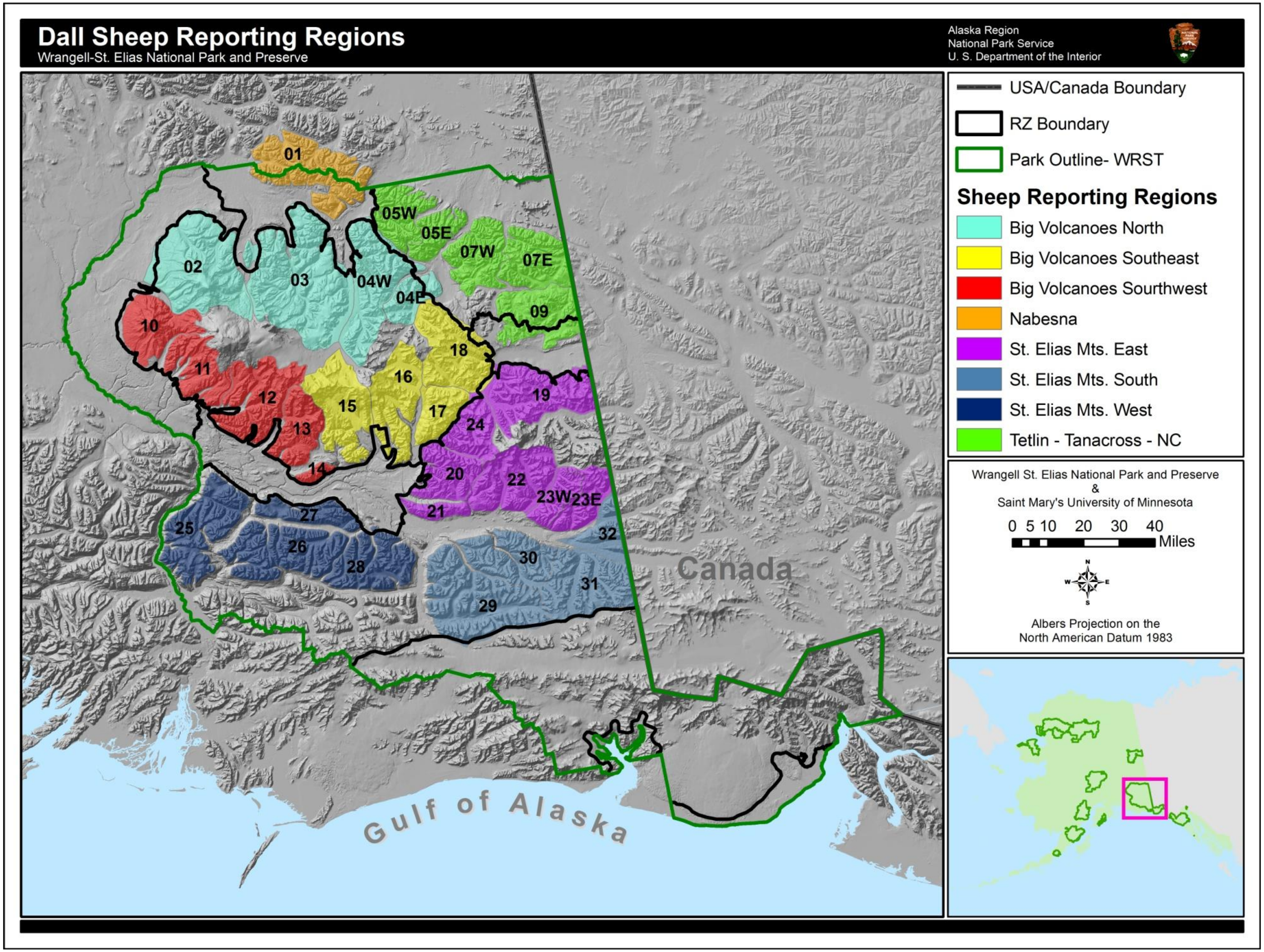
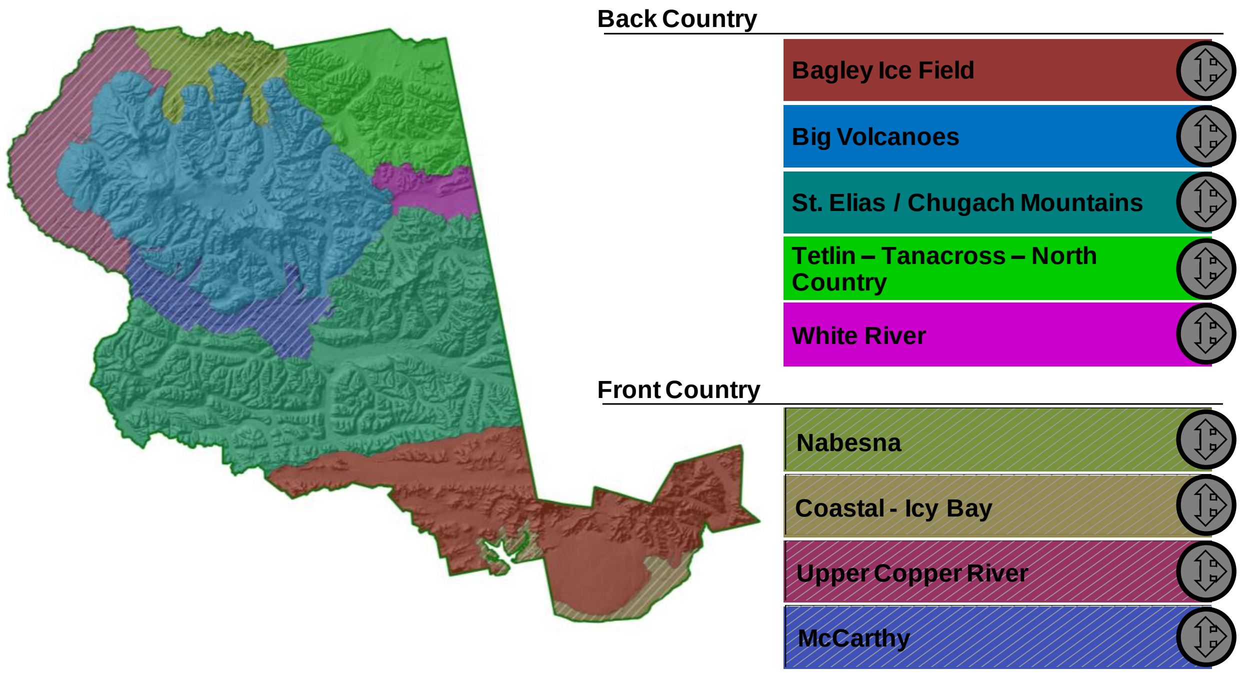


Plate 15. Dall's Sheep reporting regions, used to accommodate analysis for the reporting zones. (NPS PDS 2009a)

4.10 Wolves

Indicators and Measures

Population Size and Distribution, Pack Size and Number of Packs



Condition

The condition of wolves in WRST is unknown. Wolves exist throughout most of the park, but surveys are limited to GMUs 11 and 12. Surveys conducted in the Tetlin-Tanacross-North Country and White River RZs indicate wolf populations are below the average densities reported for Alaska and the Yukon. The lack of a quantified reference condition and up-to-date population surveys make assessing current condition difficult. Recent data show wolf harvest is declining in GMU 11, which is attributed to decreased hunter access as opposed to a change in population (Kelleyhouse 2006a). Wolf condition will remain unknown, until accurate population and distribution data are available.

Distribution and Background

No distribution data are available that speak to actual locations or sizes of wolf (*Canis lupus*) packs in WRST. However, wolves are acknowledged as present in all RZs of WRST (Putera pers. comm.).

Reference Condition

Parameters that define the “natural and healthy” reference condition are unknown. No historical survey data or TEK is available for this species.

Demographics

A study was initiated in WRST in 1995 by the USGS-Biological Resources Division with the intent to determine wolf densities and ecology within the Mentasta caribou herd range that spans portions of the Lower Copper, Big Volcanoes and Nabesna RZs. Ten wolves in six packs were captured and radio-collared on the north side of Mt. Drum and Mt. Sanford, between the Nadina and Copper Rivers. Loss of the Biological Resources Division field station, staff, and funding in 1996 compromised the study and led to sporadic monitoring of these packs. Results indicated a minimum midwinter population of 38 wolves in the 5568 km^2 (2149 mi^2) study area, resulting in a density of 6.8 wolves/1000 km^2 (Mitchell 1999). Den sites were between 579 and 1463 meters (1900-4800 ft) in elevation and pack sizes ranged from 4-6 to 8-12 wolves.

Wolf densities were also estimated in 2001 using aerial snow tracking (Stephenson 1978) within the 19,000 km^2 (7335 mi^2) range of the Chisana caribou herd (Farnell and Gardner 2002). This area lies within the Tetlin-Tanacross-North Country and White River RZs. Results indicated a population of 106 wolves and a density of 5.6 wolves/1000km^2. There were an estimated 20 packs with a mean pack size of 4.8 wolves. Wolf densities from mid 1990 to 2001 in the north portion of WRST were below the average density of 9 wolves/1000km^2 reported for Alaska and Yukon study sites (Gasaway et al. 1992). In 2004, wolf population size and density were estimated using aerial snow tracking (Becker et al. 1998) in a 3065 km^2 portion of Tetlin National Wildlife Refuge, which borders the northeast boundary of WRST within GMU 12. The survey estimated 24.8 ± 13.4 wolves in 4.8 ± 2.2 packs, with an average pack size of 4.9 ± 1.5 wolves. Density was 8.1 ± 4.4 wolves/1000km^2 (Collins and Johnson 2004).

Currently, the overall population size for wolves in WRST is unknown. ADF&G derives population estimates for GMU 11 from occasional aerial track surveys, incidental observations, and reports from public and sealing records (Kelleyhouse 2006a). Because ADF&G relies on anecdotal information to make population estimates, the accuracy of some data are questionable (Putera pers. comm.). From 1997-2005, wolf population and pack size estimates increased (Kelleyhouse 2006a). In GMU 12, ADF&G estimated 231-243 wolves in 31 packs in 1998-99 and 240-255 wolves in 31 packs in 2002-03; however, no density estimates were provided (Hollis 2006). The portion of GMU 12 outside of WRST is large, encompassing the Forty-mile caribou herd range and Nelchina caribou herd winter range. No wolf population estimates are available for GMU 05. To date, a formal wolf population survey of WRST has not been performed.

Harvest Information

Wolf harvest data are available from 1984 to 2007 (Moderow 2006). The average number of wolves harvested yearly in WRST, from 1984 to 2007, is 38.5. For the last five years of data, the average yearly harvest was 28.9 wolves (Figure 33). The most likely reason for the recent decline in wolf harvest is decreased hunter access, due to increased land access restrictions by Ahtna Inc. and the Copper River staying open in warmer winters (Kelleyhouse 2006a).

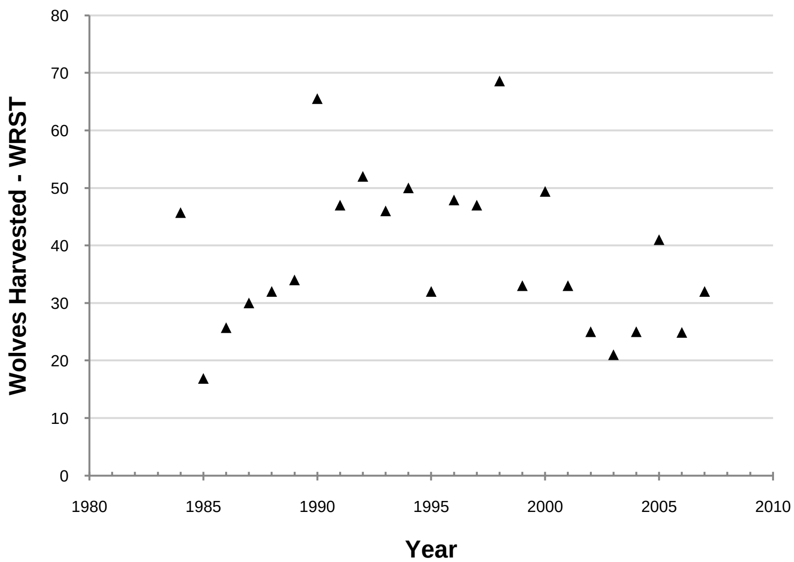


Figure 33. Wolves harvested in WRST, 1984 to 2007. (Moderow 2006)

Stressors

NPS identified two primary stressors on WRST wolf populations: predator control on adjacent lands and human presence in front-country areas. No data are available that explain the effects of human presence in front-country areas. Much of southcentral and interior Alaska, including areas adjacent to WRST, is included in the Alaska predator control area (Alaska Statutes 5 AAC 92.125, Plate 16). In January 2004, ADF&G initiated land-and-shoot wolf control in GMU 13, which accounted for the majority of wolf kills in the GMU for reporting years 2003-04 (51%) and 2004-05 (49%) (Kelleyhouse 2006b). In 2009, aerial wolf control accounted for 55 (46%) of 119 wolves taken in GMU 13 (ADF&G, 2009). There is no research to determine if wolf control in GMU 13 affects wolf populations in GMU 11 within WRST.

Data Needs

The absence of population, distribution, and prey selection data limits the ability to make informed wolf management decisions in WRST. Available population estimates rely on indices and anecdotal information. To date, there are no formal, park-wide, wolf population or distribution data for WRST.

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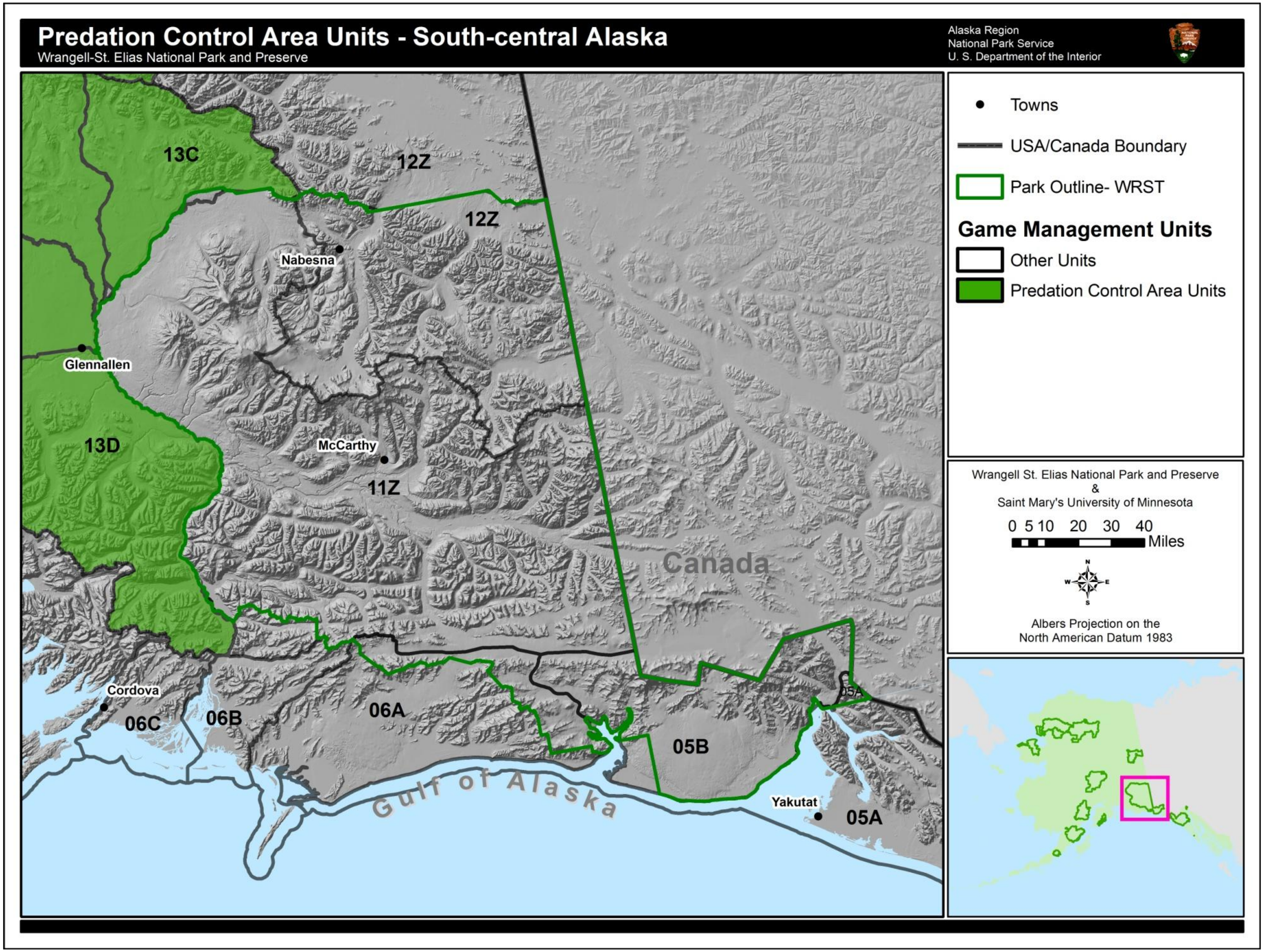
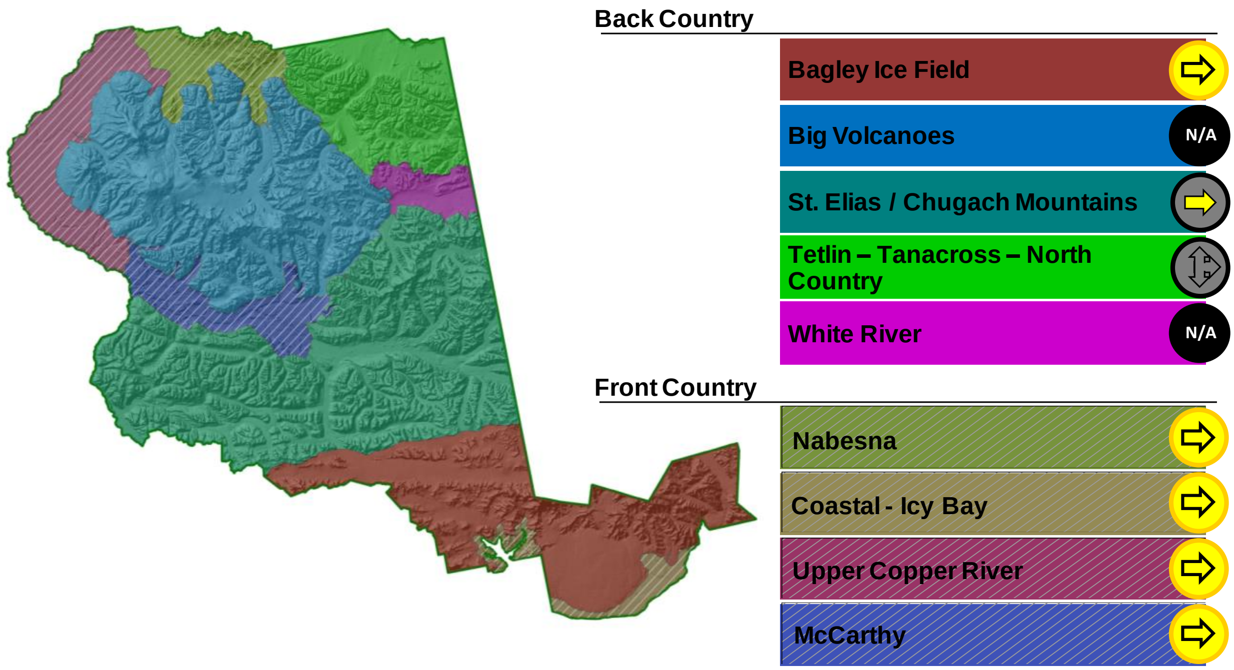


Plate 16. Predation control units adjacent to WRST. (NPS PDS 2009)

4.11 Anadromous Fish

Indicators and Measures

Population Status, Distribution, Return Rates, Age and Sex Composition



Condition

For both sockeye salmon *(Oncorhynchus nerka)* and Chinook salmon *(Oncorhynchus tshawytscha)* spawning escapement numbers are increasing even though commercial and subsistence harvest levels are increasing (Lewis et al. 2008). Sockeye escapement upstream from Miles Lake sonar increased from 2004 to 2007 and Chinook spawning escapement has gradually increased since 1998 (Lewis et al. 2008). Tanada Creek weir counts appear to be decreasing, but fluctuations in sockeye salmon populations are normal (NPS, Eric Veach WRST Chief of Resources, pers. comm.).

The condition of anadromous fish in the McCarthy RZ is of moderate concern based on recent data showing low sockeye return rates at Long Lake weir. The last Long Lake weir count was in 2008 and yielded a record low for the 34 years the facility has been in operation (NPS 2009a).

The condition of anadromous fish in the Tetlin-Tanacross-North Country RZs is unknown. The Anadromous Waters Catalog (AWC) documents anadromous fish in this RZ, but no information that addresses the condition of the stocks that are present is available.

Distribution and Background

Anadromous fish are found in six of the nine RZs within WRST: Upper Copper River, Nabesna, McCarthy, Coastal - Icy Bay, Tetlin - Tanacross - North Country, and St. Elias/ Chugach Mountains. The Copper River and its tributaries are the most well known anadromous fish holding waters in WRST. The Copper River runs along the western boundary of the park, merging with many tributaries as it flows south to the Gulf of Alaska. Tributaries entering the Copper River originate from both within and outside WRST boundaries. (NPS PDS 2009a, Markis et al. 2004)

The southeast coastal streams located in the Coastal-Icy Bay RZ are also home to anadromous fish populations. Additionally, anadromous fish are present in the Chisana River, located in the far northeast portion of the park within the Tetlin-Tanacross-North Country RZ. (ADF&G 2009d, Markis et al. 2004) (Plate 17)

There are eight species of anadromous fish in WRST: sockeye salmon (*Oncorhynchus nerka*), Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus kisutch*), pink salmon (*Oncorhynchus gorbuscha*), chum salmon (*Oncorhynchus keta*), steelhead (*Oncorhynchus mykiss*), cutthroat trout (*Oncorhynchus clarkii*) and Dolly Varden (*Salvelinus malma*). Sockeye salmon are the most abundant anadromous fish in WRST and are thought to be present in approximately 125 Copper River tributaries. They are also the most harvested of all fish species in WRST (Wade et al. 2007). Chinook salmon (also known as king salmon), have at least five genetically unique populations in the basin and are also commonly harvested from the Copper River Basin. These stocks are present in the watersheds of the following rivers: Chitina, Tonsina, Klutina/Tazlina, Gulkana, and the Upper Copper (Seeb et al. 2005). Pink and chum salmon are native to the park and surrounding area, and make up only a small percentage of the total anadromous fish population. Coho salmon are found in tributaries to the Copper River downstream of the Klutina River. Steelhead are anadromous rainbow trout (*Oncorhynchus mykiss*); the Copper River steelhead are the northernmost population of the species (Burger et al. 1983). Today, steelhead spawn in multiple areas within the Gulkana, Tazlina, and Chitina drainages (Saveride 2008).

The Copper River Basin is the chief salmon-producing watershed in the WRST area. Management of Copper River salmon does not fall solely on the National Park Service; a majority of the anadromous waters in the watershed are outside of WRST. Analysis of the ADF&G Anadromous Waters Catalog (AWC) in the Copper River Basin has shown that 31% (807 km [502 mi]) of the rivers and streams that hold anadromous fishes in the watershed are located within WRST (NPS PDS 2009a). Substantial sockeye salmon populations are usually not found in drainages that lack large lakes (E. Veach pers. comm.). AWC waters of the Copper River Basin outside of WRST are connected to many more large lakes than those within the park. The total surface area of lakes connected to AWC waters outside of the park is 38,278 hectares (94,857 acres), and those in the park are connected to 2,732 hectares (6,751 acres) of surface area (USGS 2008, ADF&G 2009d). This information supports the hypothesis that the majority of sockeye salmon reproduction in the Copper River Basin takes place outside of WRST (E. Veach pers. comm.) (Table 17).

Table 17 Summary of Anadromous Waters in the Copper River Watershed, according to the Anadromous Waters Catalog and the National Hydrography Data set.

	Number of Anadromous Rivers/Streams	River/Stream Length (km)	Number of Lakes	Lake Total Surface Area (hectares)
In WRST	76	807	23	2,732
Out of WRST	200	1765	66	38,278

Reference Condition

Traditional ecological knowledge provides us with the best information about the reference condition of anadromous fish in WRST. There is evidence that the Ahtna near Gulkana began harvesting salmon no later than 1000 AD (Simeone and Valentine 2005). While data show an increase in Copper River salmon populations over recent time (ADF&G 2009a), the Ahtna people have provided evidence that many historic salmon stocks are no longer present (Simeone and Kari 2002). Ahtna accounts also reveal that once thriving populations of salmon in Tanada Creek and Cobb Lake are now extremely limited (Simeone and Kari 2002). TEK suggests that the current distribution of salmon stocks in the Copper River Basin is limited in comparison to the time of the early Ahtna.

Management

Currently, management of salmon in the Copper River Basin falls under the jurisdiction of ADF&G and NPS. Historically, Ahtna management was a community-based effort, with responsibility falling solely on the resource users (Simeone and Kari 2002). Simeone and Kari (2002) explained that the Ahtna viewed salmon as ―sentient beings who allow themselves to be caught if they are treated properly." The management philosophies of ADF&G and NPS are very different in comparison to one another and historical Ahtna views. According to the Alaska State Constitution, the goals for development and use of replenishible resources in Alaska are determined in accordance with the principle of sustained yield, for the maximum benefit of the people of the state (ADF&G 2009c). In order to implement this policy in Alaska's fisheries, the Alaska legislature created the Alaska Board of Fisheries (ABOF) and ADF&G (ADF&G 2009c). The enabling legislation for WRST directs NPS to maintain fish and wildlife habitat and populations. ANILCA also directs NPS to maintain healthy populations in preserve lands and natural and healthy populations in park lands. In addition, ANILCA directs WRST to place emphasis on subsistence harvest opportunities over sport or commercial harvest.

Prior to outside settlement, the Ahtna managed salmon in a socio/territorial manner (Simeone and Kari 2002). Clan leaders would regulate access and harvest in their respective territories (Simeone and Kari 2002). Present-day Copper River fishery management is very complex compared to historical Ahtna management. Salmon harvest within the Copper River Basin is performed under four categories: commercial, subsistence, sport, and personal use. Within Federal waters of the Copper River drainage, federal subsistence harvest occurs and is managed by the National Park Service. ABOF is responsible for setting seasons, bag limits, harvest methods; and means for the state‘s subsistence, commercial, sport, guided sport, and personal use fisheries (ADF&G 2009b). Federal subsistence harvest is managed by the Federal Subsistence Board, which is comprised of members from the Bureau of Indian Affairs, the

Bureau of Land Management, the National Park Service, the U.S. Fish and Wildlife Service, and the U.S. Forest Service (U.S. Fish and Wildlife Service 2009).

Demographics

There are four sources of salmon population data for the Copper River Basin: the Miles Lake sonar station (ADF&G), the Tanada Creek Fish Weir (NPS2009b), the Long Lake Fish Weir (NPS2009a) and the Gulkana River Tower (ADF&G).

Yearly data collected from the Miles Lake sonar station help to determine upriver spawning escapement. Upriver spawning escapement is the best indicator of salmon population health in the Copper River Basin (E. Veach pers. comm.). From 1997 to 2007, a mean of 530,647 sockeye salmon escaped upstream from the Miles Lake sonar station to spawn in the Copper River Basin (Lewis et al 2008, Figure 34). Over that same time span, 1997 had the most escapement after harvest with an estimated 749,571 salmon, and 2000 had the least escapement with an estimated 302,464 salmon (Lewis et al. 2008). From 1997 to 2007, mean Chinook salmon escapement following harvest was 25,287 salmon per year, with a maximum of 59,406 in 2006, and a minimum of 11,386 in 2008 (Lewis et al 2008, Figure 35).

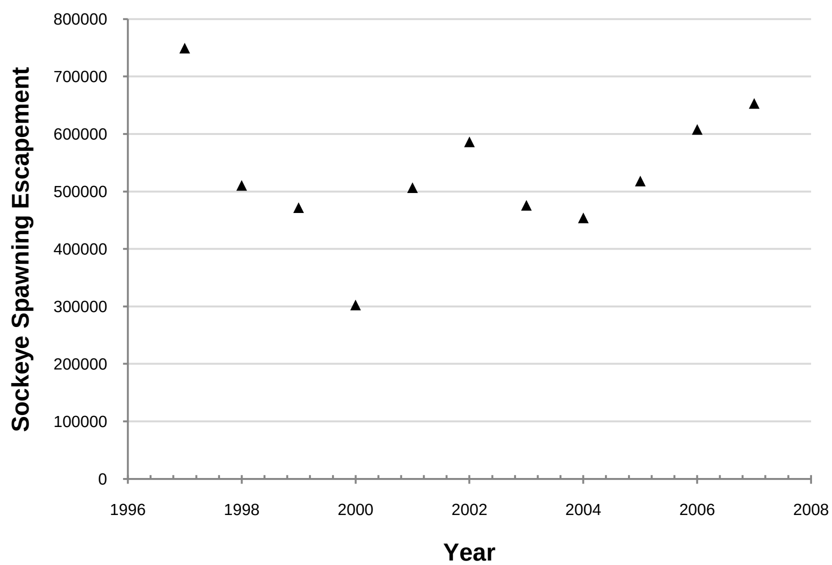


Figure 34. Annual sockeye salmon spawning escapement in the Copper River Basin, upstream of Miles Lake, 1997-2007. (ADF&G 2009a)

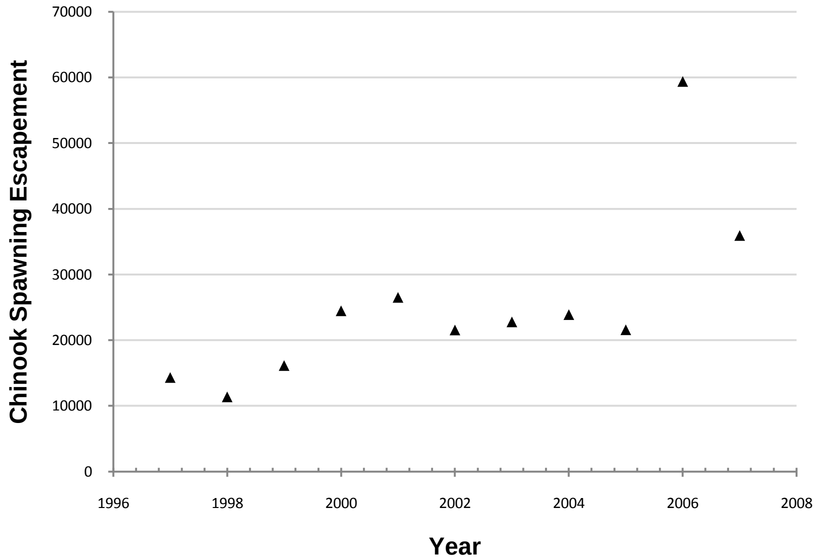


Figure 35. Annual Chinook salmon spawning escapement in the Copper River Basin, upstream from Miles Lake, 1997-2007. (ADF&G 2009a)

The Tanada Creek and Long Lake weirs provide information about specific salmon stocks located in the Copper River system. NPS began operating the Tanada Creek weir in 1997 (NPS 2009b). Data from the weir were available for the following years: 1997, 1998, and 2001 through 2008 (Sarafin 2009). The Tanada Lake sockeye salmon population, one of the uppermost sockeye salmon stocks in the Copper River drainage, supports both the Copper River and Batzulnetas subsistence fisheries (Sarafin 2009). The mean run size estimate, based on Tanada Creek weir data, is 10,366 salmon per year; mean run size ranged from 2,850 in 2008, to 28,992 in 1998 (Sarafin 2009, Figure 36)

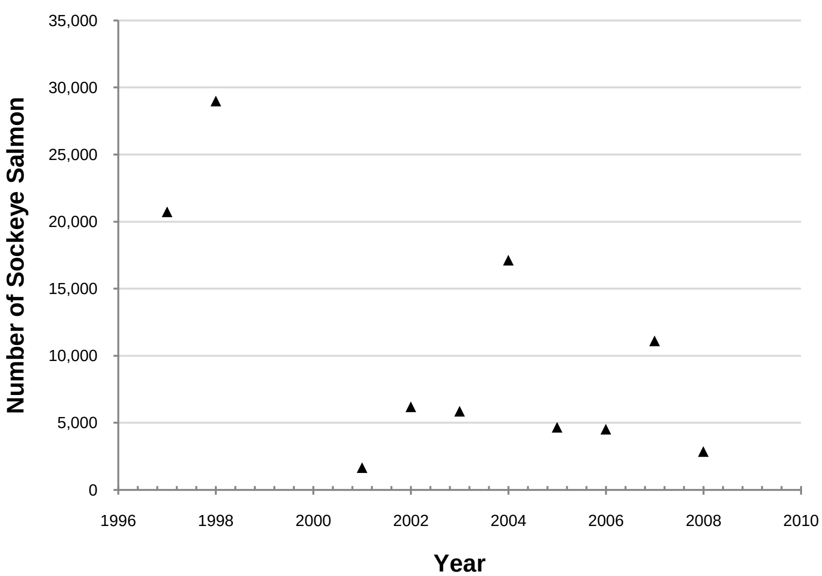


Figure 36. Yearly sockeye salmon counts at the Tanada Creek Weir, 1997-2008. The weir is located 16 kilometers southeast of Slana and 160 meters downstream from the Batzulnetas fish camp. (McCormick and Sarafin, 2008)

The salmon of Long Lake are of particular biological interest because they have the longest known annual spawning duration, August through April, of any sockeye salmon in North America (NPS, 2009a). In 1974, the Long Lake weir began operation under ADF&G. In 1976, Cliff Collins, owner of the land where the weir is located, voluntarily took over operation of the weir when ADF&G was no longer able to fund the operation. In 2003, when Collins was unable to continue operation of the weir, NPS took over operation. The Long Lake weir has provided 35 years of data, more than any other salmon weir counting station in the Copper River Basin. The mean run size over the duration of data for Long Lake is 16,110 salmon per year, ranging from 631 salmon in 2008 to 50,000 salmon in 2002 (McCormick 2008, Figure 37).

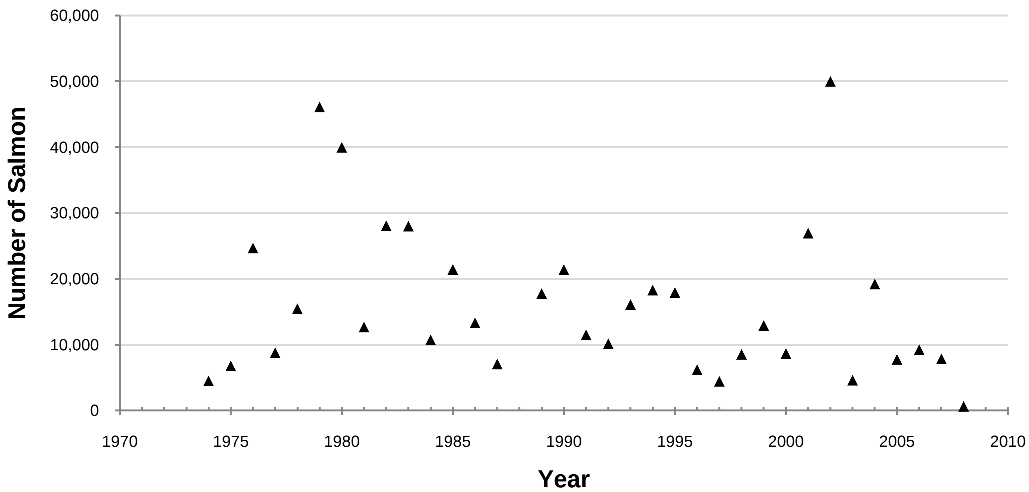


Figure 37. Yearly fish counts at the Long Lake Weir, 1974-2008. (Lewis et al. 2008, NPS 2009a)

Gulkana River fish count data are available yearly since 2003 (ADF&G, 2009a). The Gulkana River is a Copper River tributary, located outside of WRST. Both sockeye and Chinook salmon counts take place at the Gulkana River counting tower. Sockeye salmon counts at the Gulkana counting tower have averaged 19,229 fish per year; 2006 and 2007 were outliers, with counts of 34,428 and 30,766, respectively (Figure 38). The mean number of Chinook counted at the Gulkana station from 2003 to 2009 was 3,738, with a high of 5,502 in 2003 and a low of 2,658 in 2005 (Figure 39).

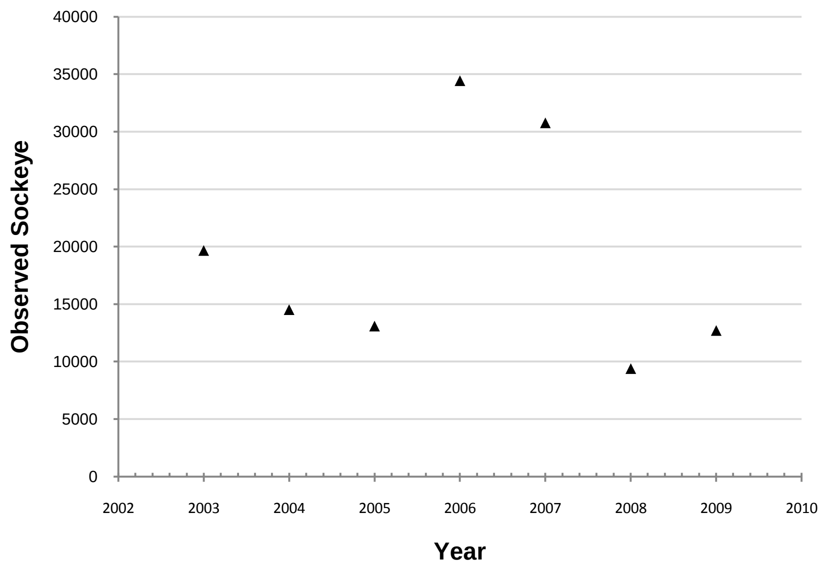


Figure 38. Yearly sockeye salmon counts at the Gulkana River Tower, 2003-2009. Counts were performed from late May to early August. (ADF&G 2009a)

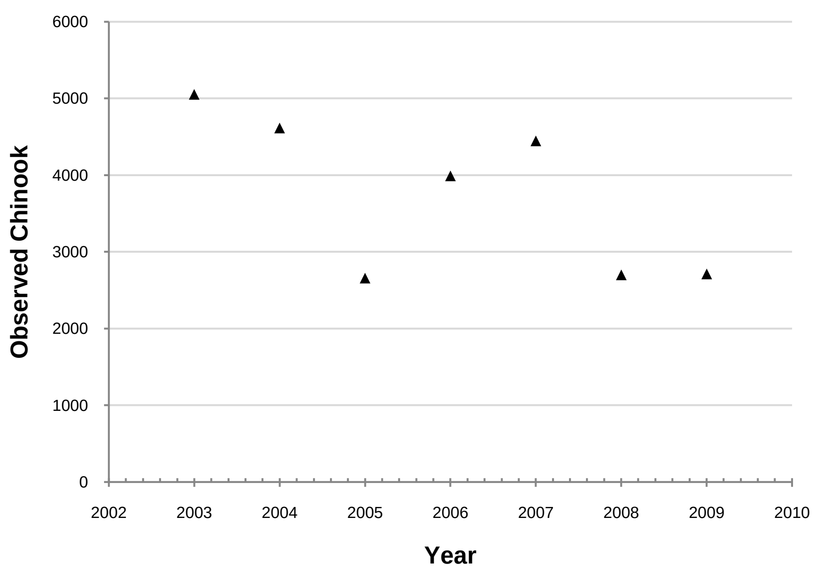


Figure 39. Yearly Chinook salmon counts at the Gulkana River Tower, 2003-2009. Counts were performed from late May to early August. (ADF&G 2009a)

Another important aspect of the Copper River salmon fishery is the use of hatchery raised fish to augment salmon populations. There is one hatchery present within the Copper River drainage, and it is located on the Gulkana River. The ADF&G funded Gulkana Hatchery is operated by the Prince William Sound Aquaculture Corporation. The Gulkana Hatchery is the largest sockeye salmon fry producer worldwide. From 1996-2006, an average of 22 million sockeye salmon fry per year have been released into the Gulkana River Watershed, with a mean return rate of 1.28% (Prince William Sound Aquaculture Corporation 2009).

Harvest

Commercial harvest of anadromous fish has been gradually increasing over the last 30 years (Figure 40). Of all salmon commercially harvested during this time, sockeye salmon make up 70% of the total, followed by coho (24%) and Chinook (2.9%). Pink and chum salmon account for 1% (Lewis et al. 2008). Subsistence harvest of sockeye salmon has remained relatively stable from 1996 to 2007 (Figure 41) (Lewis et al. 2008).

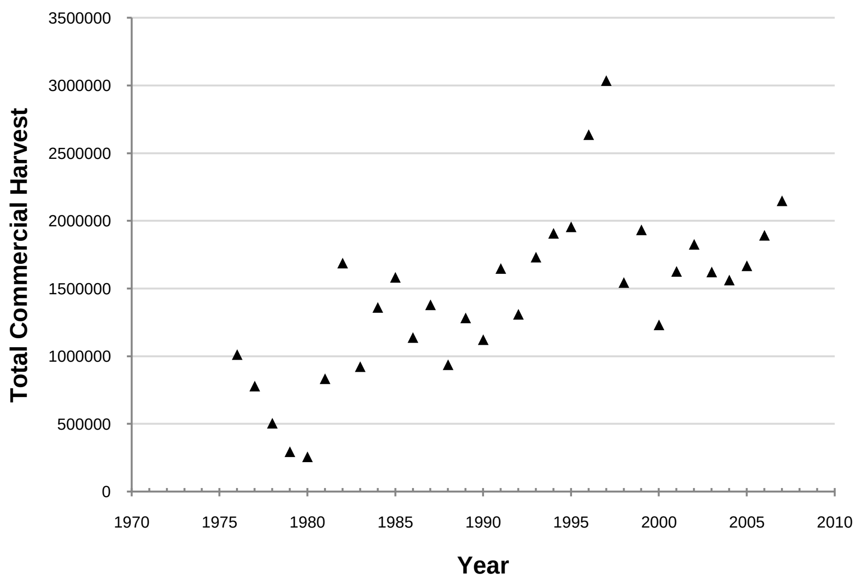


Figure 40. Total commercial harvest of salmon in the Copper River District, 1976-2007. (Lewis et al. 2008)

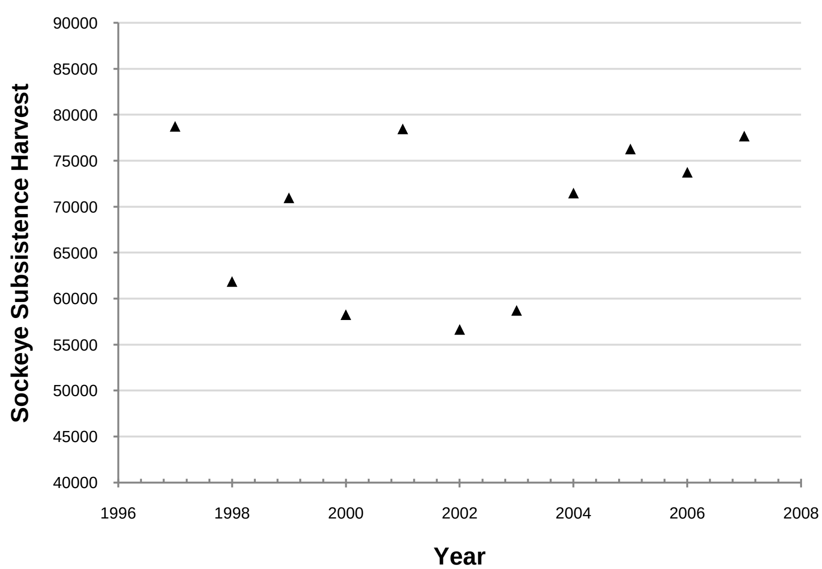


Figure 41. Number of sockeye salmon harvested for subsistence purposes, 1997-2007, Glennallen and Batzulnetas state subsistence; Glennallen and Chitina federal subsistence. (Lewis et al. 2008)

Of all sockeye salmon originating from the Copper River Watershed from 1997 to 2007, 59.7% were harvested commercially, 21.9% were not harvested and could potentially spawn upstream of Miles Lake, 6.9% escaped to the Copper River Delta, 4.5% were harvested for personal use, 2.9% were harvested for subsistence, 3.1% contributed to hatchery broodstock, and 0.4% were harvested for sport (Lewis et al. 2008, Figure 42). Of all returning adult Chinook from 1997 to 2007, 52.9% were harvested commercially, 30.7% escaped to spawn upstream of Miles Lake, 6.6% were harvested for sport, 4.9% were harvested for personal use and 4.7% were harvested for subsistence (Lewis et al. 2008, Figure 43).

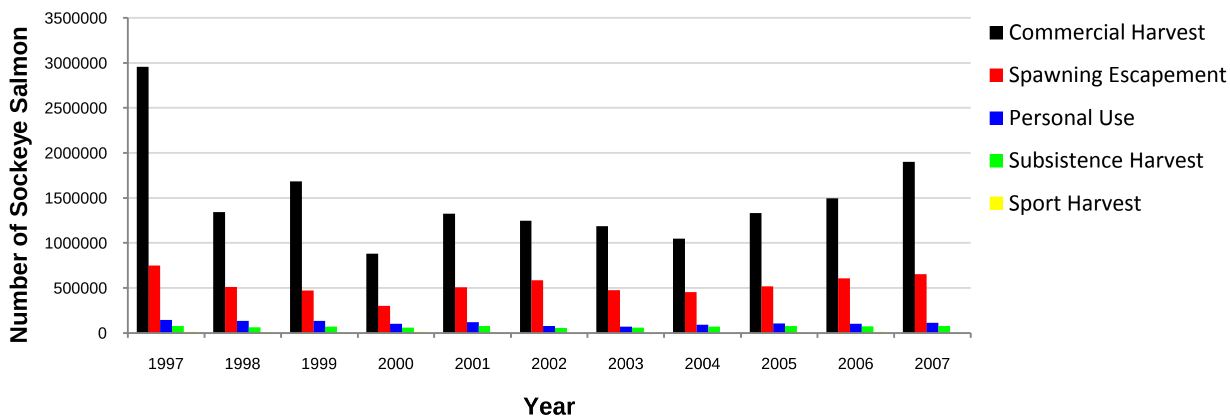


Figure 42. Yearly fate of returning adult sockeye salmon in the Copper River, 1997-2007. (Lewis et al. 2008)

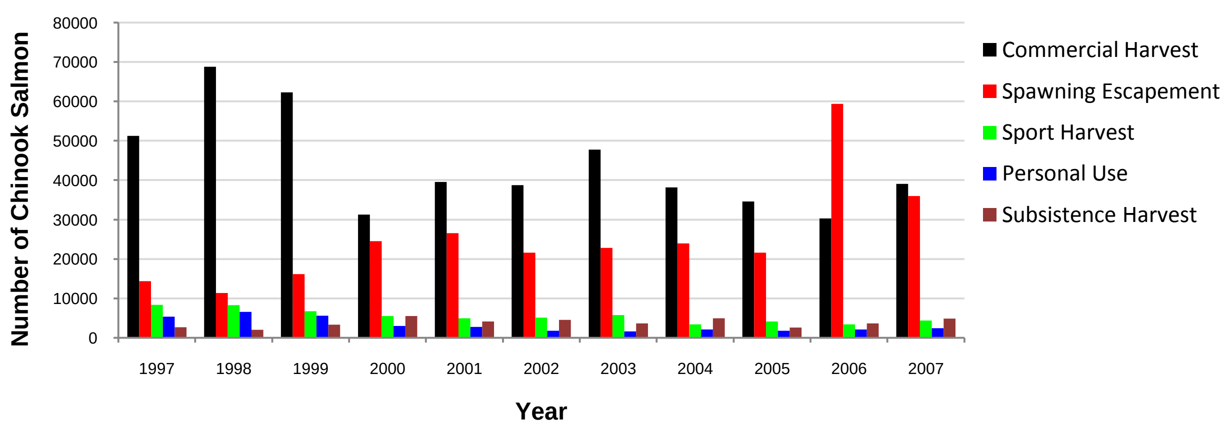


Figure 43. Yearly fate of returning adult Chinook salmon in the Copper River, 1997-2007. Data were retrieved from the Alaska Department of Fish and Game. (Lewis et al. 2008)

Stressors

NPS staff identified a suite of stressors that could affect salmon stocks in WRST. These included commercial harvest, recreational harvest, subsistence harvest, climate change, invasive species, oil development, and construction and presence of pipelines. Currently, commercial harvest has the greatest effect on salmon stocks in the Copper River Basin. Each year, on average (1997-2007), 60% of returning sockeye salmon and 53% of returning Chinook salmon are harvested commercially (Lewis et al. 2008). Recreational and subsistence fisheries do not influence the entire salmon population as significantly as the commercial fishery does, but these fisheries can affect unique salmon stocks. Seeb et al. (2005) identified multiple unique stocks of Chinook salmon in the Copper River drainage. The Ahtna people have also explained that there are many different types of sockeye salmon present across many different stream reaches (Simeone and Kari 2002). ADF&G is currently gathering genetic information regarding specific Copper River sockeye salmon stocks, but these data have yet to be published (E. Veach pers. comm.).

Invasive species are of major concern to salmon populations throughout Alaska. Atlantic salmon *(Salmo salar)* farms in British Columbia and the Pacific Northwest pose a threat to salmon fisheries in Alaska because of the Atlantic salmon's ability to outcompete native species (ADF&G 2002). Accidental and deliberate releases of Atlantic salmon from holding pens are common. ADF&G (2002) stated, "Deliberate release of ‗non-performing' fish (estimated at 3-5% of production) total hundreds of thousands of fish annually and this number is neither precisely known nor reported." In 2002, an Atlantic salmon (*Salmo salar*) was captured in salt water at the tidal edge of the Copper River delta. Species identification was confirmed through genetic analysis (Nielsen et al. 2003).

Climate change has the potential to affect both lentic and lotic ecosystems in WRST. Small, standing bodies of water in WRST have been decreasing in size since the 1950s (Weeks 2003). Permafrost thawing can change the hydrology of stream systems by altering sediment, stream flow, and temperature regimes in nearby streams (Oswood et al. 1992). Altered atmospheric temperatures at high latitudes could also change net primary production, sediment loads, and habitat complexity in lotic systems (Williams 1989). It is suggested that increased temperatures and carbon dioxide levels will alter the distribution of plants, consequently altering the amount of leaf litter and woody debris in waters (Meyer and Pulliam 1992, Sweeney et al. 1992). It is also possible that warming waters may result in juvenile salmon spending less time in freshwater because of increased growth rates (E. Veach pers. comm.).

Culverts can prove to be an overwhelming obstacle to fish movement if not properly designed and maintained (Kane et al. 2000). Most of the available literature on culverts and fish passage is species specific and not applicable to all species. However, poorly designed culverts, such as those with unusually high perches or steep gradients, can inhibit all fish passage in a certain direction. Such culverts are in WRST, as documented by Copper River Watershed Project (CRWP) surveys, and are a concern for both anadromous and resident fish populations. Plate 18 shows the locations of known culverts along the roads within and adjacent to WRST. The CRWP culvert database (2008) has coordinate locations of 28 known culverts along McCarthy Road; ten are perched downstream and could limit upstream fish movement.

A culvert inventory performed by ADF&G counted 33 culverts between the towns of Gulkana and Nabesna, along the Tok Cutoff Highway and Nabesna Road. In order to assess probability of fish passage, known culverts were classified based on culvert gradient, degree of channel constriction, and perch height independent of daily flow conditions. Culverts were classified as red (assumed inadequate for fish passage), gray (additional data collection and analysis needed), or green (assumed adequate for fish passage). Of the culverts investigated between Gulkana and Nabesna, 13 (39%) were classified red, 19 (58%) were classified gray, and only one (3%) was classified green (Plate 18).

Data Needs

Because of accessibility issues in WRST, a complete inventory of anadromous waters would be highly difficult. Little information is available regarding specific salmon stocks within WRST, with the exception of Tanada Creek and Long Lake Weir data. In addition, limited documentation or information exists regarding salmon stocks in the southeastern coastal waterways. In addition, the Native Village of Eyak performs mark-recapture studies to determine sockeye salmon abundance in the Copper River, this information should be incorporated in future analysis (van den Broek et al. 2009).

Additional data are needed for many of the waterways and their associated culverts along McCarthy and Nabesna Roads. Research into fish passage of known culverts along McCarthy Road would provide better information about whether or not these culverts are stressing salmon populations by preventing passage or migration. In addition, further investigation of gray class culverts along Tok Cutoff Highway and Nabesna Road is needed.

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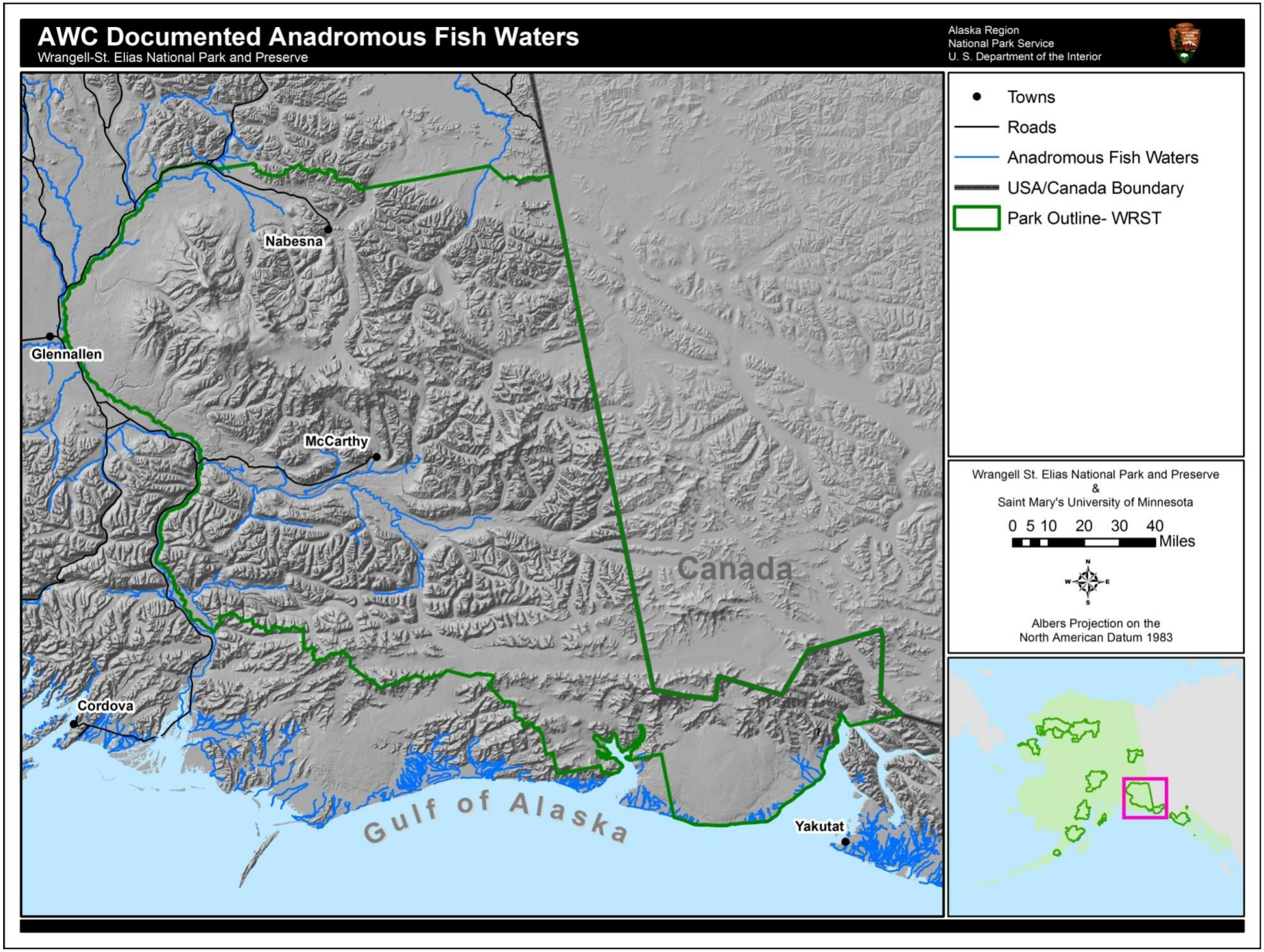


Plate 17. Documented anadromous fish waters from Anadromous Waters Catalog. (NPS PDS 2009a)

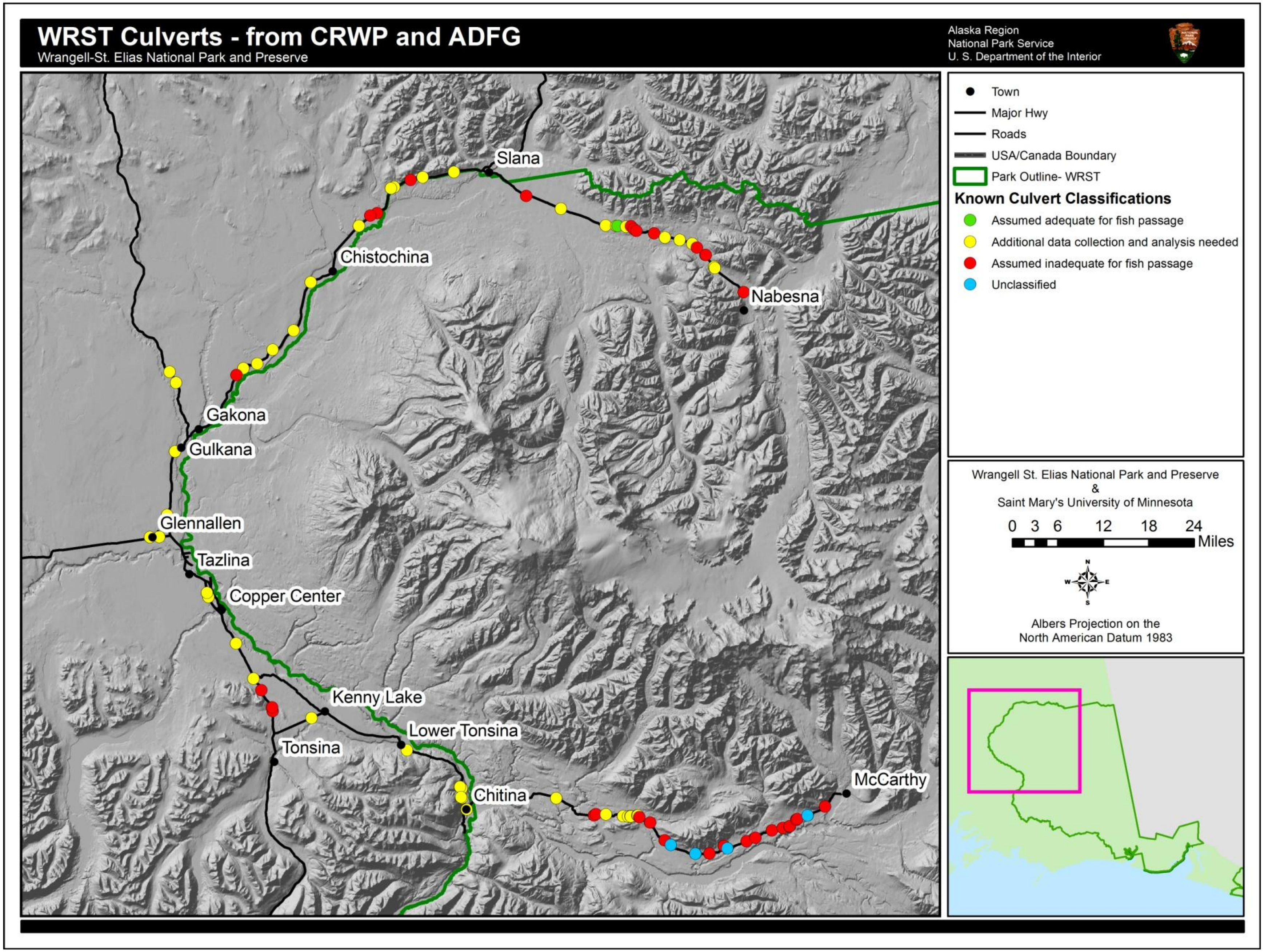
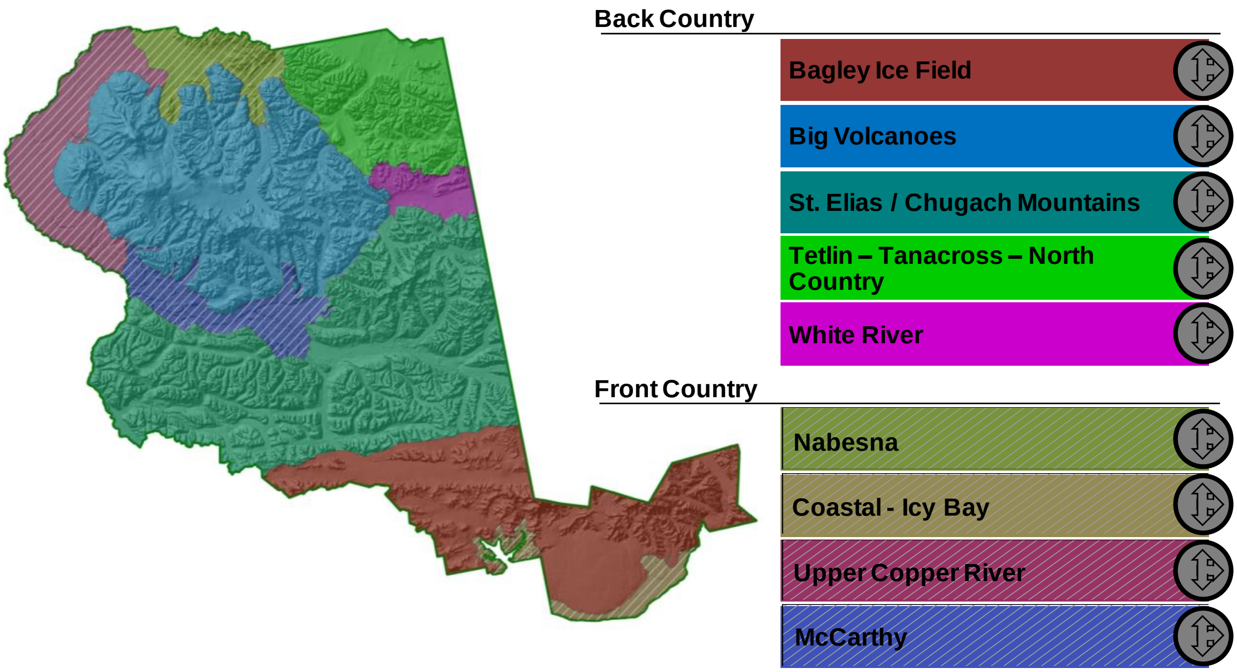


Plate 18. Known culvert locations in WRST along McCarthy Road, Nabesna Road, and the Alaska Highway. (NPS PDS 2009b, CRWP 2009)

4.12 Resident Fish

Indicators and Measures
Population Status and Distribution



Condition
The condition of resident fish in WRST is largely unknown, due to the lack of a quantified reference condition. No information is available that explains the NPS defined reference condition "natural and healthy populations." However, recent surveys have developed a partial presence/absence and distribution listing of resident freshwater fish in the Park. In the future, distribution data from surveys could be used as a reference condition for similar analyses. No population data of resident fish at a landscape level is available.

Distribution and Background

Data gathered from literature searches and from ongoing inventory surveys started in 2001 document different 22 species of fish in WRST‘s freshwater systems (Table 18, Markis et al, 2004, McCormick personal communication). Plate 19 through Plate 25 show the known distributions of resident fish in WRST, based on data from the 2004 freshwater fish survey.

Table 18. Current resident fish species present within WRST (Markis et al, 2004, McCormick personal communication)

Common Name(s)	Scientific Name
Arctic grayling	*Thymallus arcticus*
burbot	*Lota lota*
Chinook salmon, king salmon	*Oncorhynchus tshawytscha*
chum salmon	*Oncorhynchus keta*
coho salmon, silver salmon	*Oncorhynchus kisutch*
cutthroat trout	*Oncorhynchus clarkii*
Dolly Varden	*Salvelinus malma*
humpback whitefish	*Coregonus pidschian*
lake trout	*Salvelinus namaycush*
longnose sucker	*Catostomus catostomus*
pink salmon	*Oncorhynchus gorbuscha*
rainbow trout, Steelhead,	*Oncorhynchus mykiss*
round whitefish	*Prosopium cylindraceum*
slimy sculpin	*Cottus cognatus*
sockeye salmon	*Oncorhynchus nerka*
threespine stickleback	*Gasterosteus aculeatus*

WRST is also host to a diverse marine-estuarine fish community. Arimitsu et al. (2003) performed a study that aimed to inventory both marine and estuarine fishes of southeast and central Alaska National Parks. The goal of the study was to establish baseline information about fish communities in these overlooked portions of Alaska‘s National Parks. The survey documented 32 different species from 16 families in WRST (Table 19), 16 species in pelagic habitats, 14 species in demersal habitat, and 14 species in near shore habitats. Sampling during this study was restricted due to floating ice in Icy and Yakutat bays.

Table 19. Marine-estuarine species present in WRST. (Arimitsu et al. 2003)

Common Name	Scientific Name
arrowtooth flounder	*Athereshes stomias*
bigmouth sculpin	*Hemitripterus bolini*
buffalo sculpin	*Enophrys bison*
capelin	*Mallotus villosus*
crescent gunnel	*Pholis laeta*
daubed shanny	*Lumpenus maculatus*
Dover sole	*Microstomus pacificus*
eulachon	*Thaleichthys pacificus*
flathead sole	*Hippogossoides elassodon*
great sculpin	*Myoxocephalus polyacanthochephalus*
longfin smelt	*Spirinchus thaleichthys*
longsnout prickleback	*Lumpenella longirostris*
Pacific cod	*Gadus macrocephalus*
Pacific herring	*Clupea pallasii*
Pacific sand lace	*Ammodytes hexapterus*
Pacific sandfish	*Trichodon trichodon*
Pacific spiny lumpsucker	*Eumicrotremus orbis*
pink salmon	*Oncorhynchus gorbuscha*
rock greenling	*Hexagrammos lagocephalus*
shortfin eelpout	*Lycodes brevipes*
slender sole	*Lyopsetta exilis*
snailfish	*Liparis* spp.
snake prickleback	*Lumpenus sagitta*
soft sculpin	*Psychorolutes sigalutes*
spineyhead sculpin	*Dasycottus setiger*
starry flounder	*Platichthys stellatus*
stout eelblenny	*Anisarchus medius*
surf smelt	*Hypomesus pretiosus*
sidepool sculpin	*Oligocottus maculosus*
walleye polluck	*Theragra chalcogramma*
wattled eelpout	*Lycodes palearis*
whitespotted greenling	*Hexagrammos stelleri*

Reference Condition

No data are available that describe the reference condition "natural and healthy." TEK documentation related to population or distribution of resident fish is minimal. In addition, no historical survey or monitoring data are available for resident fish species in the park. However, current knowledge of resident fish distribution in WRST, from recent survey efforts, may act as a reference condition for future analyses regarding condition.

Demographics

No data are available that describe long-term trends of resident fish populations in WRST. This makes survey data published in association with Markis et al. (2004) the best data source for information regarding resident fish for WRST. Future monitoring of the sites that were surveyed Markis et al. (2004) could prove valuable in determining presence/absence trends in resident fish populations of sampled waters in upcoming years.

Harvest

Historically, non-salmon fish such as whitefish, trout, Arctic grayling, and burbot were crucial to the subsistence economy of the Copper Basin (Simeone and Kari 2005). However, records of non-salmon fisheries in the Copper Basin prior to 1960 are rare, and available data are limited to major lakes and streams (Simeone and Kari 2005). The ADF&G 1987 Copper Basin/Upper Copper River community survey and the ADF&G Division of Subsistence 2002 Copper Basin community survey indicate a continued reliance on non-salmon fish.

The most frequently reported non-salmon species harvested include (from most to least harvested) Arctic grayling, burbot, rainbow trout, lake trout, Dolly Varden, and whitefish within the Copper River Basin communities of Chistochina, Chitina, Copper Center/Silver Springs, Gakona, Glennallen, Gulkana, Kenny Lake, Lake Louise, McCarthy/McCarthy road, Mendeltna, Mentasta, Nelchina, Paxson, Slana, Tazlina/Copperville, Tolsona, Tonsina, and Willow Creek (Simeone and Kari 2005, ADFG 2009, Table 20). This represents the most current information available regarding the current harvest of non-salmon fish by communities in or near WRST.

Table 20. Non-salmon fish harvest, Copper Basin Communities, 2001. (ADF&G 2009)

Community	Non-salmon harvest per capita (lbs)	Mean non-salmon harvest/ household (lbs)	Total non-salmon harvest (lbs)
Chistochina	6.7	14.4	533.9
Chitina	2.5	6.5	240.9
Copper Center	5.8	18.3	3256.8
Gakona	8.1	24.2	2039.1
Glennallen	2.8	8.0	1637.5
Gulkana	6.8	13	431.4
Kenny Lake	5.0	9.9	1415.7
Lake Louise	31.9	66.8	2728.8
McCarthy/ Mc. Road	3.2	8.0	378.9
Mendeltna	4.1	6.9	159.9
Mentasta	6.5	17.9	967.4
Nelchina	19.4	6.1	525.7
Paxson/Sourdough	6.3	11.4	240.4
Slana	18	35.4	2198.5
Tazlina	5.8	14.6	1756.5
Tolsona	2.7	5.6	84.2
Tonsina	4.9	10.3	352.2
Willow Creek	2.8	5.9	472

Stressors

NPS staff identified many stressors to resident fish, including non-native species, water quality, culverts, roads, OHV stream crossings, land cover change from non-natives, climate change affecting land cover, vertical (elevation) distribution of aquatic habitat types/characteristics, and subsistence harvesting.

Poorly designed or maintained culverts can be an overwhelming obstacle to fish movement (Kane et al. 2000). Of the 28 known culverts on the McCarthy Road, ten are perched downstream and could limit upstream fish movement as documented by the Copper River Watershed Project (CRWP) in 2008 (Plate 26). Another culvert inventory, performed by ADF&G, counted 33 culverts between the towns of Gulkana and Nabesna, along the Tok Cutoff Highway and Nabesna Road: 13 (39%) of these were classified inadequate for fish passage (Plate 26). ADF&G classified known culverts into three groups that indicate fish passage ability: red (assumed inadequate for fish passage), gray (additional data collection and analysis needed), and green (assumed adequate for fish passage). The three variables used to determine fish passage ability were culvert gradient, degree of channel constriction, and perch height independent of daily flow conditions. Of the culverts sampled between Gulkana and Nabesna: 13 (39%) were classified red, 19 (58%) were classified gray and only one (3%) was classified green (Plate 26).

OHV stream crossings are also potential stressors on resident fish. Point data inventorying OHV trail features in the Nabesna, Tetlin-Tanacross-North Country and McCarthy RZs was compiled from 2004 to 2007 by the WRST National Park OHV Technical Assistance Team (NPS PDS, 2009a). This data documented 197 OHV stream crossings in the Nabesna RZ (Plate 27), 39 OHV stream crossings in the McCarthy RZ (Plate 28), and 31 OHV stream crossings in the Tetlin Tanacross-North Country RZ (Plate 29).

Climate change could affect both lentic and lotic systems in WRST. Small, standing bodies of water in WRST have been decreasing in area since the 1950s (Weeks 2003). Permafrost thawing can change the hydrology of stream systems by altering sediment, stream flow, and temperature regimes in nearby streams (Oswood et al. 1992). Altering of atmospheric temperatures at high latitudes could also change net primary production, sediment loads, and habitat complexity in lotic systems (Williams 1989). It is also possible that increased temperatures and carbon dioxide levels will alter the distribution of plants, consequently altering the amount of leaf litter and woody debris in waters (Meyer and Pulliam 1992, Sweeney et al. 1992). Changes in the aforementioned variables would have considerable effects on fish species composition in WRST streams, lakes, and rivers (Hood et al. 2006).

Water quality and aquatic habitat information is very limited for WRST. Stream and riparian monitoring protocols are in development for the Central Alaska Network (Simmons, 2006).

Data Needs

An accurate and complete distribution profile of resident fish in WRST would be beneficial information for park management, but completing an inventory of this magnitude would be very challenging given the size of the park and the extent of the waterways and water bodies (Markis et al. 2004). The vast and rugged terrain of WRST makes an intensive survey seem both impractical and uneconomical. The 2004 Freshwater Fish Inventory provides the most comprehensive information about resident fish population status and distribution in WRST, but only a fraction of the total waters in the park were included in that effort. Increased monitoring of resident fish populations in areas that sustain increased impact from stressors may be the best investment of resources.

Although limited information is available about resident fish communities in WRST, there is some information available regarding stressors that affect them. Research into the effects of culverts, OHV crossings, and other human use factors on resident fish would undoubtedly help park management. Information regarding climate change and its effects on high latitude hydrology could be used to denote areas that would be most susceptible to impacts if changes in climate occur in the future. Lastly, increased monitoring of sport harvest of resident fish would provide valuable information about areas where most fishing pressure occurs and where management of aquatic resources is most needed.

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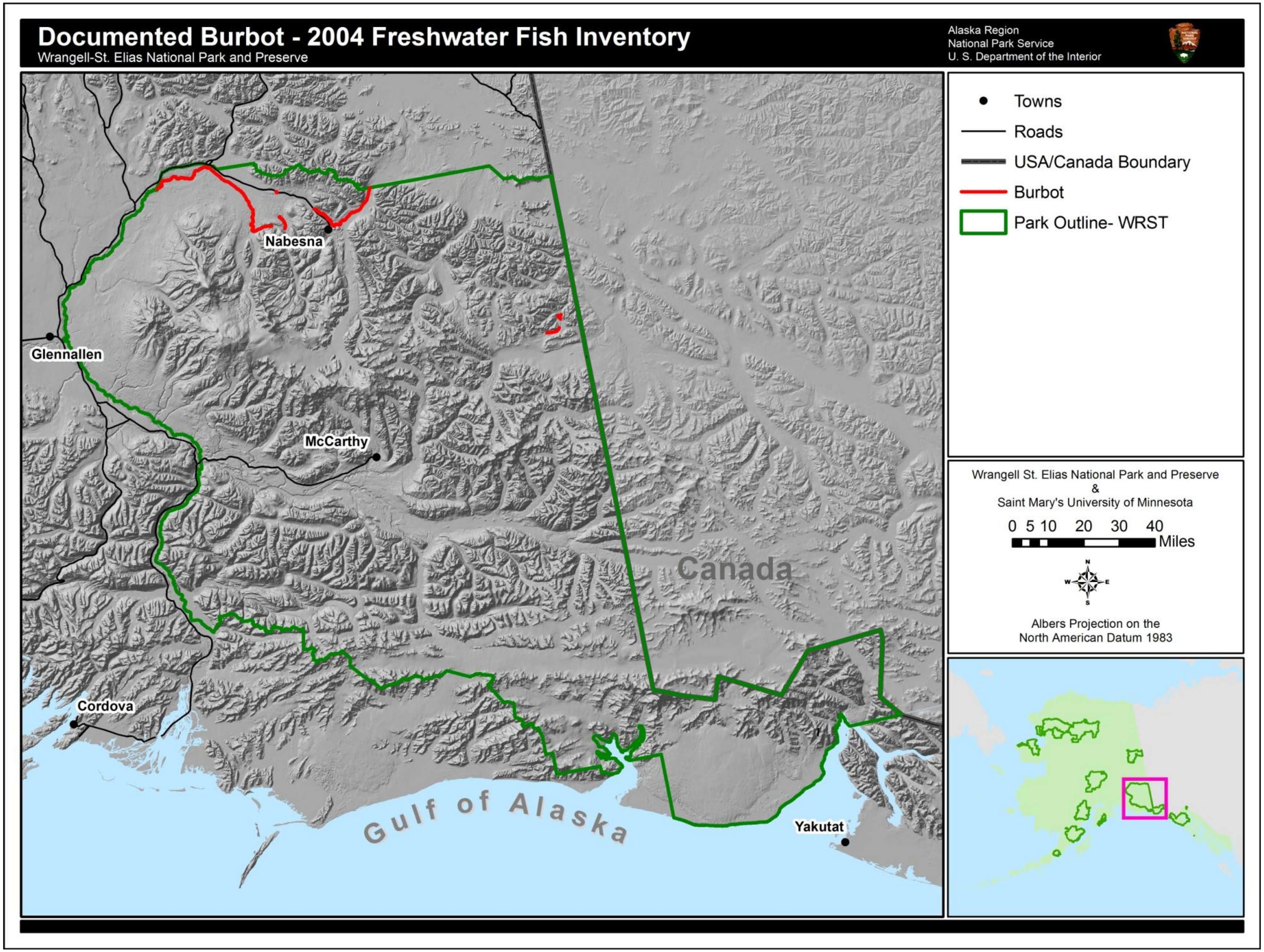


Plate 19. Documented Burbot distribution, 2004 Freshwater Fish Inventory. (Markis et al. 2004)

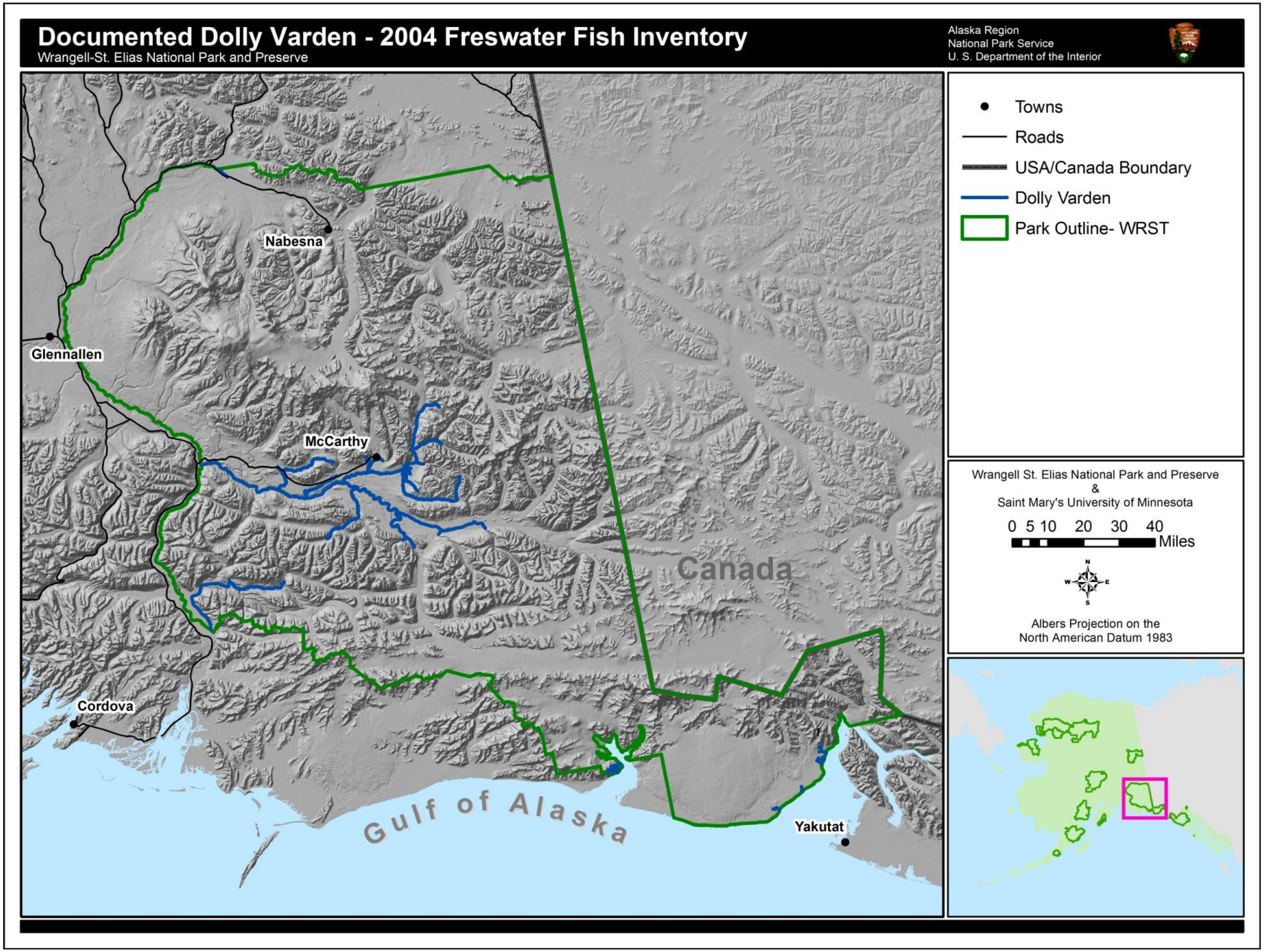


Plate 20. Documented Dolly Varden distribution, 2004 Freshwater Fish Inventory. (Markis et al. 2004)

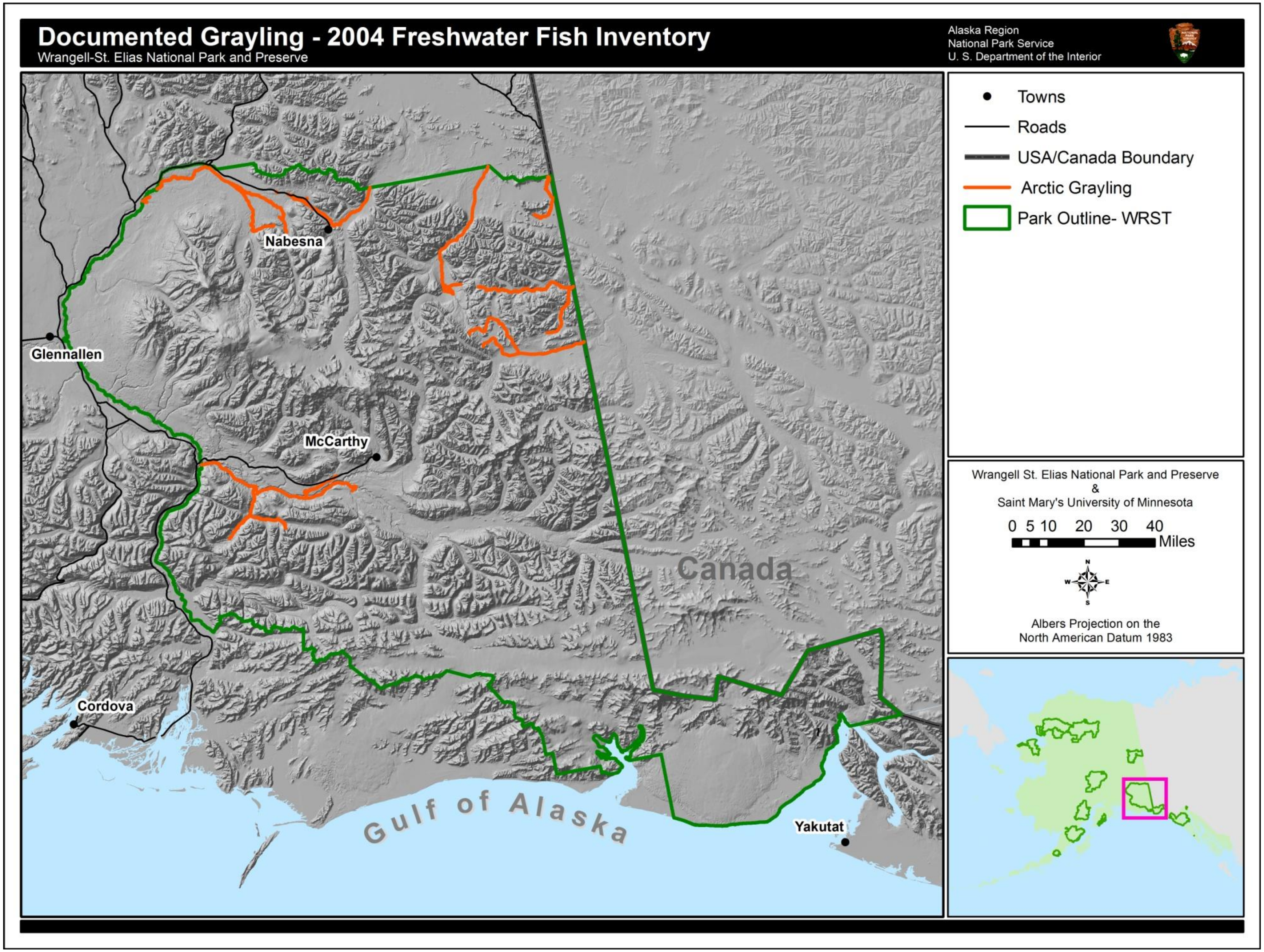


Plate 21. Documented Grayling distribution, 2004 Freshwater Fish Inventory. (Markis et al. 2004)

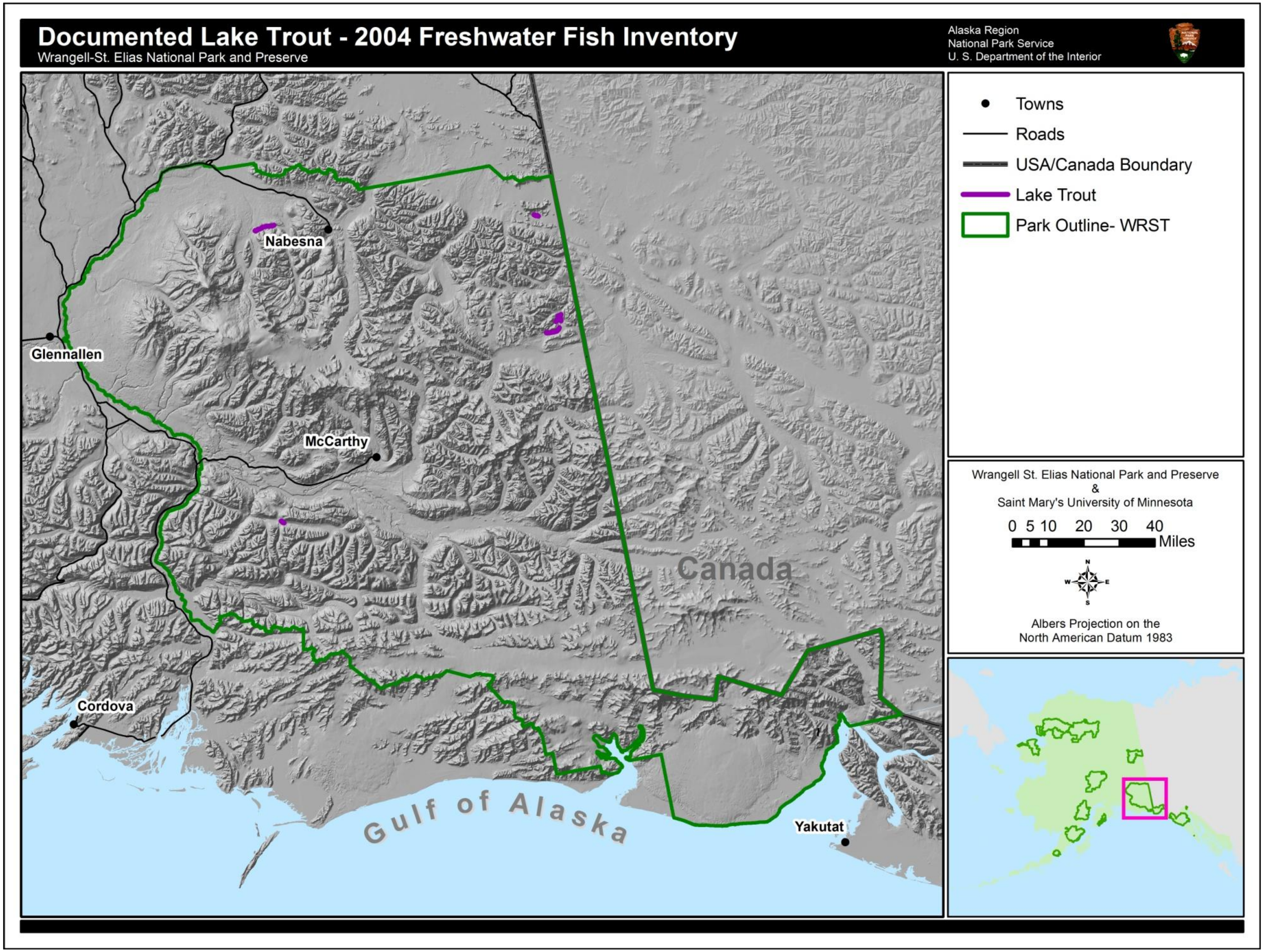


Plate 22. Documented Lake trout distribution, 2004 Freshwater Fish Inventory. (Markis et al. 2004)

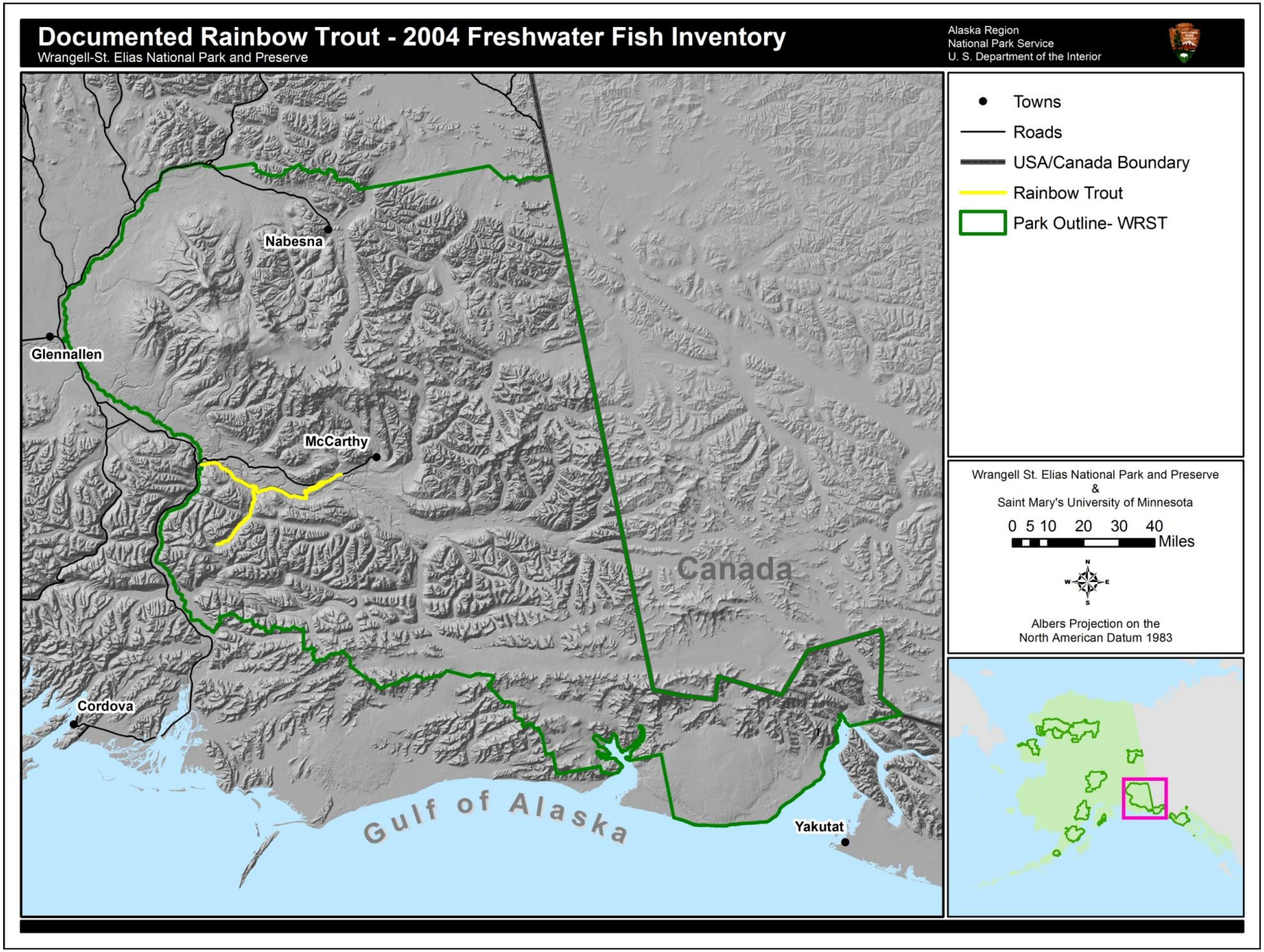


Plate 23. Documented Rainbow trout distribution, 2004 Freshwater Fish Inventory. (Markis et al. 2004)

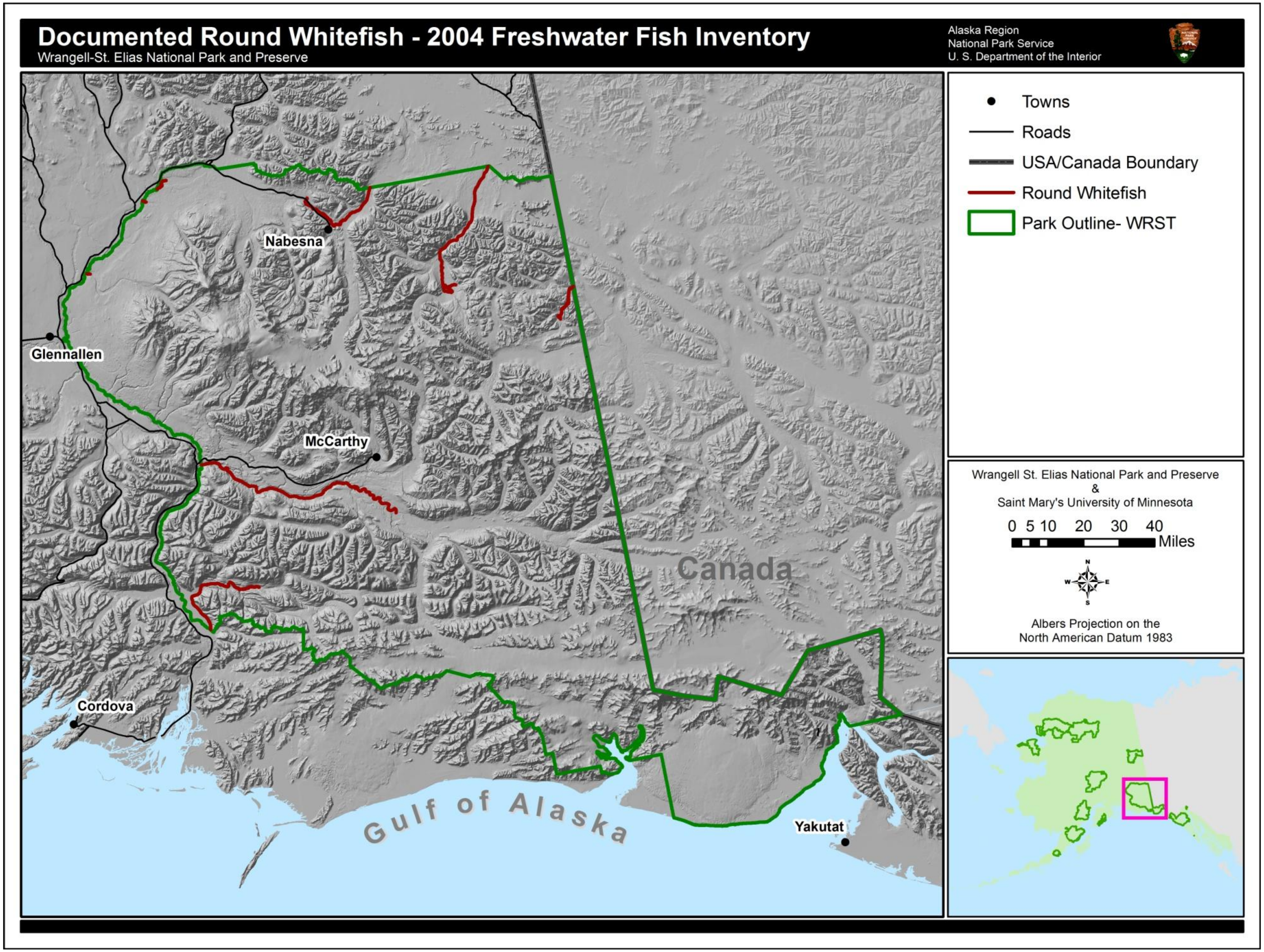


Plate 24. Documented Round whitefish distribution, 2004 Freshwater Fish Inventory. (Markis et al. 2004)

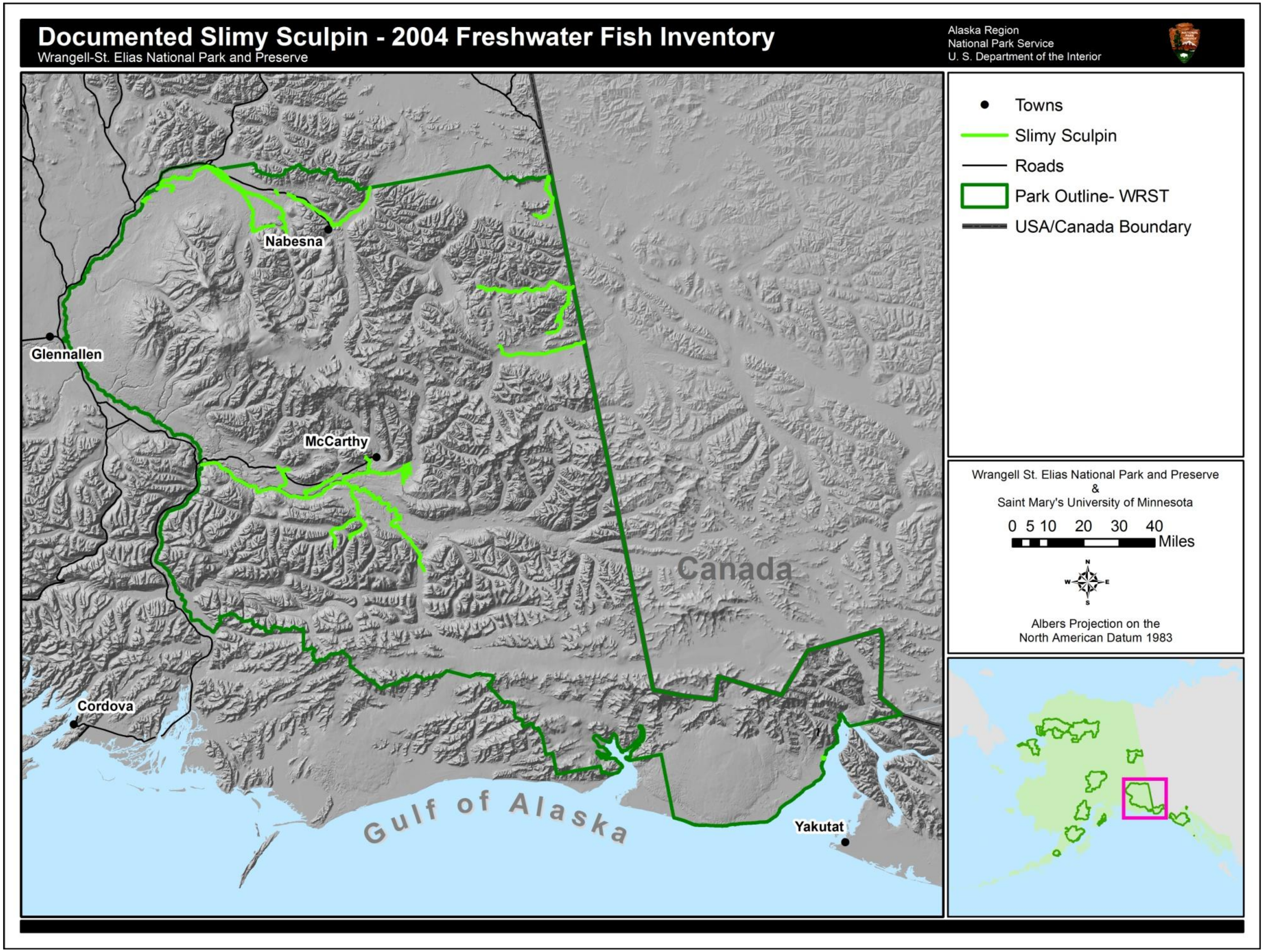


Plate 25. Documented Slimy sculpin distribution, 2004 Freshwater Fish Inventory. (Markis et al. 2004)

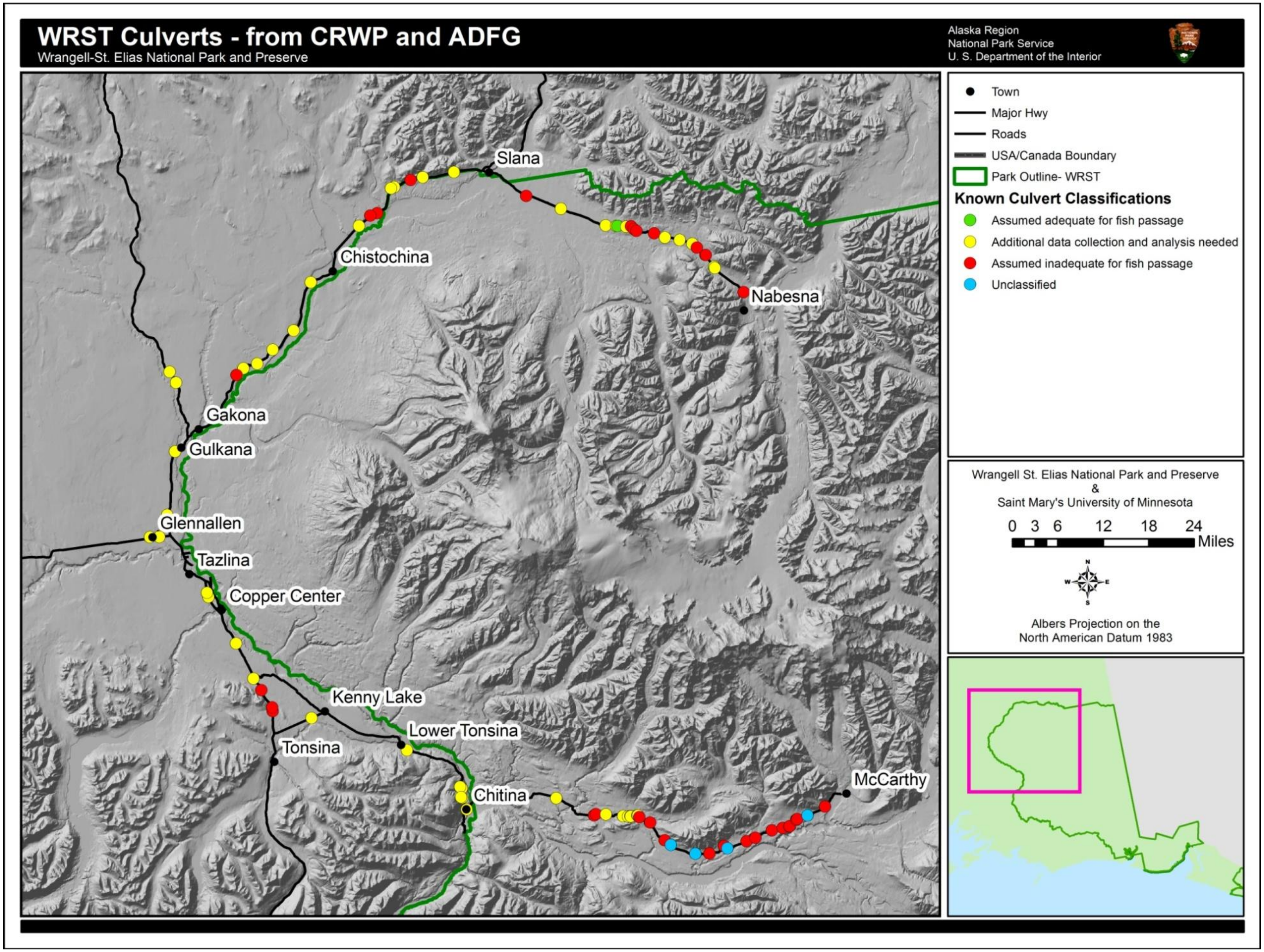


Plate 26. Known culvert locations in WRST along McCarthy Road, Nabesna Road, and the Alaska Highway. (NPS PDS 2009b, CRWP 2009)

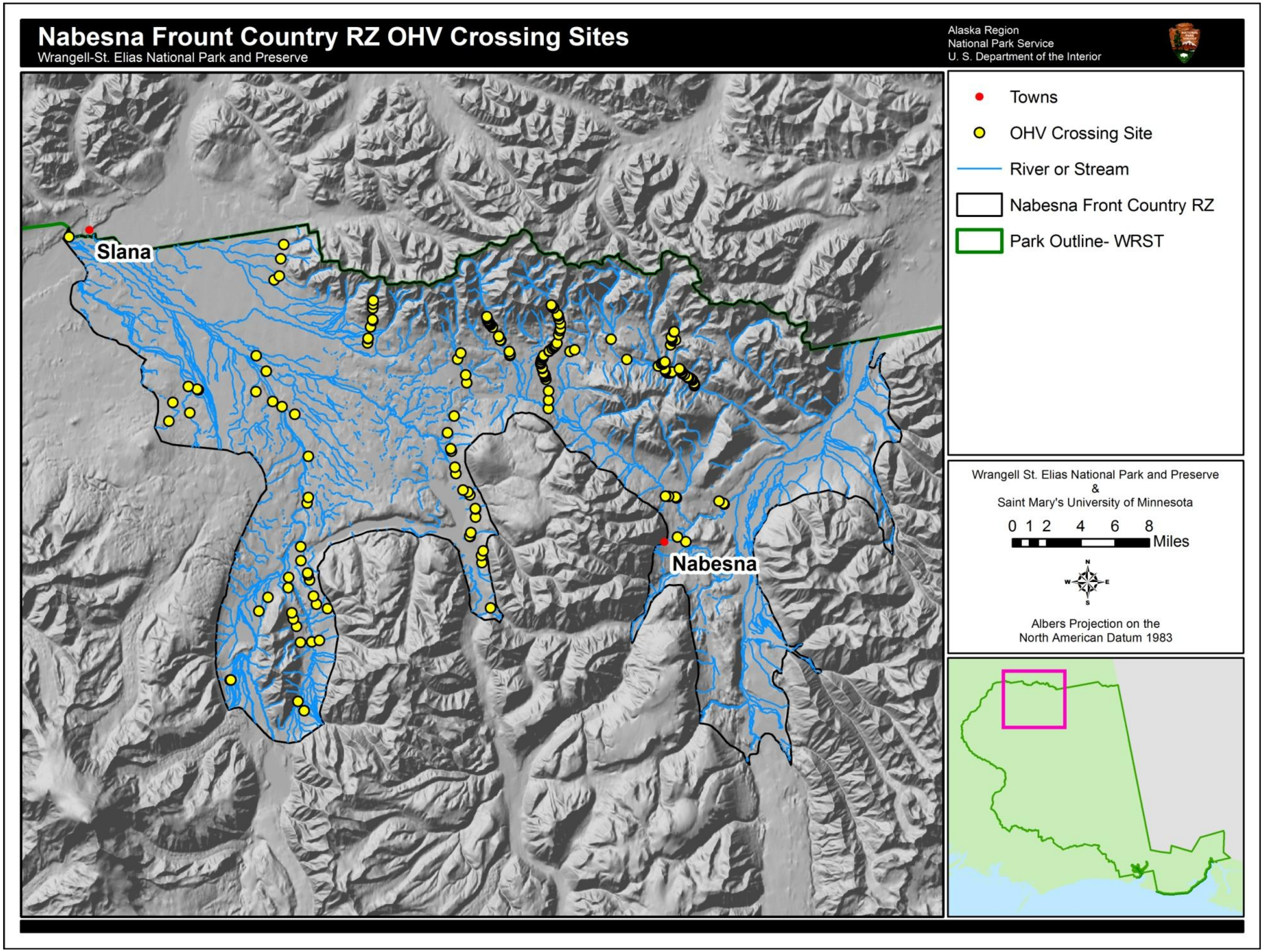


Plate 27. Known OHV stream crossing sites, Nabesna RZ. (NPS PDS 2009a)

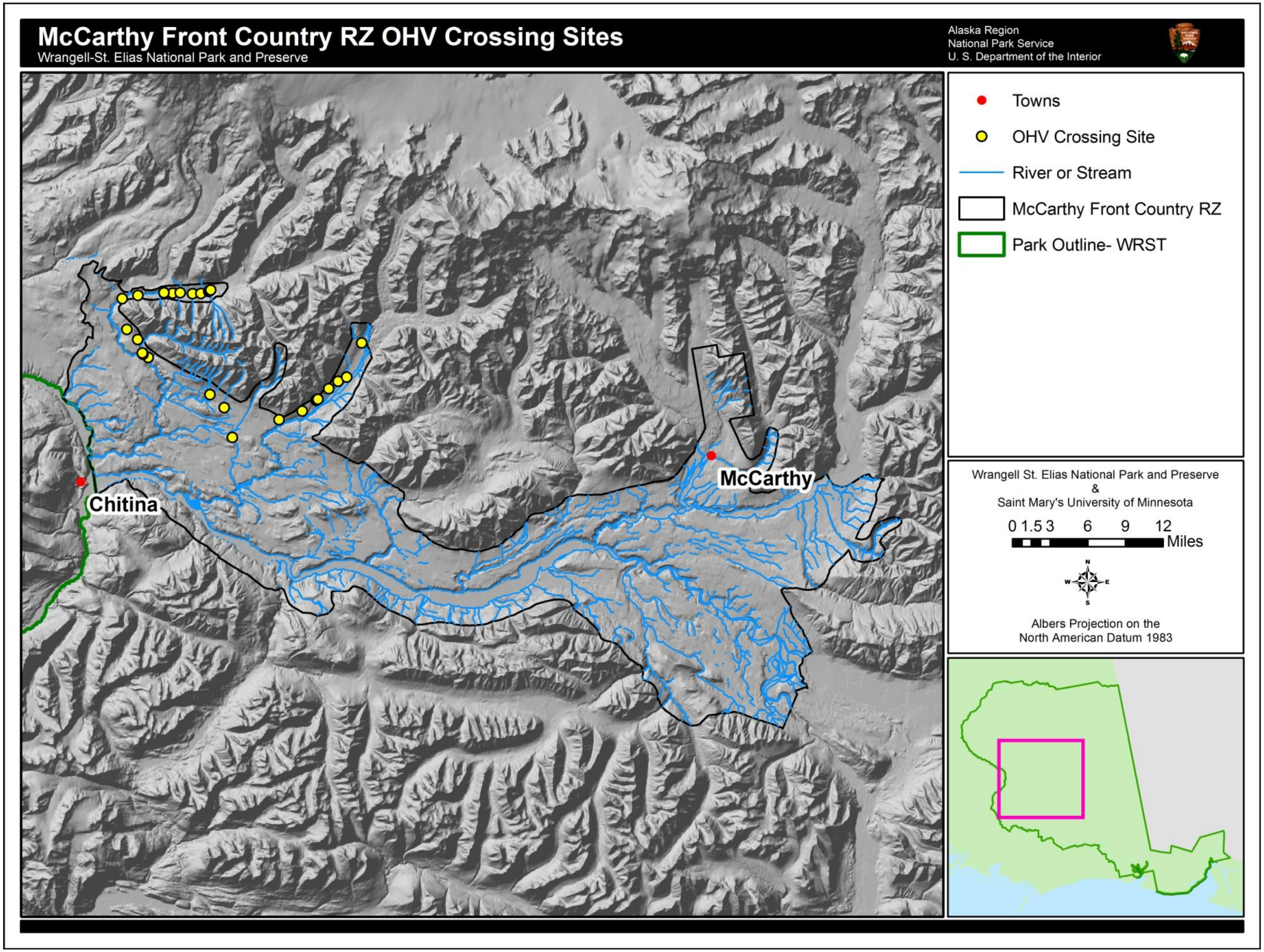


Plate 28. Known OHV stream crossing sites, McCarthy RZ. (NPS PDS 2009a)

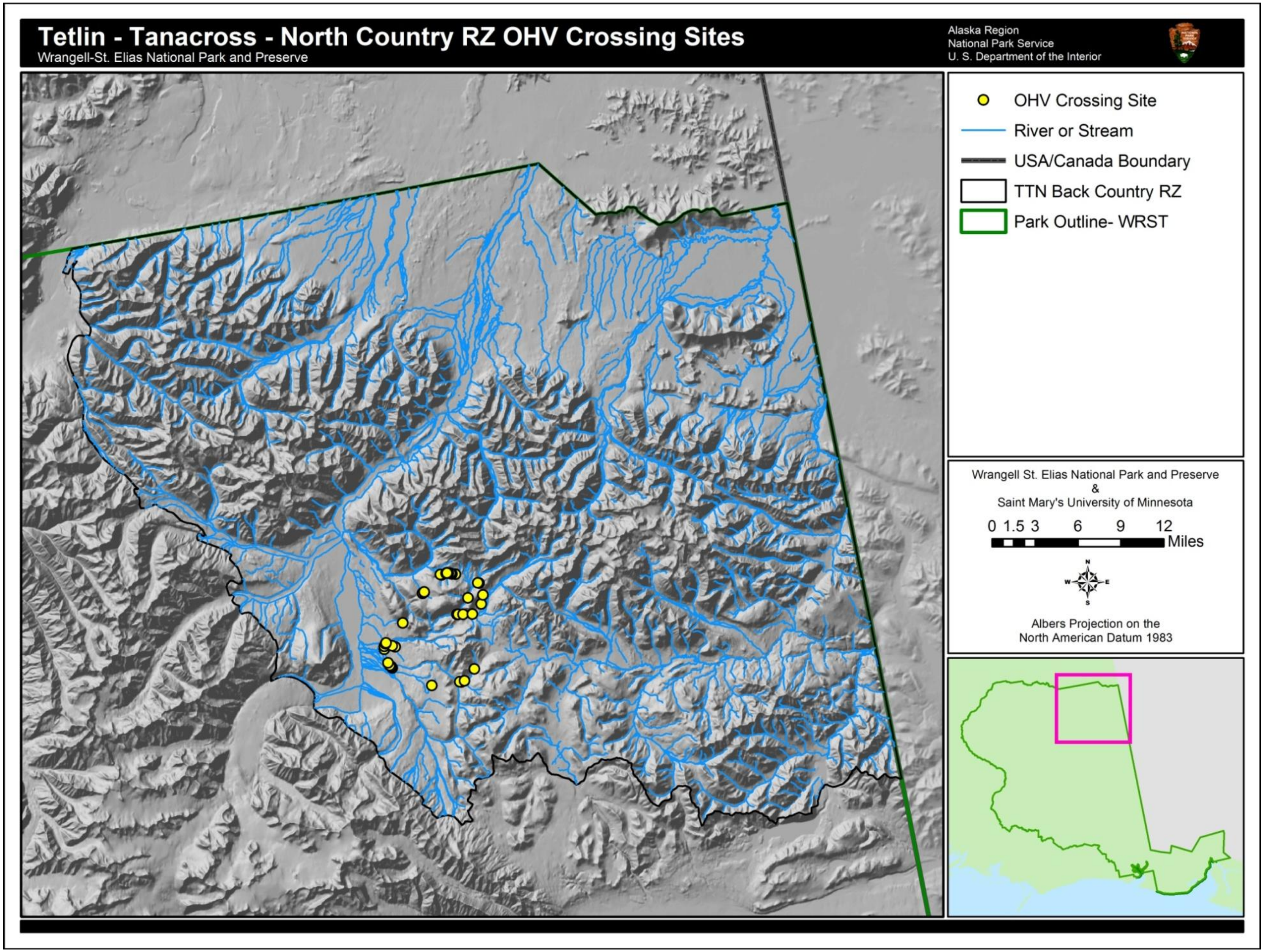
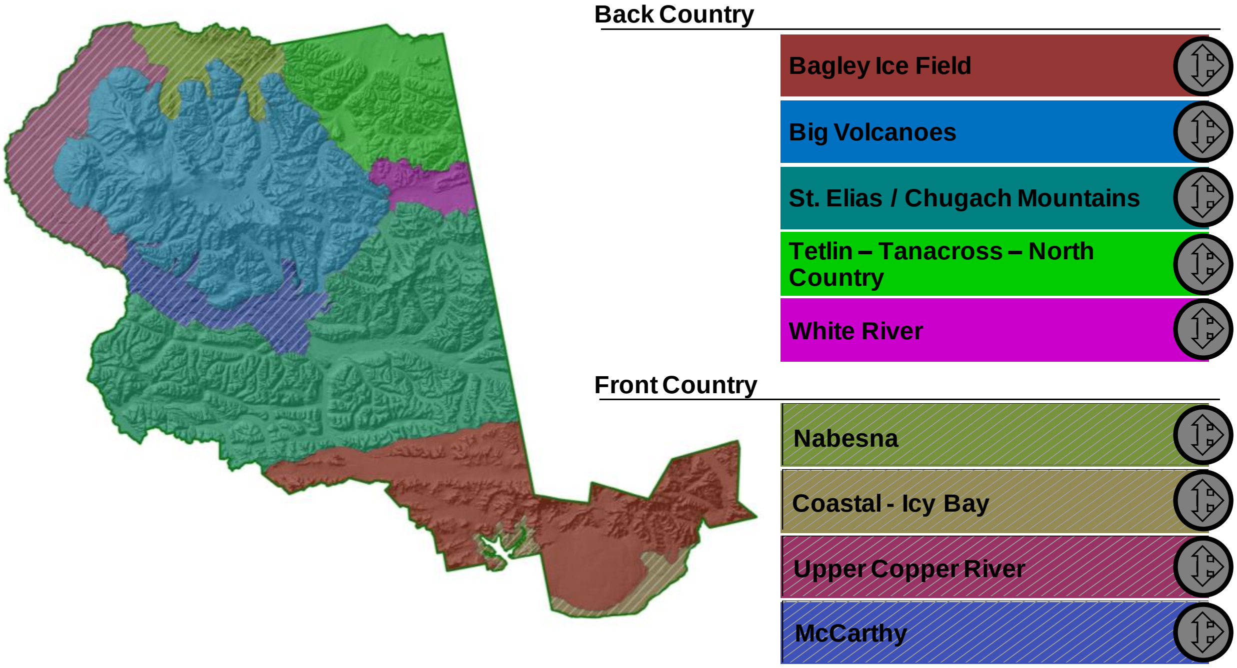


Plate 29. Known OHV stream crossing sites, Tetlin-Tanacross-North Country RZ. (NPS PDS 2009a)

4.13 Breeding Birds

Indicators and Measures
Species Distribution, Diversity, and Abundance



Condition
The condition of breeding birds in WRST, for all RZs, is unknown. While the USGS (2010) North American Breeding Bird Survey (NABBS) data provide insight into the species distribution of a few small areas in the WRST front country, it does not provide insight to the abundance and species distribution of breeding birds on a park-wide scale. Little is known about the condition and trends of breeding bird abundance and species distribution in WRST with the exception of Kittlitz's Murrelet and Trumpeter Swans; both species of concern are well understood and information is available in their individual component sections. Currently, CAKN is developing protocols for monitoring breeding birds in DENA, YUCH, and WRST.

Distribution and Background

Birds comprise greater than 75% of terrestrial vertebrates in CAKN (McIntyre 2006). 189 species of breeding birds are found in WRST, with five additional species potentially present (NPS 2010a, Appendix D). Breeding birds, specifically those in the Order *Passeriformes*, are relatively easy and economical to detect (McIntyre 2006). Given their significance and ease to detect, breeding birds are an important aspect of the CAKN's inventory and monitoring efforts.

Reference Condition

Breeding bird reference condition, as defined in the WRST framework, is natural and healthy populations. There is no information available that quantitatively or qualitatively describes historical breeding bird populations in WRST. The earliest breeding bird survey in the park was in 1975, along Nabesna Road and annual surveys did not begin in WRST until 1989. Thus, it is difficult to determine a reference condition with any accuracy.

Diversity

There are 10 Orders, 40 Families, and 189 species of birds in WRST (NPS 2010 a). Orders Ciconiiformes and Passeriformes are the most represented, with 71 and 70 species respectively. Of the 40 Families of birds in WRST, Scolopacidae (26 species, Order: Ciconiiformes) and Anatidae (29 species, Order: Anseriformes) are the most represented. Appendix E provides a list of bird species in WRST broken down by Order and Family.

Species Distribution

Knowledge and data about breeding bird species distribution is limited to NABBS routes. Developed in 1966 in response to an increased use of synthetic pest control chemicals, the NABBS monitors breeding bird populations over large geographic areas across North America (USGS 2010). Every NABBS route in and around WRST is located in areas designated as front country (Plate 30). Appendix D provides a list of species documented on NABBS routes within and adjacent to the park boundary.

The 1992 the WRST Coastal Wildlife Survey provided information on the species present in the WRST coastal region. This survey assessed wildlife species at risk from oil exploration (Kozie 1993). The species found to be at greatest risk were bald eagles, peregrine falcons and marbled murrelets (scientific names in Appendix F) (Kozie 1993). Plate 31 shows surveyed locations from this study. The five most commonly viewed bird species in this survey were the surf scoter (563 observations), ruddy turnstone (285 observations), least sandpiper (170 observations), common merganser (110 observations), and black turnstone (85 observations). Appendix F provides a table of all bird species inventoried in this survey.

Audobon Society Christmas bird counts (2010) provide some indication of species wintering in WRST. WRST Christmas bird counts began in 1991 and continue through today. These counts are performed by volunteers between December 14 and January 5 every year at two sites near WRST, Kenny Lake and Gakona. Since the beginning of these counts, 38 species of birds have been identified (Appendix G).

Species distribution data are unavailable for back country RZs in WRST. Off road breeding bird surveys (ORBBS) were performed by the USGS in the mid 1990s as part of protocol development for the Alaska Landbird Monitoring Survey (ALMS) (USGS, Colleen Handel

Wildlife Biologist, pers. comm.). These surveys, performed only a few times, have been discontinued (Handel pers. comm.).

In 2007, the Alaska Bird Observatory performed a springtime study (24 May 2007 - 13 June 2007) that identified the composition of waterfowl species in portions of the park (Meixell 2007). The study area roughly corresponded with the McCarthy, Upper Copper River, and Nabesna RZs. Nineteen waterfowl species were identified in the survey from four tribes (a taxonomic classification between family and genus, usually containing several genera) (Meixell 2007). The tribes Aythyini and Mergini (identified by Meixell as diving ducks) were most common followed by the tribe Anatini (dabbling ducks) and the tribe Anserini (geese and swans) (Meixell 2007). The most abundant species were scaup species (*Aythya affinis, Aythya marila*). Other common species were trumpeter swans (*Cygnus buccinator*), American green-winged teal (*Anas crecca*), American wigeon (*A. americana*), mallards (*A. platyrhynchos*), scoters (*Melanitta spp.*), bufflehead (*Bucephala albeola*), and Barrow‘s goldeneye (*B. islandica*).

Abundance
Little is known about the abundance of specific bird species in WRST. To date, population estimates are available only for species of concern in the park: Kittlitz's Murrelet and trumpeter swans. Population data for these two species are located in the component sections specific to these species within this document. In addition, NABBS trends for WRST routes are currently unanalyzed.

Stressors
Stressors to breeding birds in WRST, as indicated in the framework for this NRCA include climate change and invasive and non-native species

Climate change can drive the influx of invasive non-native species in Alaska's forests. With current trends showing the lengthening of growing season and less severe winters, changes in the latitudinal or elevational ranges of insects can be expected (Schrader and Hennon 2005). Species such as the spruce beetle, larch and wooly sawflies, spruce aphid, and the amber-marked Birch leaf miner are of particular concern in Alaska (Schrader and Hennon 2005). It will be important to monitor changes in invasive non-native insects as climate changes (Schrader and Hennon 2005). In many cases, die-offs of large tracts of trees from insect infestations are followed by clear cutting or salvage logging (Matsuoka and Handel 2007). Many of these dead areas still provide nesting habitat for a variety of bird species, and preserving some of these areas is recommended to maintain bird-nesting habitat (Matsuoka and Handel 2007).

Insects are not the only invasive species of concern; Norway rats and starlings occur in well-established ports in cities in Alaska (Schrader and Hennon 2005). Norway rats could pose a threat to shorebirds of coastal regions in Alaska, but this has not been researched (Schrader and Hennon 2005). Likewise, the possibility of starlings displacing other cavity-nesting birds in Alaska is unexplored (Schrader and Hennon 2005).

Data Needs
In 2005, CAKN described inventory and monitoring goals for WRST (MacCluskie and Oakley 2005). CAKN selected *Fauna Distribution and Abundance* as one of its top three Vital Signs (MacCluskie and Oakley 2005). The goals for passerine monitoring included determining

population trends in common species, community structure and distribution, and ecology of species of conservation concern (MacCluskie and Oakley 2005). Currently, a breeding bird monitoring protocol does not exist for WRST, but a new monitoring protocol for the entire CAKN is expected to be completed early in 2011 (NPS, Carol McIntyre DENA Wildlife Biologist, pers. comm.).

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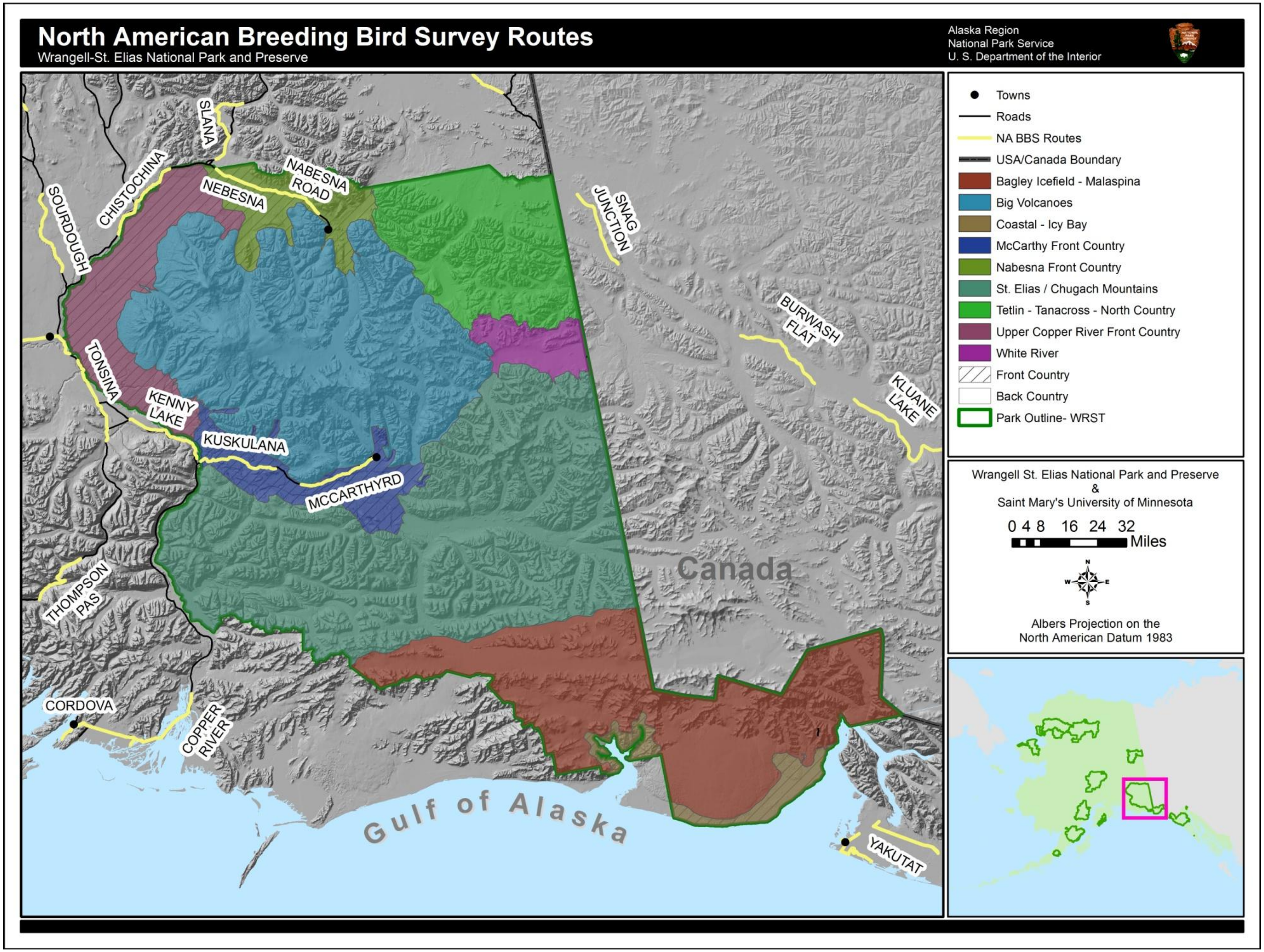


Plate 30. North American Breeding Bird Survey routes, WRST area. (USGS 2004)

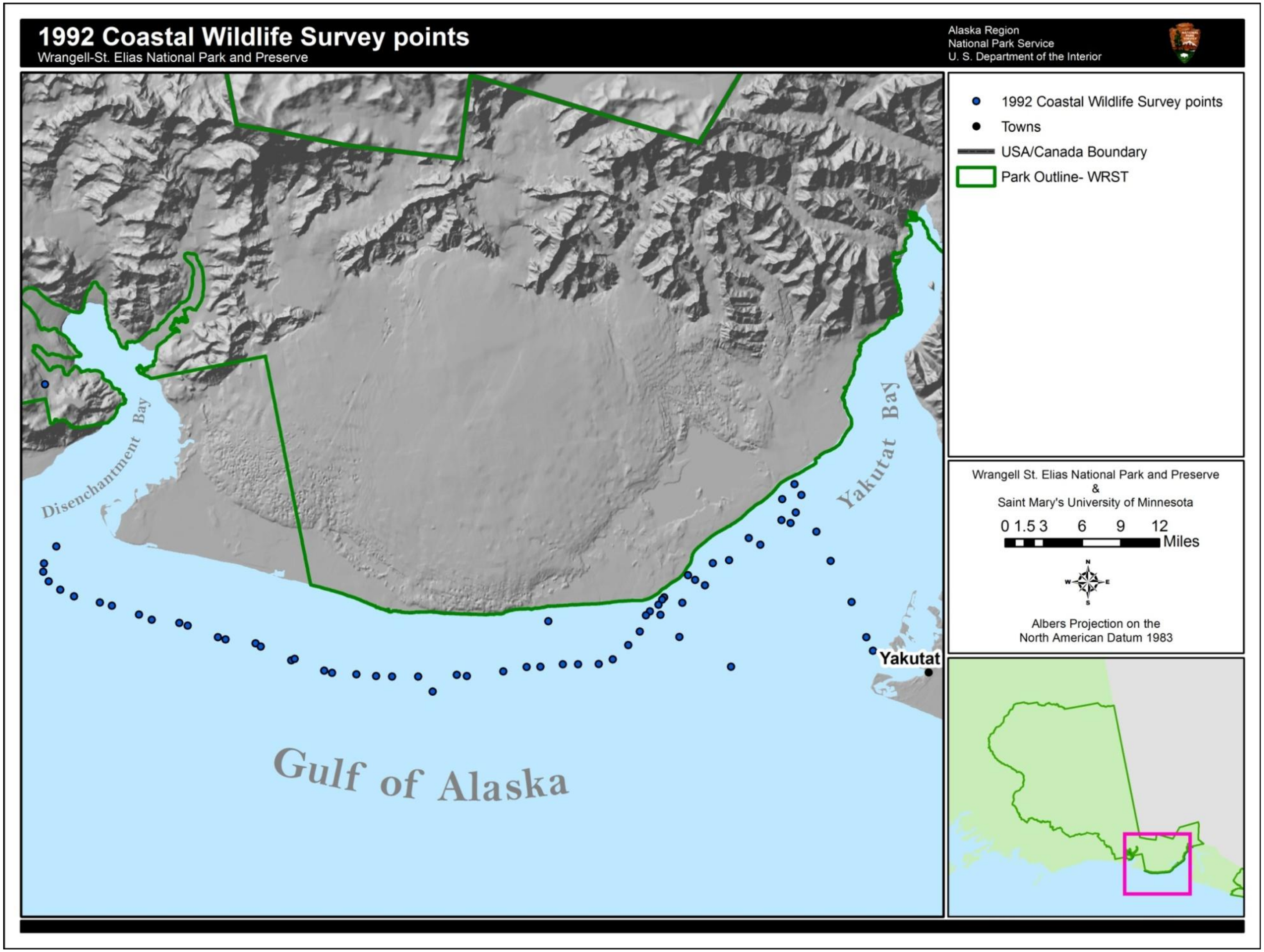
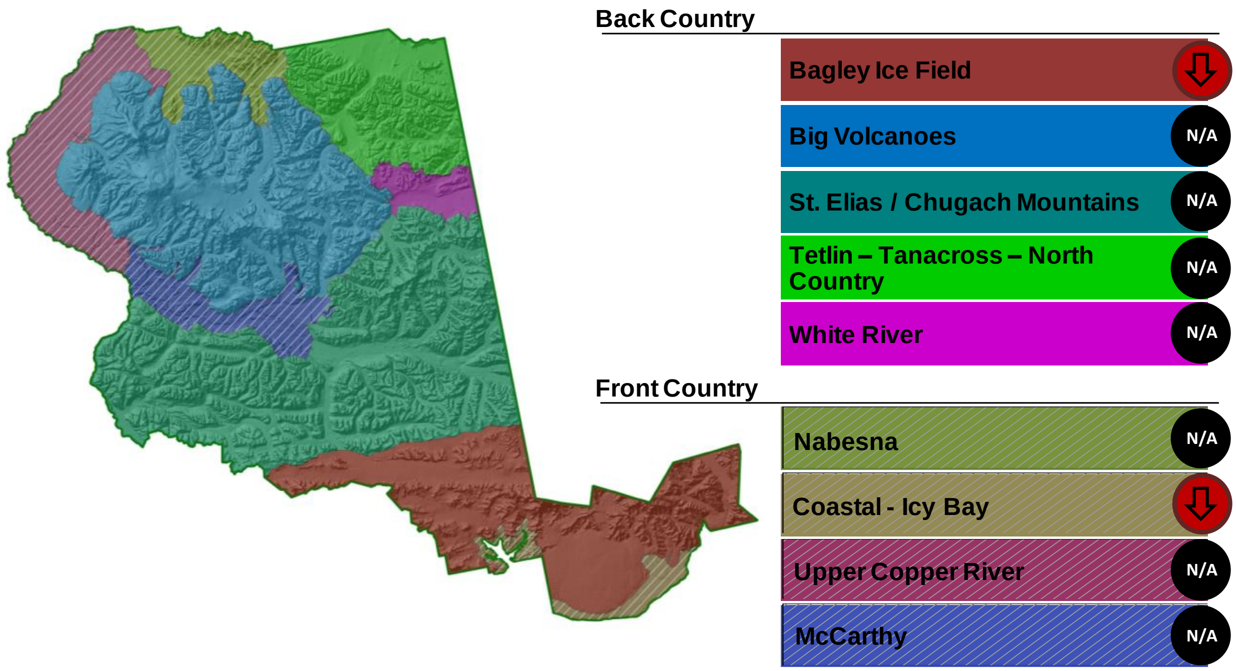


Plate 31. 1992 Coastal Wildlife Survey locations, WRST. (NPS PDS 2009)

4.14 Kittlitz's Murrelet

Indicators and Measures

Population and Distribution



Condition

The literature suggests no change in the distribution of Kittlitz's murrelets within WRST; however, there is limited historical information about their distribution. Knowledge of nest distribution and abundance in the park is especially lacking. The density of Kittlitz's murrelets within Icy Bay is still one of the highest known of any survey area in Alaska, but the stability of the population is unclear. The estimated population has declined since at least 2002, and steep declines in the overall Alaskan population are a cause for concern. The estimated population of Kittlitz's murrelets for 2009 is the lowest estimate since 2002. There are substantial ongoing efforts to better understand the species and monitor its condition. The knowledge gained by this work may inform management about actions that could help the condition of the Kittlitz's murrelet; however, the species still faces significant stressors, some of which are not yet clearly understood or realistic to manage (e.g. climate change).

Distribution and Background

The complete range of the Kittlitz's murrelet (*Brachyramphus brevirostris*) includes far eastern Russia (Okhotsk Sea and Chukchi Sea), and various locations along the Alaskan coast from Point Lay in the northwest to the northern portions of southeast Alaska (USFWS 2006). The majority of Kittlitz's murrelets are believed to breed in Alaskan core breeding areas which include the south side of the Alaska Peninsula, Prince William Sound, Lower Cook Inlet and Kenai Fjords, Icy Bay, Yakutat Bay and the Malaspina Forelands, and Glacier Bay (USFWS 2006). WRST includes portions of Icy Bay, Yakutat Bay, and the Malaspina Forelands (Figure 44, Plate 32). Icy Bay is estimated to support the highest density and up to 12% of the world's population of Kittlitz's murrelet during the breeding season.

The current global population of Kittlitz's murrelets is estimated to be 24,688 (USFWS 2009). The Alaskan population is estimated at 19,578 birds (95% CI: 8,190-36,193) (USFWS 2009). The Kittlitz's murrelet is considered critically endangered according to the International Union for Conservation of Nature and Natural Resources (USFWS 2008). It is also listed as one of the top 10 most endangered birds in the United States by the National Audubon Society (2006). NatureServe considers the species to be Globally Imperiled (USFWS 2008). In 2004, the U.S. Fish and Wildlife Service identified the Kittlitz's murrelet as a candidate for protection under the Endangered Species Act, and its listing was elevated to Priority 2 in 2007 (USFWS 2006, USFWS 2008). As a candidate species it is not protected by regulations; however, the listing encourages collaborative research and conservation activities that may prevent the species from needing to be listed as threatened or endangered (USFWS 2006).

Kittlitz's murrelet, considered ―one of the rarest and least known seabirds in North America," is a member of the Alcid family along with other diving birds such as puffins and auklets (USFWS 2006, Piatt n.d.). Their stubby bodies with mottled plumage taper smoothly at both ends and can appear gray, silver, or a warm tan color depending on the light conditions. Outer white tail feathers, which distinguish them from marbled murrelets, are sometimes seen as they take off from the water (Piatt n.d.). They fly in a straight line, often low to the water, and their relatively long wings beat rapidly (Piatt n.d.). Kittlitz's murrelets are nearshore divers that are found near tidewater glaciers, among icebergs, or at outflows of glacial streams and rivers. They feed on small pelagic schooling fish, invertebrates, and microplankton (USFWS 2006, Piatt n.d.).

Breeding Kittlitz's murrelets are generally found in areas associated with tidewater or remnant high elevation glaciers and areas that have experienced recent deglaciation, sometimes up to 45 miles inland (Agler et al. 1998, USFWS 2006). Kittlitz's murrelets are solitary and secretive breeders that rely on camouflage to protect their nests. They breed from May to August and lay one egg in a small scrape often on unvegetated scree or cliff faces in rugged mountains, making them very difficult to find (USFWS 2006). As of 2007, only 25 nests had ever been documented for this species; however, through new research projects, additional nests have been found on Agattu and Kodiak Islands, as well as in Icy Bay (USFWS 2009).

Photo 10. Kittlitz's murrelet (USGS n.d.)

Reference Condition

Kittlitz‘s murrelets are found in Icy Bay, Malaspina Forelands, and Yakutat Bay. The 2008 species assessment and listing priority assignment report cites an estimate by Isleib and Kessel (1973) of hundreds of thousands of Kittlitz‘s murrelets in the northern Gulf of Alaska prior to the 1970s (USFWS 2008). Additional population estimates exist from the last 2-3 decades, but almost nothing is known about important vital rates such as survival and reproductive success. It is difficult to determine naturally sustainable population levels without this knowledge.

Population Surveys

Several population surveys employing various techniques have been conducted along the WRST coastline from Yakutat to Icy Bay (Table 21). Additional survey work occurred in 2008 and 2009, but the data are not yet analyzed. A coastal survey of seabird and marine mammals was conducted in 1992 in response to potential off shore oil and gas exploration adjacent to WRST (Kozie 1993). Although a population estimate was not determined, locations and numbers of Kittlitz‘s murrelets identified during the survey are displayed in Plate 32.

Icy Bay supports one of the largest populations of Kittlitz‘s murrelets in the world and the highest density of Kittlitz‘s murrelets ever recorded (Kissling, USFWS, unpublished data). Icy Bay is approximately 240 km^2, with four fjords that extend from the deep inner Icy Bay and each having a tidewater glacier, (Kissling et al. 2006). Taan Fjord appears to support the highest density of Kittlitz‘s murrelet in the bay (Kissling et al. 2006, 2007a, Kissling, U.S. Fish and Wildlife Service, unpublished data).

Although long-term historic abundance estimates are unknown, steep population declines have been noted in several core population locations in WRST (USFWS 2006). According to the USFWS, the population of Kittlitz‘s murrelets along the Malaspina Forelands appears to have declined by 38% - 75% between 1992 and 2002 (USFWS 2006). The population in Icy Bay has declined by 18% per year since 2002, equating to a loss of over 1100 individuals (Kissling, USFWS, unpublished data).

Table 21. Estimated Kittlitz's murrelet abundance in Yakutat Bay (2000), Icy Bay (2002, 2005, 2007-2009), and Malaspina Forelands (2002). (Reid 2002, USFWS 2008; Kissling 2009)

Location	Year of Survey	Population estimate (Range or 95% CI)	Source or Responsible Agency
Yakutat Bay	2000	927 (694 - 1,160)	Stephenson and Andres 2001
Icy Bay	2002	2,212 (±721)	SEES/USFWS, unpubl. data
	2002	2,098 (1,368 - 2,828)	Kissling *et al. 2006*
	2005	1,317 (1,023 - 1,611)	Kissling, unpubl. data
	2007	1000 (734 – 1,362)	Kissling et al. unpubl. data
	2008	1,907 (126 – 2889)	Kissling et al. unpubl. data
	2009	728 (515 - 941)	Kissling 2009
Malaspina Forelands	2002	906 (300 - 1,512)	Kissling *et al. 2006*
	2002	1,058 (±1100)	SEES/USFWS, unpubl. data

Declines within WRST are consistent with regional trends. In Prince William Sound, data indicate an 84% decline in the population from 1989 to 2000 (Kuletz et al. 2003). Kittlitz's murrelets along the coast of the Kenai Fjords were estimated to have experienced a 74% decline, at a rate of 8.7% per year from 1986 to 2002 (USFWS 2008). Survey results indicated an 80% population decline in Glacier Bay from 1991 to 2000 (USFWS 2008).

Ongoing and Future Research

A multi-year collaboration between the U.S. Fish and Wildlife Service and the National Park Service began in 2005 with the goal of creating a long-term monitoring plan for Kittlitz's Murrelets and identifying important nesting and foraging habitats in Icy Bay. Between 2005 and 2009, 340 Kittlitz's murrelets were captured and banded (Kissling, USFWS, unpublished data). Morphological measurements and blood samples were obtained from each individual. A total of 122 adults and 4 juveniles have been radio-marked, and two satellite transmitters were successfully deployed in 2009.

By tracking these radio-marked birds, a total of only 8 nests were located from 2007 to 2009 (Kissling, USFWS, unpublished data). In 2007, it was determined that 84-95% of the radio-marked females had initiated egg production at the time of capture, but despite this high fecundity, only 13% of radio-marked birds nested. A remote video camera system was used to monitor a portion of the nests in order to record prey deliveries and fledging of the young. Of the eight nests located, three were known or presumed successful, three were known or presumed to have failed, and the outcome of two was unknown. A total of twelve mortalities were discovered between 2007 and 2009 amongst radio-marked Kittlitz's murrelets. The majority of these deaths were attributed to bald eagle (Haliaeetus leucocephalus) and peregrine falcon (Falco peregrinus) predation.

The work completed to date has laid the foundation for continued research between the U.S. Fish and Wildlife Service, National Park Service, Alaska Department of Fish and Game, and Colorado Division of Wildlife. Recent years of population decline are now documented for Kittlitz's murrelet; however, it has not known at what life stage population growth is limited. A combination of mark-recapture and radio telemetry efforts as well as abundance estimates will be used to generate an empirically-based population growth model. The US Fish and Wildlife

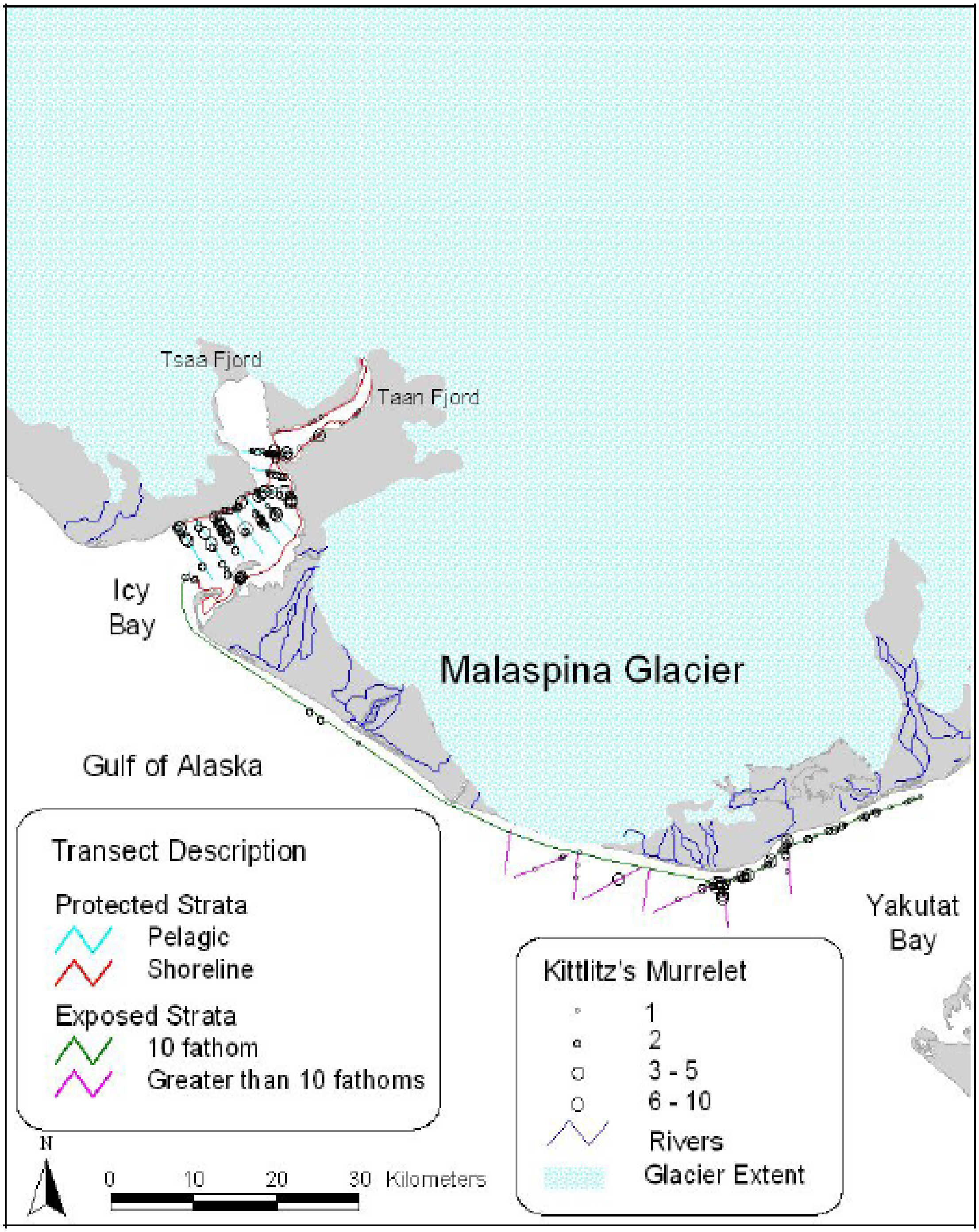


Figure 44. Kittlitz's murrelet distribution and abundance on-transect July 7-14, 2002. (Kissling et al. 2007b)

Service will use this model, and the fecundity and productivity measures derived from it, to inform the Kittlitz's murrelet recovery plan.

Stressors

NPS identified several stressors to Kittlitz's murrelet populations, including mortality due to fishing gillnets, mortality due to oil spills, changes in food supply or habitat, predation, and disturbance by boats or scenic air flights. Having small bodies and being nearshore divers make Kittlitz's murrelets susceptible to both gillnet fisheries and oil spills. Mortality from both causes is documented, including a relatively high number of individuals killed by the 1989 Exxon Valdez oil spill (USFWS 2006). Although an individual small oil spill may not eliminate an entire population, the cumulative impact of small scale oil spills from tours and other boat traffic could be significant (USFWS 2006).

Another factor considered as a possible stressor is disturbance by boats and scenic air flights (USFWS 2006). Tour operations are increasing in all core breeding areas. In 2007, there were four yachts, one tour boat, two logging ships, one research vessel, three private kayak groups, and one commercial kayak group that regularly used Icy Bay in addition to the groups associated with the two lodges and the logging operation at the west entrance of the bay (Kissling, USFWS, unpublished data). In 2008, twenty-two groups were known to use Icy Bay (Kissling, USFWS, unpublished data).

Kittlitz's murrelets are also believed to be sensitive to changes in food supply or habitat, which may be impacted by cyclical changes in the ocean environment and glacial retreat (USFWS 2006). The greatest threat to Kittlitz's murrelet may be the pervasive effects of climate change on tidewater glaciers, many of which are now receding (Kuletz et al. 2003). If the species' relationship to tidewater glaciers is obligatory, loss of such habitat could quickly result in irreversible losses for the species.

Natural predators in WRST include bald eagles and peregrine falcons (Kissling, USFWS, unpublished data). Glaucous-winged gulls (*Larus glaucescens*) have also been known to prey on Kittlitz's murrelets eggs (USFWS 2008).

Data Needs

In order to more confidently determine the condition of Kittlitz's murrelets, more information regarding the population structure and characteristics of the species is needed. Critical information needs in WRST include: (1) generating a monitoring design for tracking population trend and precise population estimates; (2) identifying nesting and foraging habitats within and adjacent to NPS lands to help identify where conservation efforts should be concentrated; and (3) quantifying adult survival and reproductive measures (i.e., fecundity and productivity) to identify which aspects of Kittlitz's murrelets' life history is limiting population growth, and help identify factors that influence these life-history parameters. This last priority is central to understanding population decline and developing issue-specific management and conservation priorities that will be most effective. The relationship between Kittlitz's murrelets and glaciers needs to be better understood as well. Work planned for 2010-2012 will contribute important information for future condition assessments of the Kittlitz's murrelet and recovery efforts.

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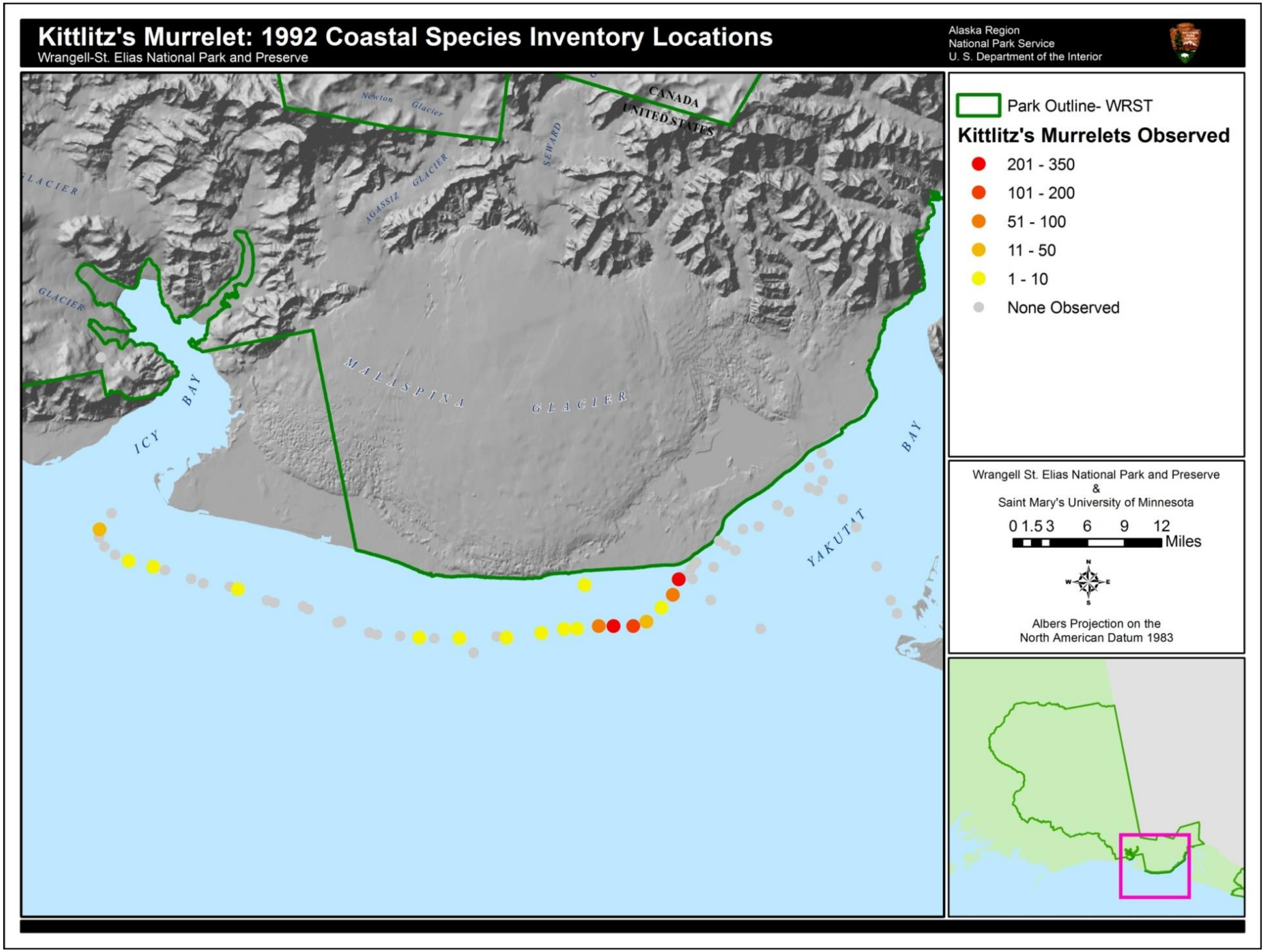
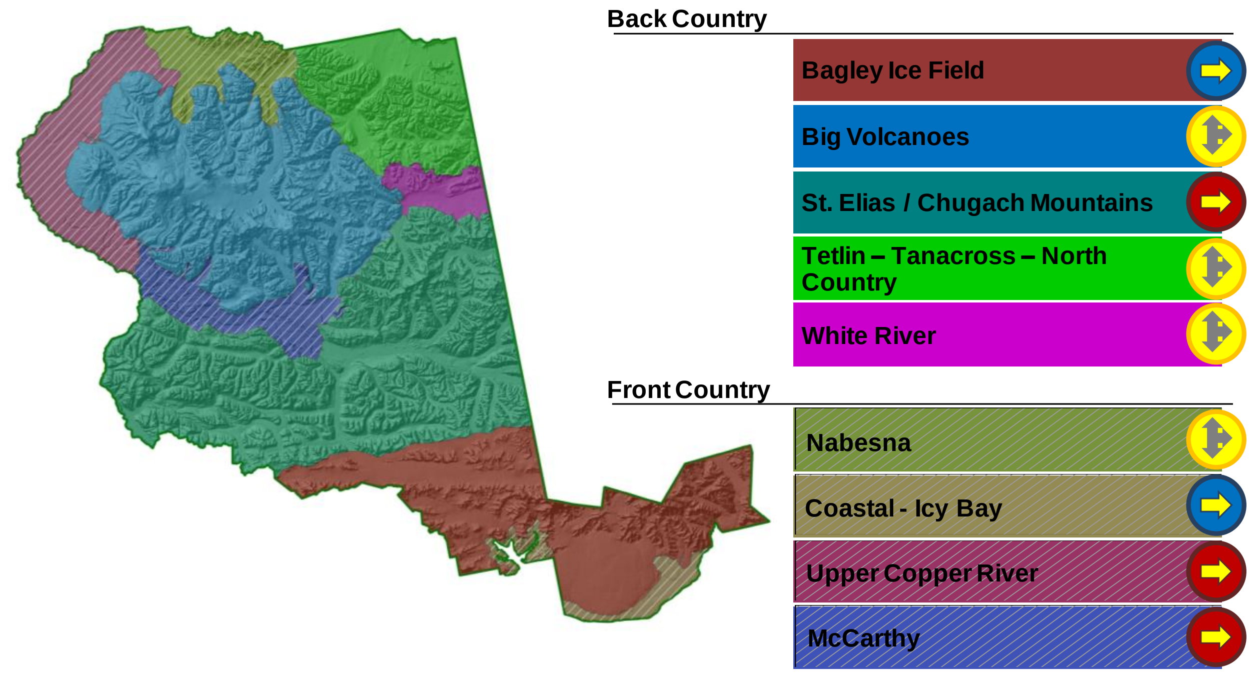


Plate 32. Kittlitz’s murrelets: 1992 coastal species inventory locations. (Kozie 1993)

4.15 Forest Insects and Disease

Indicators and Measures
Frequency of Infestation, Extent of Infestations



Condition
The vast majority of spruce beetle (*Dendroctonus rufipennis*) infestations occur in the Upper Copper River, McCarthy, and St. Elias/ Chugach Mountains RZs. (Plate 33) Historic records indicate the last major outbreak in the Copper River Basin occurred between 1910 and 1920, in which an estimated 81,000 hectares (approximately 200,000 acres) of white spruce (*Picea glauca*) stands were impacted by the beetles (Moffit 1922; Holsten 1990).Other epidemic outbreaks occurred in the late 1990s, but recently infestation levels have decreased. The condition of spruce beetle infestations is a significant concern as a natural disturbance in the white spruce forests of WRST. Although very few spruce beetle infestations are documented in Big Volcanoes, Tetlin-Tanacross-North Country, Nabesna RZs, spruce forests in these RZs may provide some potential for future infestations. As a result, these zones are considered to have a condition of moderate concern with an unknown trend. Coastal-Icy Bay and the very southeastern portion of the Bagley Icefield RZ contain spruce forest that is dominated by Sitka spruce (*Picea sitchensis*). No spruce beetle activity is documented to date; therefore, these represent zones of good condition.

Background

Several insect damage agents and two disease agents are documented in WRST with the most prevalent species being the spruce beetle. The spruce beetle is the most influential of the insects creating extensive natural disturbances in Alaska (Allen et al. 2006). Given its prolific nature, this insect is the focus of this assessment. Spruce beetle damage accounted for 72 % of the total mapped damage by area in WRST, with a total of 185,409 ha. (458,356 acres) affected from 1989 to 2007 (NPS PDS 2009a).

According to the database of aerial surveys (conducted by the U.S. Forest Service (2009)) of forest and insect diseases over the same 18 year survey period, damage from six other insect and disease agents individually accounted for at least one percent of the total cumulative damage (NPS PDS 2009a). These insects are: aspen leaf miner (likely *Phyllocnistis populiella*), large aspen tortrix (likely *Choristoneura conflictana*), aspen leafroller (likely *Pseudexentera oregonana*), and willow leafblotch miner (likely *Micrurapteryx salicifoliella*) (Figure 45). The only disease agents detected by the aerial survey are spruce needle rust (*Chrysomyxa ledicola*) and spruce broom rust (*Chrysomyxa arctostaphyli Diet*). Other damage agents summarized in surveys and accounting for less than one percent of total mapped damage were: willow leafblotch miner (*Micrurapteryx salicifoliella*), hardwood defoliation, flooding damage, Ips beetle (likely *Ips perturbatus*), birch defoliation, and alder leafroller.

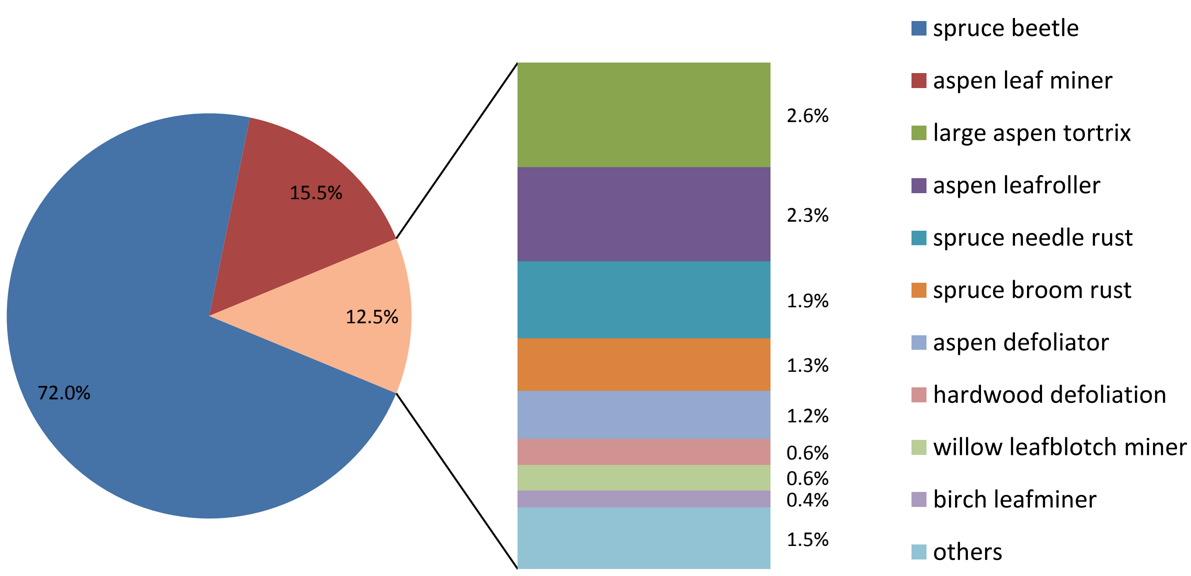


Figure 45. Forest damage agents, WRST, 1989-2007. (NPS PDS 2009a)

Aspen leaf miner is the most widespread and prevalent of all insect pests in Alaskan forests (Lamb et al. 2009). Defoliation caused by this insect generally does not kill the entire tree, but it reduces growth rates and can result in branch dieback. Repeated severe defoliation may cause full tree mortality on affected aspen trees (*Populus tremuloides*) (Lamb et al. 2009). In WRST, aspen leaf miner was identified as a forest damage agent in 57,381 acres or 15.5% of the total damage mapped from 1989 to 2007. Aspen leaf miner did not appear in the survey data until 2005, but the reason for the lack of documentation prior to 2005 is unknown (Figure 46). In the two years of recorded damage aspen leaf miner has become significant in terms of acres of detected forest damage in WRST.

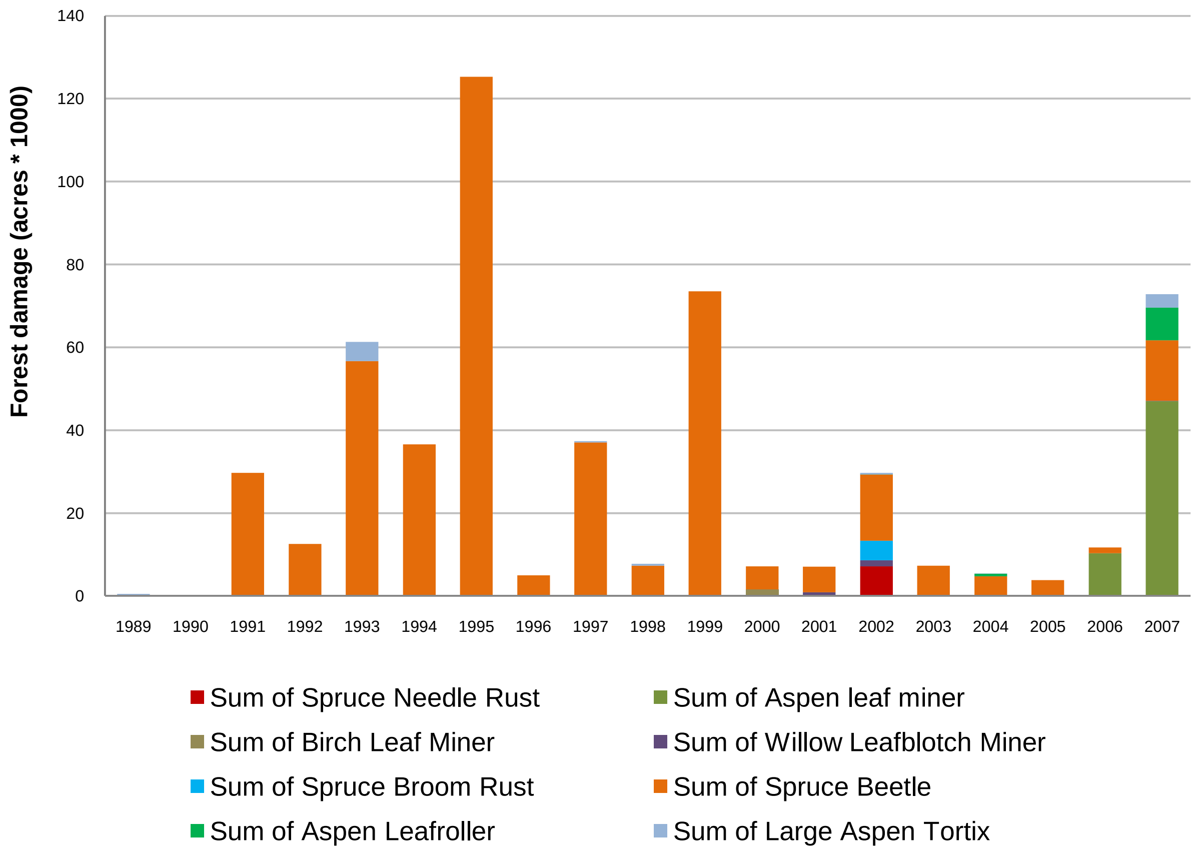


Figure 46. Common forest damage agents by damage area, WRST, 1989-2007. (NPS PDS 2009a)

The main data source available to understand the frequency and extent of insect and disease disturbances in WRST comes from surveys conducted by the USFS, Forest Health Protection (FHP) and the Alaska Department of Natural Resources (ADNR 2009), Division of Forestry. The resulting spatial data, which reside in the forest damage geodatabase (NPS PDS 2009a), provides locations, rough estimates of intensity, and resulting trends of damage agents detectable by air from 1989 to 2007. Though these data do not identify mortality, it provides some indication of intensity by classifying areas as low, medium, or high infestation levels. Unfortunately, the data were not consistently recorded over the period of record and therefore, no examination of the intensity is conducted here.

The aerial method of damage detection only allows for extent mapping of damage agents detectable by air; thus, many of the most destructive diseases may not be represented in the resulting data. The data are based on aerial observations manually recorded onto a map. Since the data cover such extensive areas, it can be used as an initial identification of detectable pest areas for landscape level planning and examination of insect and disease activity trends. More spatially accurate delineation of pest damage boundaries should be obtained by ground assessments or approximations of several individual years of mapped data.

Reference condition

Reference condition is defined as natural disturbance regimes of healthy ecosystems as identified by historical record prior to climate change and significant commercial industrial activity.

Spruce beetles are a native insect in Alaska and the forest damage that they inflict is a part of natural forest disturbance. However, there is some concern that climatic warming is creating conditions that allow spruce beetle to reach epidemic levels outside of traditional natural disturbance regimes. If current climate warming predictions are realized, spruce beetle populations could continue to reach epidemic levels, as the spruce beetle‘s life-history is largely controlled by temperature (Werner et al. 2006). Beetles in south-central Alaska were recorded to take 2 years to reach maturity prior to 1980, while currently warming temperatures are promoting maturation within a single year (Berg et al. 2006a). In the interior, the summers are warm enough to allow for a one year maturity of beetles to take place; however, extreme cold winter temperatures typically kill enough beetles to limit populations (Werner et al. 2006).

Research defining the parameters of natural disturbance regimes of spruce beetles is limited in WRST and surrounding areas in Alaska. On the Kenai Peninsula, spruce beetle outbreaks have occurred on average every 52 years in mature spruce forests (Berg et al. 2006a). However, in nearby Kluane National Park and Reserve, Canada, regional outbreaks are estimated to be extremely rare over the past 250 years (Berg et al. 2006a). Situated between these two areas, WRST has no documentation specifically suggesting the return interval of spruce beetle outbreaks. However, the time gap between the two documented large outbreaks in the park was 60 years (1910-1920 & 1980-1990) (Moffit 1922, Holsten 1990, Allen et al. 2006)

Study sites in Lake Clark National Park (LACL) and Katmai National Park (KATM), used tree-ring reconstruction to indicate that widespread forest thinning occurred at a mean return interval of roughly 50 years over the last 250 years (Berg and Anderson 2006, NPS 2009). Rosemary Sherriff, one of the principal investigators on the research, states that there has been a long history of extensive synchronous spruce beetle outbreaks across south central Alaska, but also identifies that most of the historical records are less than 50 years old in Alaska and tend to be geographically limited. Her findings also suggest that the most recent widespread outbreaks are not outside of the range of natural variability at a stand scale, but that spruce beetle activity may be creating higher mortality effects on the landscape scale. While this research is not specific to WRST, it may be applicable to understanding the condition of forest insect and disease caused disturbance within the park.

Extent of all forest damage

The majority of the area of forest damage from 1987 to 2007 in WRST is concentrated along the Copper River beginning near the Gulkana airport to a few miles south of Chitina. Concentrations also exist in the following areas: in proximity to Dadina Lake between the Nadina and Cheshnina rivers; the Hanagita and Tebay river valleys (the area that is now largely represented by the Chakina Fire perimeter of 2009); and an area around McCarthy Creek. Forest damage also appears in smaller pockets in the entire Chitina, Nizina and Kennicott river valleys.

Very little forest damage was detected in the northeast portion of the park or the northern portion near Nabesna or Slana. Although there is a concentration of white spruce forest in White River drainage (NPS PDS 2009b), no insect and disease survey transects were conducted in this area (Lamb et al. 2009). Some level of forest damage likely exists in these remote areas, but there is no documentation to date.

Frequency of all forest damage

Forest damage is documented for every year that the forest damage aerial surveys have been conducted in WRST. As a result, forest damage frequency for the park is every year. A more important metric for understanding insect and disease infestation as a natural disturbance regime is the return interval for a given area. With only 18 years of survey data available for WRST, it is not yet possible to calculate an estimated return interval; however, relative damage to an area by year can be visualized with current data (Figure 47).

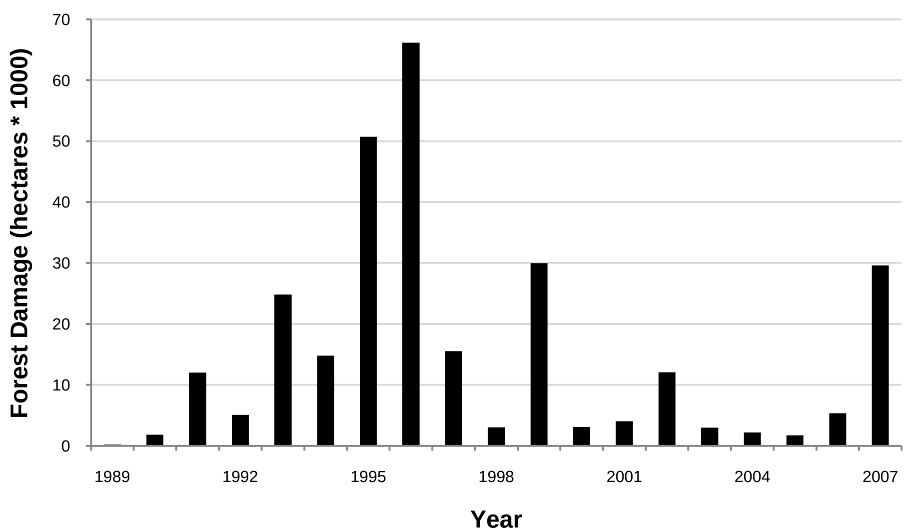


Figure 47. Yearly total area of all surveyed forest damage, WRST, 1989-2007. (NPS PDS 2009a)

Spruce beetle background

In addition to the aerial forest damage surveys, another important data source for understanding spruce beetle effects in WRST is the Copper River Basin - Spruce Beetle Effects Study (Allen et. al. 2006). This was an intensive spruce beetle and vegetation study completed for a 700,000 acre area extending from east of Copper Center to McCarthy north of the Chitina River between 1997 and 1999 (Allen et al. 2006). Part of this study included the production of a photo-interpreted beetle infestation/vegetation map in which percent of white spruce mortality was mapped on a stand by stand basis (Plate 33).

Allen et al. (2006) found that the spruce beetle outbreak that occurred between 1990 and 1999 had a major influence on forest vegetation at the stand and landscape levels. At the stand level, there were reductions in the variation of structure and composition of tree species and at the landscape level there were increases in variation of vegetation types (Allen et al. 2006). Further, areas of high spruce mortality could promote shrub species to dominate affected sites for up to a century after large beetle disturbances (Allen et al. 2006).

The spatial data resulting from Allen et al. (2006) WRST Vegetation and Beetle Infestation Map (NPS PDS 2009c) is not comparable with the data created by the Forest Health Program Annual Survey using the aerial mapping methodology discussed above. The vegetation and beetle infestation map from the Spruce Beetle Effects Study shows areas affected by spruce beetle damage that were not identified by the Forest Health Program. The photo-interpreted data from Allen et al. (2006) is a more accurate representation of field conditions at the time of photography as compared with the aerial damage assessment, and it is likely of more value as a source for baseline Spruce beetle damage data in WRST. One way the data could be used is in conjunction with fire models to assess differences in fire potential between pre and post infestation landscapes, and for finding areas to focus hazardous fuel reduction efforts (Allen et al. 2006).

Extent of spruce beetle damage

From 1990 to 2000, Alaska experienced 1.9 million ha. (2.94 million acres) of spruce mortality that was attributed to the spruce beetle. This was approximately 40% more spruce mortality than occurred over the 70 year period from 1920 to 1989 (Werner et al. 2006). Spruce beetles are the most prolific agents of mortality in white spruce stands of interior Alaska and Sitka spruce stands of southeast Alaska (Lamb et al. 2009). They have been active in the Copper River Basin (CRB) for more than ten years (Lamb et al. 2009). Werner et al. (2006) state that from 1990 to 2000, 275,000 ha (1.1 million acres) were infested in the CRB. From 1987 to 2007 a total of 185,490 ha (458,356 acres) were affected by spruce beetle activity in WRST (NPS PDS 2009a), (Plate 34). The years 1993 through 1999 represent some of the highest acres of total spruce beetle infestation within WRST (Figure 48). The CRB infestation neared its end in 2008, signaled by a decline in insect activity for two consecutive years. Some activity is still occurring at the base of the hills along the Chitina River near McCarthy (Lamb et al. 2009).

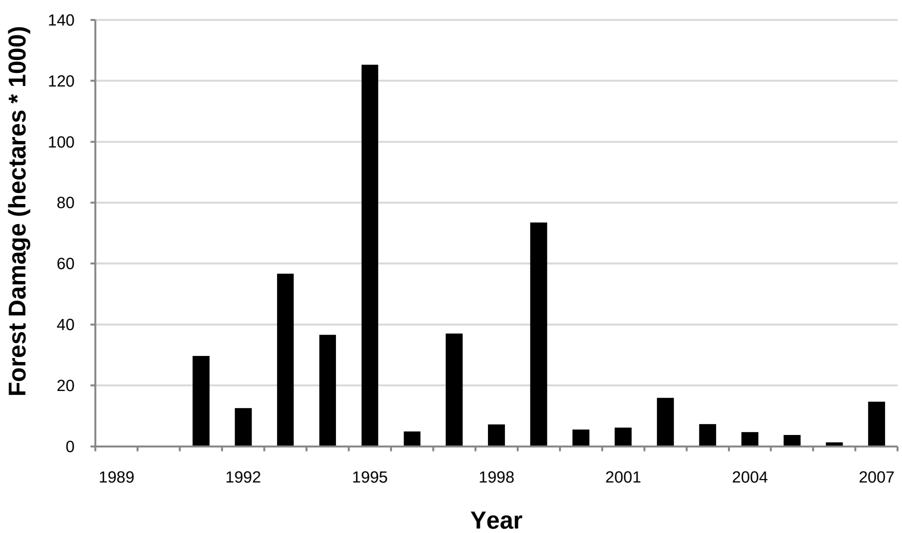


Figure 48. Yearly total area of spruce beetle damage, WRST, 1989-2007. (NPS PDS 2009a)

Frequency of spruce beetle damage

Spruce beetle damage is noted in nearly every year of the Forest Health Program Annual Survey, except for 1989 and 1990. Given the extent of spruce-dominated forest in WRST, it is expected that some level activity will occur nearly every year. However, a more important metric to track is the frequency of large scale outbreaks. The CRB saw an estimated 81,000 ha (200,155 ac) of forest infested in the 1910s and early 1920s (Werner et al. 2006). From 1991 to 1999, approximately 155,237 ha (383,600 acres) of forest was infested in WRST alone (NPS PDS 2009a).

Spruce forests of WRST

A spruce beetle effects study along the eastern side of the Copper River, found that spruce beetles generally infest late successional white spruce stands with dense feather moss and a thick surficial organic layer (Allen et al. 2006). Stands of high density white spruce with >23 cm diameter at breast height (dbh) are preferred in the CRB, whereas stands with high densities of black spruce are generally avoided (Doak 2004). Higher mortality rates also occur in large diameter trees with relatively slow growth for their size (Doak 2004). Spruce beetles have been active in these areas throughout the survey years (Plate 34). Although not preferred, Sitka spruce is targeted by spruce beetles in southeast Alaska (Lamb et al. 2009). This spruce species is much less common throughout the park (only prevalent along the Malaspina forelands,) and to date, aerial forest damage surveys indicate only spruce needle rust in these forests.

According to the Alaska Vegetation Classification (Viereck et al. 1992), white spruce dominated forest account for approximately 420,921 ha (1,092,430 ac) in WRST (NPS PDS 2009b). Plate 35 shows areas of white spruce forest density by major landform (Viereck et al. 1992). The Chakina Fire of 2009 burned an area with large concentrations of closed white spruce. Approximately 28 % of the area within the fire perimeter showed some level of spruce beetle infestation according to Allen et al. (2006).

Impacts of spruce beetle damage

Infestations of spruce beetle may result in changes in aesthetic value of the forest, modification of wildlife habitat, increased fuel loading, reduced live subsistence log availability, and impairment of forest regeneration rates for target species. Spruce beetle infestations can cause extensive tree mortality, which modifies stand structure, reducing average tree diameter, height, and stand density (Holsten et al. 1999). There has been a significant change in fuel type and increases in large woody debris from outbreaks throughout Alaska (Holsten et al. 1999). This landscape level change in forest cover can also affect hydrology through reduced evapotranspiration rates and increases in runoff to local rivers, lakes, and streams (Holsten et al. 1999).

Researchers examined changes to wildlife habitat after the 1990s spruce beetle outbreaks in south-central Alaska, finding that forests in the Copper River Basin still supported a complex community of breeding birds despite large changes in forest structure (Matsuoka et al 2001). Werner et al. (2006) specifically note in a review of thirty years of literature that wildlife population studies were conducted to assess avian and small mammal response to these infestations. The studies generally indicate that: (1) beetle-infested forests support a diverse community of wildlife species; (2) spruce beetles influence the structure of wildlife communities by altering both resource availability and relationships between predators and prey; (3) wildlife response is highly variable with important differences observed between coastal and boreal forests on the Kenai Peninsula and Copper River Basin, respectively; and (4) salvage logging has more extensive negative effects on wildlife populations than the spruce beetle infestation alone.

Extensive infestations of spruce beetle can kill large tracts of forest creating a significant fuel source and increasing the potential for large forest fires. Since dead spruce trees deteriorate slowly, the material that they provide is a potential forest fire fuel, remaining viable for a long time period. A wood deterioration study on Kenai Peninsula indicated a relatively slow overall decomposition rate or 1.5%/year (ADNR 2009). ―Beetle-killed trees are predicted to influence fire behavior and present a hazard for over seven decades" (Lamb et al. 2009 page 5).

Diseases
The only two diseases documented in the Forest Health Program Annual Survey were spruce needle rust and spruce broom rust. No other documentation of forest disease within WRST was found in the material reviewed for this report. Diseases vary in their effects on forest ecosystems and, though not specifically documented in WRST, a large variety is present throughout Alaska forests (Table 22).

Stressors
Both human and natural land disturbances contribute to spruce beetle attack and epidemic outbreaks, creating stressed trees that are more susceptible to beetle infestation (Allen 2009). Conditions that create higher susceptibility to spruce beetle infestations include warm temperatures, large quantities of spruce suitable for breeding, and disturbances such as wind-throw or logging (Werner et al. 2006). Other anthropogenic disturbances beyond timber harvest include road construction, seismic line construction, and building-construction. In addition to wind-throw, wildfire and erosion provide natural disturbances for establishment of infestations. It is also important to note that heavy, wet winter snow, during warm winters may also create conditions suitable for beetle infestation (Juday 2009).

WRST NPS resource staff identified the following stressors that affect the natural frequency and extent of forest insect and disease infestations:

Climate warming could provide more stressed tree conditions and insects and diseases could take advantage, potentially creating landscape level changes in WRST.

Anthropogenic landscape change in areas adjacent to the Park (e.g. logging, land clearing etc.) may promote infestations that can migrate into the park.

Non-native pests experience continuous introductions to North America and may significantly impact native species.

Climate directly influences the survival and spread of insects and pathogens and indirectly influences the susceptibility of forest ecosystems (Dale et al. 2001). Echoing NPS staff concerns of a warming climate‘s effects on insects and disease, (Werner et al. 2006) state that predicted changes in climatic warming could create conditions favorable for the development of epidemic populations of spruce beetle, as their life-history is largely controlled by temperature (Werner et al. 2006). Large outbreaks in both the Kenai Peninsula and the Kluane areas from 1994 to 2004 exceeded outbreaks detected in the 1870s-1880s on the Kenai Peninsula in both magnitude and intensity (Berg et al. 2006a). Berg et al. (2006a) suggest that the increased intensity of spruce beetle activity from1994 to 2004 may foreshadow future large-scale outbreaks with continued warming.

Table 22. Suspected effects of common diseases on ecosystem functions in Alaska forests. (Lamb et al. 2009)

	Ecological Function Altered			
Disease	**Structure**	**Composition**	**Succession**	**Wildlife Habitat**
Stem Diseases				
Dwarf mistletoe	3	2	2	3
Hemlock cankers	1	2	1	2
Hardwood cankers	2	2	2	1
Spruce broom rust	2	1	1	3
Hemlock bole fluting	1	1	1	2
Western gall rust	1	1	1	1
Heart Rots				
(Many species)	3	2	3	3
Root Diseases				
(Several species)	1	3	3	1
Foliar Diseases				
Spruce needle rust	1	1	1	1
Spruce needle blights	1	1	1	1
Hemlock needle rust	1	1	1	1
Cedar foliar diseases	1	1	1	1
Hardwood leaf diseases	1	1	1	1
Shoot Diseases				
Sirococcus shoot blight	1	1	1	1
Shoot blight of yellow-cedar	1	2	1	1
Declines				
Yellow-cedar decline	3	3	3	2
Animal Damage				
Porcupines	2	1	1	2
Brown bears	2	1	1	2
Moose	2	2	3	3

Effects by each disease, disorder, or animal are qualified as:
1 = negligible or minor effect
2 = some effect
3 = dominant effect

Currently, timber harvest occurs on private in-holdings, Native Corporation, DNR, and University lands within the park; however, no reports of harvest acreage are available. In addition to salvage logging, some spruce harvests were reportedly conducted preemptively, in anticipation of a loss in value due to impending beetle infestations (NPS, Miranda Terwilliger WRST Ecologist, pers. comm.). Terwilliger suggests that logging damage can trigger infestations and infestations in an area can also prompt harvest of spruce trees in anticipation of spruce beetle spread. The only quantifiable data available regarding timber harvest and land clearing activities within or immediately adjacent to the administrative boundaries of WRST is through the 1997-1999 spruce beetle vegetation map (NPS PDS 2009c). NPS PDS (2009c) indicates that, as of 1997, over 10,000 acres were clear-cut on the Ahtna and Chitina corporation lands near the confluence of the Chitina and Copper Rivers. Logging also occurs in Icy Bay immediately outside of park lands.

Invasive species threaten the integrity and sustainability of ecosystems during a time of changing climate regimes, increasing disturbance (both natural and human caused), and expanding human populations (Simberloff et al. 2005). Invasive pathogens and invasive insects could both have enormous consequences for the state‘s forest ecosystems, potentially causing widespread ecological change (Schrader and Hennon 2005). In 2005, there were no invasive tree pathogens causing significant disease damage in Alaskan ecosystems, but several invasive insect species were established in the forests of Alaska (Schrader and Hennon 2005). Schrader and Hennon (2005) created a list of invasive pathogens and insects (among other species categories), considered threats to invasion to National Forest land in Alaska, Table 24). These invasive insects and pathogens are likely important in WRST as well. To date, no invasive insects or pathogens were documented through aerial forest damage surveys in WRST.

Condition discussion

Insects, in general, are quite sensitive to temperature and most have a particular range of temperature to which they are adapted. Any deviation from this optimal range can, through various mechanisms, affect population cycles (Lamb et al. 2009). A trend of longer growing seasons and a decrease in the severity of winters is occurring across Alaska (Lamb et al. 2009). Since insects are so sensitive to temperature they can act as bio-indicators of climate change affects. New research is being developed by the Alaska Region USFS to identify specific insects which can be monitored as bio-indicators in the northern forests of Alaska (Lamb et al. 2009). WRST contains 2,249,577 acres of forest (NPS PDS 2009b). The spruce beetle may be a good candidate as a bio-indicator of climate change in WRST.

Spruce beetle outbreaks have been widespread in the last decade in the Copper River Basin and the resulting tree mortality is a driver of vegetation change in WRST. Preferring medium to larger white spruce, the spruce beetle has changed areas from mixed spruce forest to stands of pure black spruce and sometimes into patchy shrub-lands (Allen et al. 2006). As of 2008, spruce beetle activity has been decreasing for two consecutive years in the Copper River Basin and WRST, with most of the remaining activity occurring along the base of the hills along the Chitina River near McCarthy (Lamb et al. 2009). It is unknown if spruce beetles are within their natural/historic range of extent or frequency in the park. Research in Lake Clark National Park indicates a 50 year mean return interval of widespread forest thinning and on the Kenai Peninsula there was a 52 year average return interval of spruce beetle. However, in Kluane National Park and Preserve, which is immediately adjacent to the west of WRST, the return interval may be considerably longer with regional outbreaks being extremely rare over the past 250 years (Berg et al. 2006a). If these were acceptable surrogate return intervals for WRST and the primary data available to assess forest insect or disease outbreaks is currently limited to an 18 year period, determination if spruce beetle infestations or any other forest damage agent is outside of their historic mean return interval is not yet possible.

Aspen defoliation has been shown to have the largest ten year cumulative area affect in Alaska (Lamb et al. 2009). Aspen is not a dominant forest type across the landscape in WRST, covering just 62,500 acres of the 13.2 million acre area (NPS PDS 2009b). However, damage to these trees by large aspen tortrix and aspen leaf miner together covered an approximate area of 7,200 acres during the 2008 growing season in WRST (NPS PDS 2009a). The majority of this damage occurred north of the McCarthy road and near the town of McCarthy. It is unknown if these two damage agents are out of their historic ranges in terms of frequency and extent. They only began to show up in the aerial survey data in 2005 and are not present in any year from 1987 to 2004.

Alfaro and Singh (1997) note that, ―when assessing the significance of a particular forest insect or disease outbreak, it is of critical importance to compare the magnitude of the disturbance with the historical pattern, particularly in terms of extent, intensity and frequency. If the disturbance pattern is outside the historical range of variation, there is a probability that forest health may be declining. In that case, it is necessary to determine the underlying causes."

However, insect and disease disturbances are of management concern because they are predicted to change due to potential effects of climate warming.

Very little information exists regarding forest diseases specific to WRST. In the Forest Health Program Annual Survey data, spruce needle rust is the only documented disease. It is documented as present in the Sitka spruce forests along the Malaspina forelands because of its detectability via aerial survey. Most disease symptoms, however, are not typically detectable via aerial assessment. As a result, not enough is known about forest diseases in WRST to create an assessment.

Table 23. Invasive Insects of Alaska. (Schrader and Hennon 2005, Lamb et al. 2009)

Common name	Scientific name	Present in Alaska?	Invasiveness ranking
pine moth	*Dendrolimus pini* (L)	No	High
European spruce beetle	*Ips typographus* L.	No	High
Asian gypsy moth	*Lymantria dispar* L.	No	High
nun moth	*Lymantria monacha* (L.)	No	High
western and forest tent caterpillars	*Malacosoma californicum* (Packard) and Malacosoma disstria (Hübner)	No	High
larch sawfly	*Pristiphora erichsonii* (Hartig)	Yes	High
amber-marked birch leafminer	*Profenusa thomsoni* (Konow)	Yes	High
brown spruce longhorn beetle	*Tetropium fuscum* (F.)	No	High
woolly spruce aphid	*Adelges abietis* (L.)	No	Moderate
hemlock woolly adelgid	*Adelges tsugae* Annand	No	Moderate
Asian longhorned beetle	*Anoplophora glabripennis* (Motschulsky)	No	Moderate
larch casebearer	*Coleophora laricella* (Hübner)	No	Moderate
spruce aphid	*Elatobium abietinum* (Walker)	Yes	Moderate
birch leafroller	*Epinotia solandriana* L.	Yes	Moderate
birch leafminer	*Fenusa pusilla* (Lepeletier)	Yes	Moderate
larch engraver	*Ips cembrae* (Heer)	No	Moderate
European gypsy moth	*Lymantria dispar* (L.)	No	Moderate
Sitka spruce weevil	*Pissodes strobe* (Peck)	Yes	Moderate
eastern spruce gall aphid	*Adelges piceae* (Ratzburg)	Yes	Low
ugly nest caterpillar	*Archips cerasivorana* (Fitch)	Yes	Low
alder woolly sawfly	*Eriocampa ovata* (L.)	Yes	Low
European alder sawfly	*Hemichroa crocera* (Fourcroy)	No	Low
birch-edge leafminer	*Heterarthrus nemoratus* (Fallen)	Yes	Low
currant worm	*Nematus ribesii* (Scopoli)	Yes	Low
strawberry root weevil	*Otiorhynchus ovatus* (L.)	Yes	Low
European pine shoot moth	*Rhyacionia buoliana* (Schiffermüller)	No	Low
European gypsy moth*	*Lymantria dispar L.*	Yes	-
Asian gypsy moth*	*lymantria dispar dispar*	?	-
rosy gypsy moth*	*lymantria mathura* Moore	?	-
nun moth*	*lymantira monoch* L.	?	-
Siberian silk moth*	*Dendrolimus superans sibiricus* Tschetverikov	?	-
European yellow underwing moth *	*Notua pronuba* L.	Yes	-
rose Tortix moth*	*Archips rosana* L.	Yes	-
dalmation toadflax weevil*	*Gymnetron antirrhini* Paykull	Yes	-

*These species were noted in (Lamb et al. 2009). Presence in Alaska was not reported for all of the species in this source nor was the invasiveness ranking.

Table 24. Invasive pathogens either present, or not in Alaska, and invasive ranking. (Lamb et al. 2009)

Common name	Scientific name	Present in Alaska?	Invasive ranking
spruce needle rust	*Chrysomyxa abietis* (Wllr.) Unger	No	High
rhododendron-spruce needle rust	*Chrysomyxa ledi* var. *rhododendri* (de Bary.)	No	Moderate
resinous stem canker	*Cistella japonica* Suto et Kobayashi	No	Moderate
cedar shot hole	*Diymascella chamaecyparidis* (J. F. Adams) Maire	No	Moderate
poplar rust	*Lophodermium chamaecyparidis* Shir & Hara.	No	Moderate
seiridium shoot blight	*Melampsora larici-tremulae* Kleb.	No	Moderate
phytophthora root disease	*Seiridium cardinale* (Wagener) Sutton & Gibson	No	Moderate
alder Phytophthora	*Phytophthora lateralis* Tucker & Milbrath	Yes	Low[1]
black knot	*Phytophthora alni* subsp. *uniformis*	Yes	Low
pine wilt nematode	*Bursaphelenchus xylophilus*	No	Low
white pine blister rust	*Cronartium ribicola* J.C. Fischer: Rabh.	Yes	Low
fire blight	*Erwinia amylovora* (Burrill) Winslow	Yes	Low
sudden oak death	*Phytopthora ramorum* Werres deCock Man in't Veld	No	Low
birch leaf curl	*Taphrina betuale* (Fckl.) Johans.	No	Low
birch witches broom	*Tphrina btulina* Rostr.	No	Low
valsa canker	*Valsa harioti*	No	Low

[1]Pathogen found in Alaska in 2007. To date it is unknown whether it is invasive or native.

Data Needs

The primary spatial data examined in this assessment is the aerial survey data collected by the USFS, Forest Health Protection (FHP) and the Alaska Department of Natural Resources (ADNR), Division of Forestry. The aerial surveys do not detect some of the diseases known to be present because the agents are not detectable from aerial surveys. Understanding forest insect and disease damage therefore, can only be assessed as general trends the detectable species. In addition, surveys are only conducted for the Copper River valley, Chitina River valley and along the coast in WRST for a select number of damage agents (insects, disease, flooding, fire, etc.). See the NPS Permanent Data Set (NPS PDS 2009a) for a list of agents detected by the surveys. No surveys are conducted in the White River basin or the northeastern portion of WRST.

The main data needs for a better understanding of the condition of natural disturbances caused by forest insect and diseases include historic information that supports a more detailed definition of reference condition, increased coverage to understand more of the park, and ancillary data that speak to the intensity of infestations in WRST.

The only available information that speaks directly to reference condition is the research on tree rings and growth release, indicating a 50 year return interval on major forest thinning events, interpreted as spruce beetle infestations. However, this only exists for Kenai Fjords National Park (KEFJ) and Lake Clark National Park (LACL), not WRST. No data are available for assessment of historic insect and disease infestation in WRST prior to 1987.

Aerial surveys of forest damage do not represent full coverage across the forested landscape because it is cost prohibitive to annually fly all forested areas and conduct damage surveys. However, satellite image analysis could provide generalized spatial analysis of insect and disease infestation. In order to better understand the condition of the natural insect and disease extent and distribution, more information is needed on the historical patterns of these disturbances.

Another measurement that is important to assess is the intensity of infestations. Data on this topic would allow for an assessment of the quantities and qualities of forest fire fuels created by these disturbances. The aerial survey data inconsistently report a relative infestation intensity rating of low, medium, or high. Though this is likely a subjective assessment, it could provide an important starting point for understanding intensity. Additionally, the data set created by Allen et al. (2006) is an important step in understanding the intensity of spruce beetle outbreaks and potential effects, as it maps the estimated mortality by area in WRST. Finally, Werner et al. (2006) suggest that research should measure how climate change, invasive species, and other disturbances further modify successional trajectories, tropic relationships, and susceptibility of areas to more spruce beetle outbreaks.

A future project should address some of the main data needs for understanding the important role of spruce beetles as a natural disturbance vector. A joint fire science project proposal was developed in 2010 by Co-leads R. Sherriff, M. Varner (Humboldt State University), and J. Barnes and M. Terwilliger (NPS). The overall objective of this project is to assess the effects of insect outbreaks on fuel-beds and fire behavior in a representative area of spruce forests in south-central Alaska. This research will attempt to answer the basic question of how beetle disturbance alters fuel-beds and fire hazard in unmanaged forests. Three specific objectives of the research are as follows:

- Objective 1. Assess how fuel beds (ground, surface, ladder and crown fuels) change over time in response to widespread spruce bark beetle activity in the Copper River Basin of south-central Alaska.
- Objective 2. Investigate whether areas of severe fire behavior are spatially coincident with areas that recently (1990s - 2009) experienced spruce bark beetle outbreaks, specifically focusing on the Chakina Fire of 2009. Approximately 28% of the Chakina Fire area had some level of beetle infestation within its perimeter.
- Objective 3. Predict (―retrofit") broad classes of fire behavior within the boundary of the Chakina Fire using a common fire behavior model (i.e., FlamMap), daily fire weather patterns, updated fuel characteristics, and other up-to-date geospatial data sets.

Initial funding was not secured through the interagency fire research funding group; however, funding is being sought elsewhere (J. Barnes pers. comm.).

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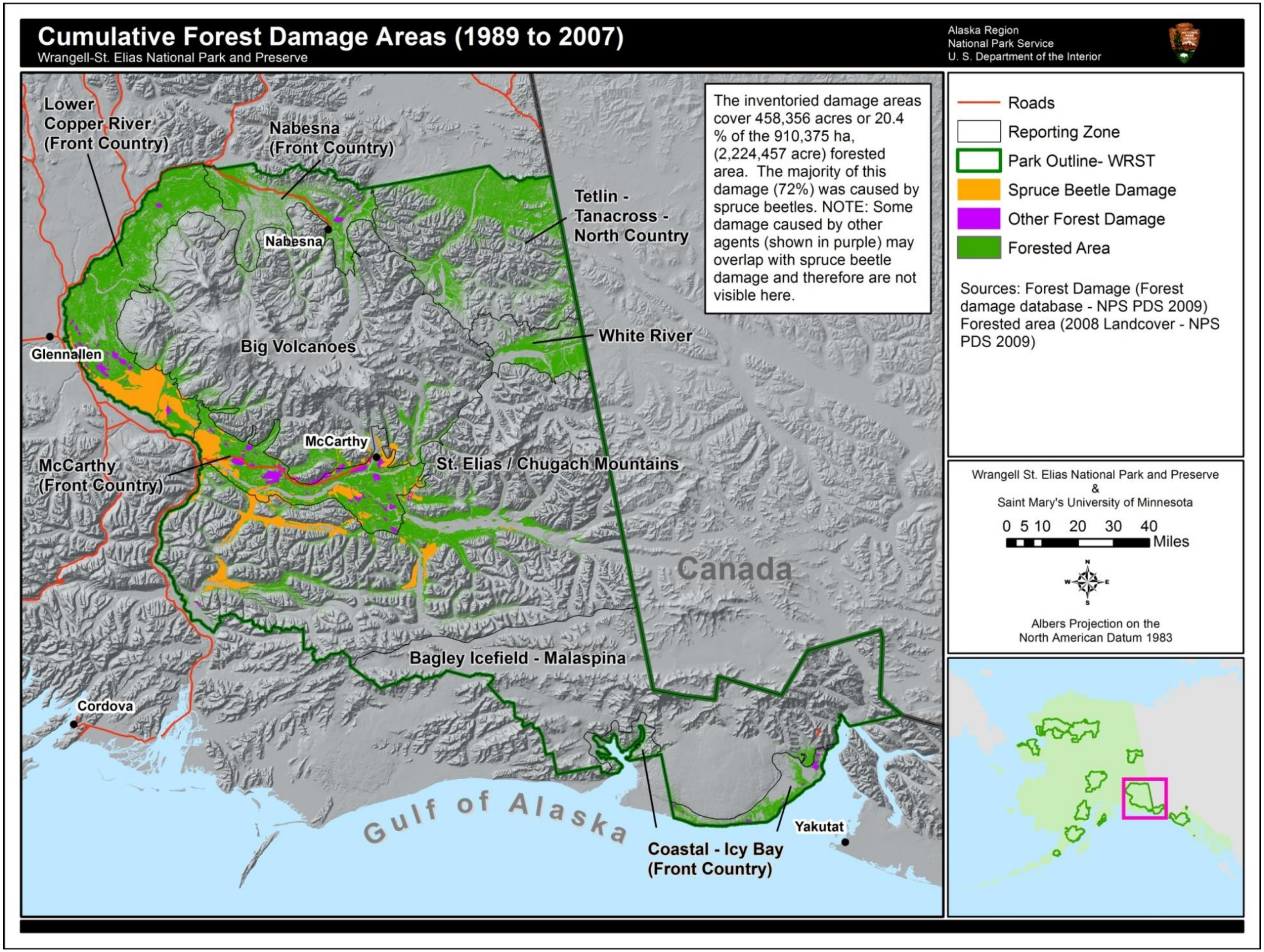


Plate 33. Forest damage areas 1987 to 2007. (NPS PDS 2009a)

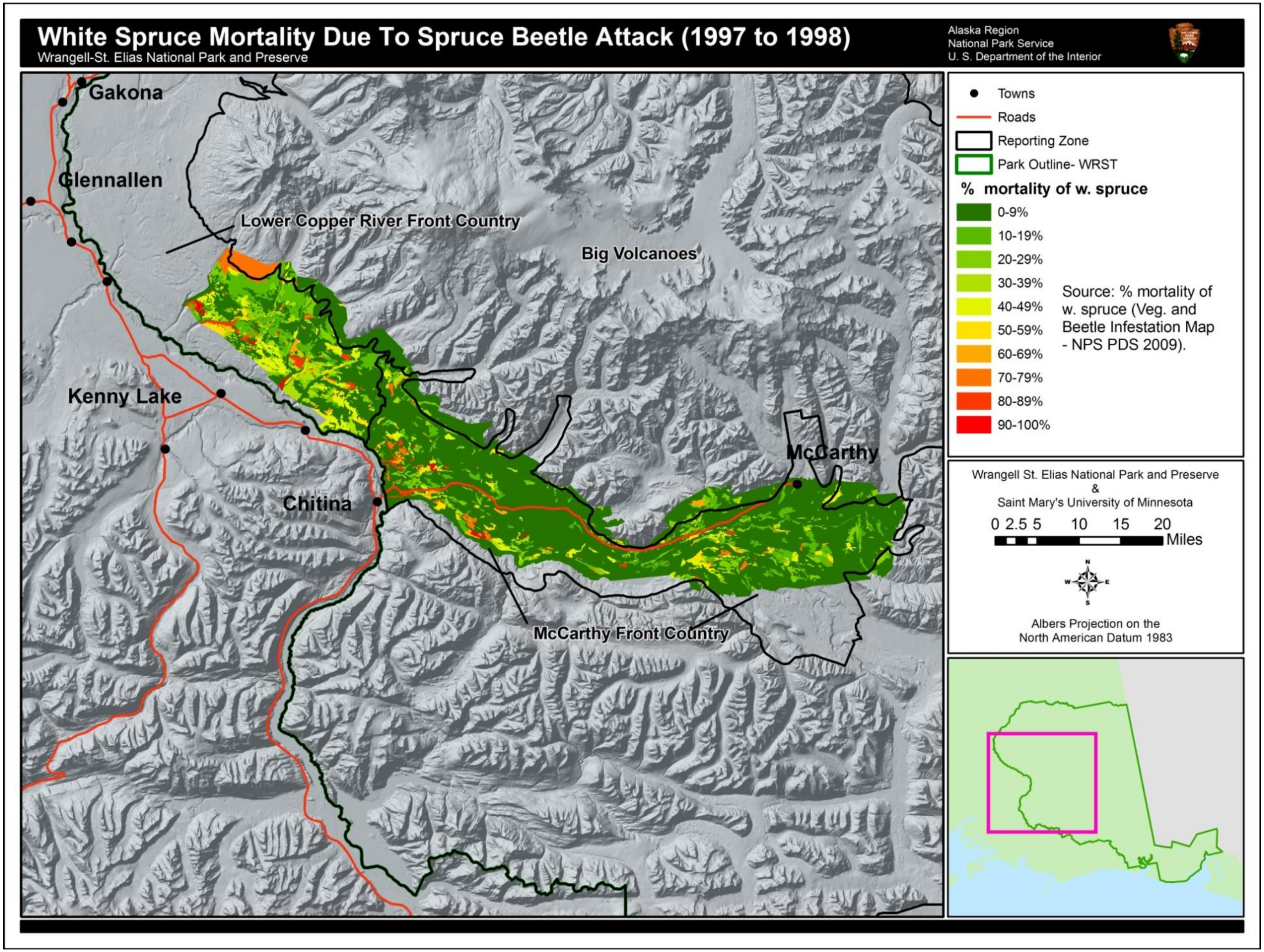


Plate 34. White spruce mortality due to spruce beetle attack 1997 to 1998. (NPS PDS 2009c)

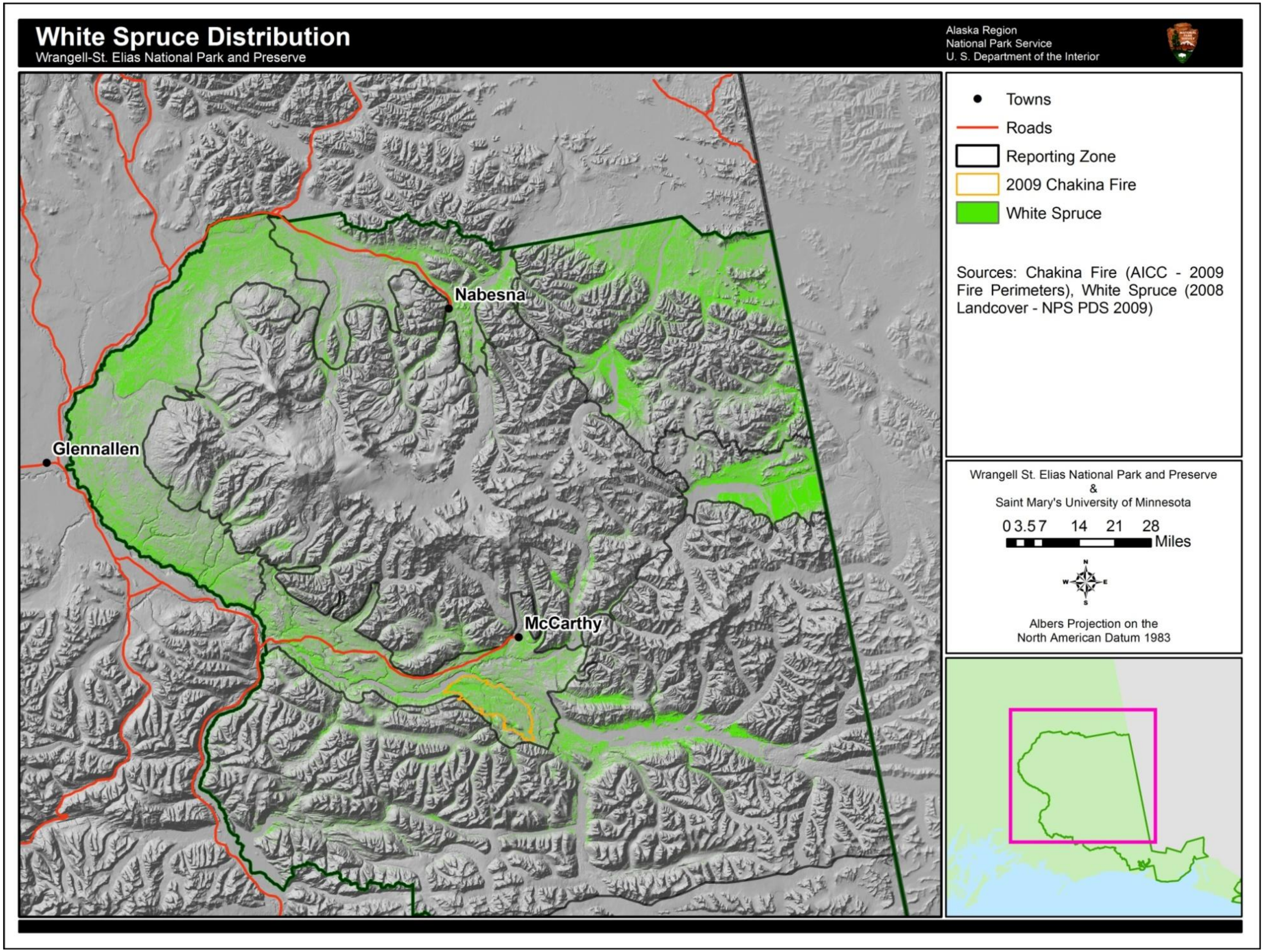
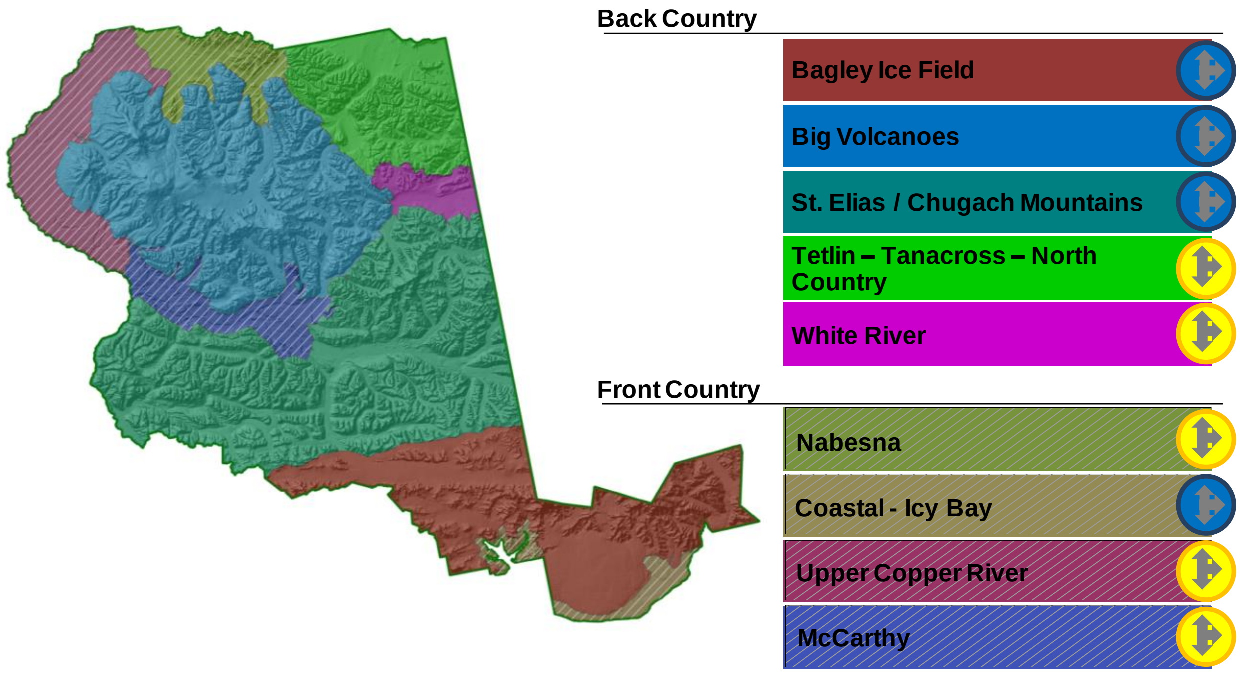


Plate 35. White spruce distribution (NPS PDS 2009b, c)

4.16 Non-Native Species

Indicators and Measures

Extent and Distribution of Infestations



Condition

The Nabesna, Upper Copper River, McCarthy, Tetlin-Tanacross-North Country and White River RZs contain the vast majority of known infestations of invasive plants in WRST. Therefore, invasive non-native plants are of moderate concern in these zones, however insufficient data are available to determine trends in condition. The other, more remote RZs have limited survey data regarding invasive non-native plants, but available data show very few invasive plant infestations in these remote areas. The condition of invasive plants in the Bagley Ice Field, Big Volcanoes, St. Elias/ Chugach Mountains, and Coastal Icy Bay RZs is good based on the few occurrences of invasive non-native plant infestations that currently exist. The trend of condition in these areas is also unknown due to the limited data. The extent and distribution of non-native fauna are limited through-out the park, therefore, the condition designations do not take them into account.

Introduction and background

Non-native plants are those whose presence in a given area is due to accidental or intentional introduction by humans, but are not necessarily problematic (NPS 2009a) Invasive non-native plants are those that exhibit a tendency to spread out of control through a given area, typically by producing viable offspring in large numbers and having limited or no native diseases or pests that help control their spread. Non-native plant species that are not invasive typically include ornamental or garden plants. Invasive non-native plant species have the potential to establish in natural areas and compromise many native plant communities (NPS, 2009a). Non-native invasive plant species can affect native plants directly by monopolizing limited resources and indirectly by altering soil stability, promoting erosion, colonizing open substrates, affecting the accumulation of liter or other soil resources, and promoting or suppressing fire (Brooks et al. 2004). They can also threaten the genetic integrity of native flora through hybridization, out-compete native plant species, cause changes in the structure and function of ecosystems through alterations in geochemical and geophysical processes, and have the potential to impact fish and wildlife habitats (Terwilliger et al. 2010). They threaten the ecological balance of native plant and animal communities (NPS 2009b).

Also of management concern are non-native invasive fauna. However, given the limited extent and distribution of invasive fauna currently known in WRST, the non-native species section of this document discusses the invasive fauna in its own section, see pages 207- 208.

In NPS units, ―exotic” species (now referred to as ―non-native” by the NPS) are not allowed to displace native species if possible (NPS 2006 Management Policies 4.4.4) (NPS 2006). For those non-native species already present and found to interfere with natural processes and the perpetuation of natural features, native species, or natural habitats, NPS attempts to eradicate if control measures are prudent and feasible (NPS Management Policies 4.4.4.2) (NPS 2006).

Most non-native plants in Alaska are restricted to relatively small areas of anthropogenic disturbance (Carlson et al. 2008). Alaska is different from other U.S. states because it has a much lower human population density, road density, and percent agricultural land area, all of which play a role in the level of invasive plant invasion for a given state (Carlson et al. 2008). The population density of the U.S. is 206.2 people/km^2 (79.6 people/mi^2), and Alaska averages 2.8 people/km^2 (1.1 people/ mi^2). The Valdez-Cordova Census, which is generally representative of population in and around WRST, found 0.8 people/km^2 (0.3 people/ mi^2) (U.S. Census 2000). Road density, measured as land area per road length, is 4.1 km^2/km (1.6 mi^2/mi) nationally, 176 km^2/km (68 mi^2/mi) in Alaska, and 1,481 km^2/km (572.2 mi^2/mi) in WRST (including only the Nabesna and McCarthy Roads). There are very few agricultural lands in Alaska, approximately 12,464 ha. (30,800 acres) in 2007 (USDA 2007a).

Alaska is on the cusp of facing serious ecological problems associated with non-native invasive plants in both natural and human-altered landscapes (Carlson and Shephard 2007). Carlson & Shephard (2007) found that the number of recorded non-native invasive plant populations in Alaska, including those considered invasive, follows an exponential growth pattern.

Documentation of non-native invasive species in WRST was initiated in 2001 by former park botanist, Mary Beth Cook (NPS, Miranda Terwilliger WRST Ecologist, pers. comm.). Other baseline studies were conducted from 2000 to 2004 (Denismore et al. 2001, McKee 2006, Bauder and Heys 2004). In 2003, the EPMT program officially started data collection for invasive plants in Alaska National Park Service Units including WRST. Currently, NPS and other land managers track invasive weed infestations in Alaska through the Alaska Exotic Plant Information Clearinghouse (AKEPIC), which serves as an inventory of GPS data points throughout Alaska. NPS also maintains an in-house invasive plant database for all infestations documented by the Alaska EPMT (Terwilliger et al. 2010).

There are several main objectives of the EPMT: to monitor known populations of invasive weeds; contain, control and, where possible, eradicate known populations of invasive plants; and inventory areas with known human disturbance where invasive plants are likely to appear (Terwilliger et al. 2010). Each year the EPMT program creates an annual report that describes the last season‘s efforts and plans for the following season. Plants with an Alaska invasiveness ranking of 50 or higher are the focus of management effort, whereas lower ranked plants are targeted at the discretion of the program‘s biological technicians. The invasiveness ranking system recognizes that not all invasive plants are equally harmful and allows resource managers to prioritize limited program funding on the most threatening species (Carson et al. 2008).

Reference condition

The reference condition for non-native species in WRST, as defined in the scoping process, is pre-non-native species or no non-native species in the park. Because it is unrealistic to reach this reference condition, an appropriate method for assessing the condition of non-native invasive species in WRST is to evaluate recent trends in number of non-native invasive species and total area of occurrence of those species.

Current condition

A summary of WRST invasive plant management accomplishments, current as of the end of the 2009 field season, is displayed in Table 25 (Terwilliger et al. 2010).

Table 25. Summary of WRST non-native (exotic) plant management. (Terwilliger et al. 2010)

		Invasive GPS Data NPS Land (non NPS Land)					
Year	Total Person Field Hours[1]	Acres Surveyed	Acres Infested*	Acres Treated	New Species	Bags Collected	Plant Vouchers
2001	-	-	-	-	17	-	13
2002	-	-	-	-	-	-	9
2003	-	*[2]	73.93 (-)	0.1	2	-	3
2004	-	12.5 (5.0)	84.4 (5.0)	0.2	3	-	15
2005	289	1.9 (7.7)[2]	86.3 (12.7)[3]	-	6	96	39
2006	1,256	300.0 (22.4)	97.1 (24.0)	2.8	5	-	232
2007	987	507.6 (64.63)	163.6 (49.3)	0.4	3	20	34
2008	562	822.1 (1,531.5)[4]	172.8 (50.5)	4.5	1	99	10
2009	1,645	215.4 (60.2)	261.6 (87.7)	7.2	3	187	9

* Acres infested are calculated by acres mapped times the percent cover in areas greater than 5 acres. If less than 5 acres, acreage mapped is counted as 100%.
[1] - EPMT personnel, Youth Groups, and other volunteer hours combined.
[2] - Data was collected but is highly inaccurate
[3] - Problems with GPS units resulted in low mapping acres in 2005
[4] - EPMT drove and mapped the Richardson Highway and the Nabesna and McCarthy Roads looking for white sweetclover only. This accounts for the unusually high acreage.

From 2003 to 2008, the majority of the EPMT efforts was spent on inventory and monitoring of non-native invasive plants in WRST. However, in 2009 more effort was spent on active control (weeding) of plants. WRST utilizes manual and mechanical methods of control, including pulling, digging, and cutting (Terwilliger et al. 2010). These control methods resulted in successful eradication of several infestations. NPS considers an infestation eradicated when it has been reduced to 1% of its original size. Given the small size of most of WRST's documented infestations this usually means that all target plants are not found the year following removal. For example, if the all plants are pulled in an area during 2007 and the plants do not come back in 2008, the species is considered eradicated from that location (Table 26) (Terwilliger et al. 2010). Control efforts have largely focused on nine species, though common dandelions (*Taraxacum officinale* spp. *officinale*) and white sweetclover (*Melilotus alba*) accounted for the majority of effort through 2008 (NPS PDS 2009a).

Table 26. Infestations considered eradicated in 2009. (Terwilliger et al. 2010)

Last Seen	Species: Latin Name	Species: Common Name	Rank	Location
2004[1]	*Crepis tectorum*	narrowleaf hawksbeard	54	Mile 31, Nabesna Road
2006	*Crepis tectorum*	narrowleaf hawksbeard	54	unused gravel pit at mile 11, Nabesna Road
2006	*Descurainia sophia*	flixweed	41	Little Jack Creek Bridge.
2007	*Lappula squarrosa*	European stickseed	44	Mile 17.9 Nabesna Road, in front of vault toilet at Dead Dog Hill rest area
2007[2]	*Vicia cracca*	bird vetch	73	Gakona Lodge
2008	*Chenopodium album*	common lambsquarter	37	McCarthy airstrip
2008	*Matricaria discoidea*	pineapple weed	32	Rowcon gravel pit near McCarthy airstrip
2008	*Thlaspi arvense*	field pennycress	(blank)	Island between footbridges over Kennicott River

[1] – Several Creeks run across the road between mileposts 29 & 35. They shift channels frequently and may have moved the plants.
[2] – This is probably due to mowing of the grounds by new owners rather than a true eradication.)

Number of species
The total number of invasive non-native species detected in WRST has increased from 2001 to 2009. However, this is mostly a reflection of cumulative effort over time verses an actual increase in the number of plant species in WRST. In 2001, 17 invasive plant species were known to exist in WRST, but by 2009, there were 40 known non-native plant species in the park.

Key species
At the end of the 2009 field season, 18 documented invasive plant species with an invasiveness ranking of 50 or higher were known to exist in WRST (Table 27). The top three species for gross infested land coverage at the end the 2009 field season in WRST are white sweetclover, common plaintain (*Plantago major*), and pineapple weed. However, the white sweetclover includes area mapped along the hwy outside of WRST. Common dandelion (ranked 58), white sweetclover (ranked 81), and common plantain (*Plantago major)* (ranked 44), account for the majority of total land area that is colonized by invasive plants as well as the majority of sites observed in 2003 to 2008 surveys. These species also account for the majority of hours spent controlling invasive plants through the 2008 field season. Common dandelion is pervasive in all the areas covered in the 2009 field season report and has such a widespread distribution in the McCarthy-Kennecott area that it is generally beyond control by manual methods (Terwilliger et al. 2010).

White sweetclover (ranked 81) is one of the most-widely distributed invasive plants in Alaska (Wurtz et al. 2006). It reproduces aggressively with each plant capable of producing more than 350,000 seeds that remain viable for up to 80 years (NPS 2009c). It is the highest priority invasive plant species found in WRST according to the Alaska ranking system, and has shown a large increase in distribution across the state over the past several years. In WRST, during 2003, there were approximately 200-500 plants near the junction of the Nabesna Road and the Tok Cut-Off. By the following year, this particular infestation had grown to an estimated 10,000 plants. White sweetclover remains a high priority in the Slana area. Populations exist on the Glenn and Richardson highways, outside of the park, but were not monitored in 2009. In 2008, there was a notable increase of white sweetclover along roadways throughout south-central Alaska (Lamb et al. 2008), and in 2009, it was found in new locations along McCarthy Road and near the park headquarters (Terwilliger et al. 2010). Though not yet documented in the floodplains of WRST, Spellman (2008) concludes that white sweetclover can impact recruitment of native plants within floodplain habitats of Alaska.

Table 27. Invasive plants with invasiveness ranking greater than 50 in WRST.

Latin Name	Common Name	Invasive Ranking
Melilotus alba	white sweetclover	81
Vicia cracca	bird vetch	73
Caragana arborescens	Siberian pea shrub	66
Melilotus officinalis	yellow sweetclover	65
Hordeum jubatum	foxtail barley[1]	63
Bromus inermis	smooth brome grass	62
Linaria vulgaris	yellow toadflax or butter and eggs	61
Leucanthemum vulgare	oxeye daisy	61
Trifolium repens	white clover	59
Elymus repens	quackgrass	59
Medicago lupulina	black medic	59
Taraxacum officinale ssp. *officinale*	common dandelion	58
Trifolium hybridum	alsike clover	57
Tanacetum vulgare	common tansy	57
Phleum pretense	common timothy	56
Lupinus polyphyllus	bigleaf lupine	55
Crepis tectorum	narrowleaf hawksbeard	54
Trifolium pretense	red clover	53

[1] – Hordeum jubatum is no longer considered an invasive species in Alaska.

Other important invasive plants established around WRST include: narrow-leaf hawksbeard (*Crepis tectorum)* (ranked 54), and butter and eggs or yellow toadflax (*Linaria vulgaris)* (ranked 61). Though not yet highly prevalent, bird vetch (*Vicia cracca*) (ranked 73) is also present and has the potential to be very damaging (Gilmore 2009). Finally, common tansy (*Tanacetum vulgare*) (ranked 57), which is found at the park maintenance yard, is currently a very high priority species in WRST.

Extent & Distribution

Following the 2009 field season, there were a total of 105.6 ha (261.6 acres) of known invasive plant distributions on park lands and 35.5 ha (87.7 acres) of known invasive plants on adjacent, non-park lands (Table 25) (Terwilliger et al. 2010). Known areas of infestation are generally found through opportunistic surveys of the roads, trails, town sites, NPS facilities, remote sites, airstrips, cabins, and river flood plains. Given the large amount of non-NPS managed land found within the WRST boundary and the potential vector that this represents, the Alaska EPMT also actively surveys non-park lands that may impact NPS lands.

<u>Road and trail accessible locations</u>

The majority of survey efforts in or adjacent to the park that are accessible by road and trail have occurred in four main areas: the Nabesna/Slana area, the headquarters/Copper Center area, the Chitina area, and the McCarthy/Kennecott area. In 2009, nine of the fourteen trails leading from the Nabesna Road were surveyed and all trails leading out of Kennecott were at least partially evaluated, mapped, and weeded (Table 28) (Terwilliger et al. 2010).

Table 28. List of maintained trails and invasive weed identification efforts (Terwilliger et al. 2010).

Name	What	Ownership	Year*	Invasives present
Batzulnetas & Fish Wier	Trail	Nabesna Rd m. 8.5	2009	None
Bonanza Mine	Trail	Kennecott	2009	
Chititu Camp	Trail	May Creek	2009	*Taraxacum officinale*
Crystalline Hills	Trail	McCarthy Rd m.34.7		
Dan Creek	Trail	May Creek	2009	*Taraxacum officinale*
Dixie Pass	Trail	McCarthy Rd m.14.5		
Donoho Basin	Trail	Kennecott	2009	
Erie Mine	Trail	Kennecott		
Jumbo + Bonanza	Trail	Kennecott	2009	*Taraxacum officinale, Trifolium hybridum, others*
Jumbo Mine	Trail	Kennecott	2009	*Taraxacum officinale*
Long Lake	Trail	McCarthy Rd m.45.2	2009	potentially *Vicia cracca*
Long Lake	Trail	Nabesna Rd m.22.9	2009	potentially *Vicia cracca*
Nugget Creek	Trail	McCarthy Rd m.14.5		
Old Wagon Road	Trail	McCarthy -Kennecott		
Public Use Cabin	Trail	May Creek	2009	*Taraxacum officinale*
Rambler Mine	Trail	Nabesna Rd m.42	2009	none
Root Glacier[3]	Trail	Kennecott	2009*	*Taraxacum officinale*
Skookum Volcano	Trail	Nabesna Rd m.36.2	2009	none
Strelna Lake	Trail	McCarthy Rd m.10		
Viking Lodge	Trail	Nabesna Rd m.21.8	2009	none
West Glacier Trail	Trail	McCarthy	2009	*Taraxacum officinale,* potential *L. perenne*
Young Creek	Trail	May Creek	2009	*Taraxacum officinale*
Big Grayling Lake	Trail (OHV)	Nabesna Rd m. 30.8		
Caribou Creek	Trail (OHV)	Nabesna Rd m.19.2	2009	none
Copper Lake	Trail (OHV)	Nabesna Rd m.12.2		
Kennecott Glacier Toe	Trail (OHV)	McCarthy	2009	Taraxacum officinale, potential *L. perenne*
Lost Creek[2]	Trail (OHV)	Nabesna Rd m.30.8	2009*	
Reeve's Field	Trail (OHV)	Nabesna Rd m.40.2	2009	none
Soda Creek	Trail (OHV)	Nabesna Rd m.31.8		
Suslota Lake	Trail (OHV)	Nabesna Rd m.11	2009	none
Tanada Lake	Trail (OHV)	Nabesna Rd m.24		
Trail Creek	Trail (OHV)	Nabesna Rd m.29		

* - Year indicates the last year that this area was visited by the EPMT crew.
[1] – *M. alba* was found in 2007 and 2008 (Gilmore and Goldsmith 2007, Gilmore and Harper 2008).
[2] – Only the beginning portion of this trail was mapped.
[3] – Weeded to Amazon Creek.

Remote Sites

Generally, there are few invasive plant species in the remote sites within WRST. However, these remotes sites are important to the WRST non-native invasive plant monitoring efforts, as once an non-native invasive species is established in a remote location, keeping control of the population distribution may be difficult. Remote sites surveyed by the EPMT include areas such as airstrips, cabins, campsites, river floodplains, and coastal portions of the park.

Remote airstrips have the potential to support the introduction and dispersal of invasive plants in the park interior (Terwilliger et al. 2010). Of all airstrips within the boundary of the park, 20 are park-maintained, several are privately maintained, four are state-maintained, and over 100 unmaintained airstrips may be regularly used (Terwilliger et al. 2010). Within the administrative boundaries of WRST, 90 landing strips, 22 float lakes, 3 airports, and two unclassified airstrips are documented in NPS PDS (NPS PDS 2009b). However, Scott (2009) documents over 454 locations as an airport, air strip, landing strip, or float lake in WRST. As of 2009, nine airstrips in the park were inventoried for invasive plants. The following landing strips or airports have invasive plants present: Amphitheatre Creek; Chitina; Nizina/Chitina confluence; Glacier Creek; May Creek; Peavine; Ptarmigan Lake; Skolai Pass; and Tana River (Table 29) (Terwilliger et al. 2010). While any airstrip in the park could act as a vector for non-native invasive plant dispersal, the McCarthy Airstrip is specifically important because of the relatively heavy use it receives (Gillmore & Harper, 2008). Additionally, airstrips and airports outside of the park are important as they are starting points for many flights into the park. The primary airports in the WRST area are located in Chisana, Gulkana, McCarthy, Tok, and Yakutat.

Other remote areas that have been surveyed for non-native invasive plants include portions of the White River, the Chitina River, and the Copper River between Chitina and Cordova; and locations near Bonanza Ridge, Horsfeld, Karr Hills, and some costal portions of the park. The areas surveyed along the Copper River in 2008, which included both NPS land and United States Forest Service (USFS) land, resulted in zero non-natives found (Gilmore and Harper, 2008). However, in 2009, foxtail barley was identified along the Copper River (Terwilliger pers. comm.). The White River, Chitina River, Bonanza Ridge, Horsfeld, and Karr Hills have documented non-native plants (Gilmore 2006). The first non-native plant survey of coastal portions, in the Coastal-Icy Bay RZ, did not identify any invasive or non-native plants on park lands (Terwilliger et al. 2010).

Non-park lands

The EPMT also monitors adjacent non-park lands, including: areas along the Nabesna and McCarthy Roads; areas along the Edgerton, Glenn, Richardson, Old Richardson, and Tok Cut-Off Highways; and several private in-holdings near town sites. White sweetclover is the only invasive plant that is monitored outside of the park boundary, along state roads (Cook 2006).

Table 29. List of landing strips and airports and weeding identification efforts (Terwilliger et al. 2010).

Name	What	Ownership	Year*	Invasives present
Ampitheatre Creek	Landing Strip	Park	2006	*Hordeum jubatum*
Baultoff	Landing Strip	Park		
Black Mountain	Landing Strip	Park		
Bremner	Landing Strip	Park		
Chelle Lake	Landing Strip	Park	2006	none
Chisana	Airport	State	2009	*none*
Chistochina	Airport	State		
Chitina	Landing Strip	State	2009	*Melilotus alba*
Chitina/ Nzina Confluence	Landing Strip	Park	2006	none
Doubtful Creek	Landing Strip	Park	2006	none
Glacier Creek	Landing Strip	Park	2006	*Taraxacum officinale*
Gulkana	Airport	State	2009	
Huberts	Landing Strip	Park		
Jakes Bar 1	Landing Strip	Park		
Jakes Bar 2	Landing Strip	Park		
May Creek	Landing Strip	Park	2009	*Taraxacum officinale*
McCarthy #2	Airport	State	2009	*Taraxacum officinale, Descurainia sophia,Hordeum jubatum*
Nizina/ Chitina	Landing Strip	Park		
Nugget Creek	Landing Strip	Park		
Peavine	Landing Strip	Park	2006	*Hordeum jubatum, Taraxacum officinale*
Pennisula	Landing Strip	Park		
Sanford 1	Landing Strip	Park		
Sanford 2	Landing Strip	Park		
Skolai Pass	Landing Strip	Park	2009	*none*
Solo Creek	Landing Strip	Park		
Tana River	Landing Strip	Park	2008	none
Tok	Airport	State		

* - Year indicates the last year that the facility was visited by the EPMT crew

Reporting Zones

The majority of documented distributions of invasive plants occur along roads in and around the park. These areas include the following RZs: Nabesna, Upper Copper River, and McCarthy. Some small distributions occur in the back country St. Elias/ Chugach Mountains and Big Volcanoes RZs. Spatial data collected by EPMT are not easily visible when displayed at a park-wide scale as the total area surveyed for non-native invasive species and locations of significant distributions are at such a small scale in comparison to the scale of the land area of the park. However, the GIS data indicate that a large percentage of the park has not been surveyed and are important for planning subsequent years monitoring and control efforts.

Vectors of spread

Roads, OHV trails, hiking trails, landing strips, abandoned home sites, and portions of some in-holding properties where there is growth of non-native plants for food and ornamental value are areas that act as vectors of spread for some non-native invasive plants (Gilmore, 2006). Additionally, some in-holders graze pack animals that rely on supplemental feed flown in from outside of WRST (Terwilliger et al. 2010). Because certified weed-free feed is not readily available in the area, invasive plants could spread through pack animal feces. These weeds are typically pioneer species that could establish themselves in areas of natural disturbances such as changing streambeds, areas of recent de-glaciation, and mudslides, though these type of establishments are undocumented to date within WRST (Terwilliger et al. 2010, Terwilliger pers. comm.).

In general, areas of high visitor use are important in terms of their susceptibility to establishment and spread of non-native plants. Other areas that exhibit high potential for non-native invasive establishment are river floodplains and those areas that have burned recently. Narrowleaf hawksbeard is currently extremely abundant along roads throughout Alaska and is beginning to appear on glacial river floodplains (Carlson & Shephard, 2007). Large burned areas that are adjacent to roads that have invasive plant infestations are also particularly susceptible to establishment (Villano and Mulder 2008). Villano and Mulder (2008) found that burn severity and slope were important factors in determining the success of invasive plant spread in these areas of Alaska.

Disturbance Type

According to the WRST Exotic Plant Survey data (2003-2008), 55% of the inventoried area is within 100 meters of a road. This includes major roads within 15 miles of WRST. This was determined by using a simple GIS selection of the polygons that fall within 100 meters of the roads. Importing fill gravel/materials, referred to in the data set as ―Fill importation” for road construction, is the most significant disturbance type indicated in the WRST Exotic Plant Survey data, accounting for a total of 1,137 sites and 1,773 sites (NPS PDS 2009a).

Non-native fauna of concern

In addition to plants, non-native species of concern include existing non-native fauna that could pose threats in the future, non-native invasive species suspected but not confirmed; non-native invasive species that have not yet arrived; and native species that exhibit invasive or noxious qualities. Horses (*Equus* spp.) represent another species of non-native fauna in the park; concessionaiers are allowed to have domesticated horses in WRST.

Plains bison (*Bison bison bison*), introduced as a game species to WRST in 1962, currently consist of two separate herds: the Copper River and Chitina River herds (Tobey 2008a, Tobey 2008b) (Plate 36). ADF&G currently manages the bison herds through the control of hunter harvest, with an objective of maintaining a minimum of 50 overwintering adults for the Chitina herd and a minimum of 60 overwintering adults in the Copper River herd (Tobey 2008a, Tobey 2008b). Both herds are limited in size by snow depth, hunter harvest, habitat availability, accidental deaths, and potential predation (Tobey 2008a, Tobey 2008b). The Chitina herd may realize an increase in their preferred habitat in the future due to the Chakina Fire in 2009, which burned approximately 23,472 ha (58,000 acres) (Terwilliger et al. 2010). This could allow their population to increase and potentially affect which plant species will reestablish in the burn area, which in turn may affect native wildlife populations. A concern also exists that the non-native plains bison could impede possible future introductions of native wood bison (*Bison bison athebascae*) because of concerns about inter-breeding and the risk of the spread of disease, particularly brucellosis (ADF&G 2007).A species unconfirmed in WRST, but suspected to be present, is Chytrid fungus (*Batrachochytrim dendrobatidis*) (Terwilliger et al. 2010). Chytrid fungus may be in the Yakutat area, as evidenced by local knowledge of Western toad *(Bufo boreas boreas*) population declines and other amphibian die-offs and malformations (Reeves 2008). The European black slug (*Arion ater*) was recently identified in the Yakutat area (outside the park) (Terwilliger et al. 2010). This mollusk species is of concern due to its omnivorous behavior and its ability for hermaphroditic self-fertilization (Terwilliger et al. 2010).The slugs appears to have been introduced through gardening material and appear capable of overwintering in WRST (Terwilliger et al. 2010). Schrader and Hennon (2005) are unsure if the slugs will escape town borders and expand into sensitive environments such as estuaries and marshes.

Other invasive species that have not yet arrived, but are of particular concern include European green crab (*Carcinus maenas*), Atlantic salmon (*Salmo salar*), and white-nosed syndrome fungus (*Geomyces destructans*) (McClory and Gotthardt 2008, Terwilliger et al. 2010). European green crab may find ideal habitat in Rio Bay, just outside the park in Icy Bay, according to ADF&G habitat mapping (Harney 2007). Atlantic salmon are not documented in the park or the Copper River to date, but a risk exists due to Atlantic salmon aquaculture in waters near British Columbia, Canada, and the Pacific Northwest of the lower contiguous United States. Documentation of one Atlantic salmon occurred at the mouth of the Copper River delta near Grass Island and a suspected Atlantic salmon in the Martin River was determined to be a Coho salmon (*Oncorhynchus kisutch*) (Nielson et al. 2003). SEAN (2008) notes that Atlantic salmon are suspected to be in the waters of Glacier Bay National Park just south of WRST (Terwilliger et al. 2010).

Native species that appear to exhibit invasive qualities may be indicators of broad ecological changes. An example of this is the lotic diatom *Didymosphenia teminate*, known as Didymo or Rock snot. Didymo was found growing as mats at four sites during an NPS Central Alaska Network flowing waters pilot study (Simmons, 2009). This species, usually found in low abundance in Alaska, is now being recognized as exhibiting invasive behavior through its ability to create mats that dominate stream beds (Spalding and Elwell 2007). Although it is undetermined if this diatom is a major concern, Terwilliger (2010) recommends monitoring of this species, as it is known to spread via human vectors such as waders and boat bottoms. Another native species that can exhibit invasive qualities is the spruce bark beetle (*Dendroctonus rfuipennis*), which killed large swaths of spruce trees in WRST during the 1990s (Allen et al. 2006). There are concerns that spruce beetles could reach epidemic levels with shifting patterns in climate and temperatures, as their life history is controlled mostly by temperature (Allen et al. 2006). Foxtail barley (*Hordeum jubatum*) is native species of grass present in WRST that can be potentially invasive in Alaska (AKEPIC 2009).

Condition discussion

NPS established the Alaska EPMT in 2003 and WRST obtained the first seasonal employee specifically for the EPMT program in 2005 (Gilmore 2005). Efforts from 2005 to 2008 primarily focused on inventorying and monitoring known occurrences or infestations of non-native invasive plants along areas developed and frequently used by humans (Terwilliger et al. 2010).

Much of the sampling effort in the field to date has been opportunistic. Given the relatively short time span and the opportunistic nature of surveys, available data do not support trend analyses.

Carlson & Shephard (2007) found that the number of non-native plant population records in Alaska follows an exponential growth pattern. However, the increased survey effort from 2001 to 2009 should logically reflect an increase in the number of non-native plants on record. The 2009 effort doubled that of the previous two seasons (Table 25). It is unclear whether the increase in acres infested is a function of increased survey effort or actual increases in infestation.

The RZs defined for this NRCA may not be the most appropriate method to report the condition of non-native plants in the park, because they represent such large diverse areas and non-native invasive plant infestations appear localized and highly variable across the landscape. Survey efforts focus primarily on areas of human development (roads, town sites, airstrips, home sites, etc.) and high human use areas (campsites, trails, etc.). From 2003 to 2008, 55.5 % of the surveyed area in WRST was within 100 meters of roads, including roads within 15 miles of park boundary (NPS PDS 2009a). The Nabesna, McCarthy, and Upper Copper River RZs have received the majority of survey effort and consequently, have the majority of invasive plant data available to date. Together they are a representation of the general condition of known invasive plant species.

The total area of infestations on NPS lands has steadily increased since 2004, but the amount of survey effort and area surveyed has also increased. The condition of non-native invasive plants in the McCarthy, Nabesna, and Upper Copper River RZs is of moderate concern. Accounting for large increases in survey and control efforts, the current condition non-native invasive plants in these areas seems to be stable.

Very little data exist for areas outside of the McCarthy, Nabesna, and Upper Copper River RZs. Given that survey efforts have only identified a few, small, non-native invasive plant infestations in remote sites of WRST, the remaining RZs are in good condition. There are not enough data to be certain if infestations are increasing in these remote areas; therefore, the trend for these RZs is unknown.

Most non-native invasive plant spread is through human disturbed sites; however, some invasive plants can establish themselves in undisturbed locations (Gilmore & Harper, 2008). Additionally, some invasive plants establish in areas of natural disturbance such as wildfire, naturally changing streambeds and floodplains, mudslides, and recently de-glaciated areas (Terwilliger et al. 2010). If infestations occur in these areas, they are more likely to go undetected, and more likely to develop to levels beyond manual control. Though not yet documented in the floodplains of WRST, Spellman (2008) concludes that white sweetclover may negatively impact recruitment of native plants within floodplain habitats of Alaska.

Climate change shifts the range of suitable habitat for plants, aquatic organisms, wildlife, insects, and diseases, and is causing increases in the number and frequency of forest fires and insect outbreaks in Alaska (Hauser et al. 2008). Climate change may allow non-native invasive plant species a competitive advantage and allow more of them to become invasive in nature.

Miranda Terwilliger (WRST ecologist) suggests that, while the number of acres infested may be more important than the number of invasive species present in WRST, the number of acres is highly reflective of the yearly, on-the-ground effort to address non-natives each season, and currently the two cannot be teased apart. However, if the amount of yearly effort is accurately recorded, the area of known infestations could be normalized by that effort. This might provide a way to compare WRST other Alaska national parks to determine relative condition.

Data needs

The National Institute of Invasive Species Science (NIISS) suggests that, ―…non-native invasive species may pose the single most formidable threat of natural disaster of the 21st century" (USGS 2005). Non-native invasive flora and fauna can dominate entire ecosystems or cause other damage to ecosystems without dominating in either numbers or biomass (Simberloff 1996). Non-native species can affect native species through predation, competition, and introduction of disease (Simberloff 1996). While invasiveness plants are carefully tracked and managed in WRST, other threats from plant pathogens and fauna are not well understood. WRST needs continual updates of information regarding existing threats of non-native invasive flora and fauna, including further examination of known threats such as Atlantic salmon, the Chytrid fungus, Didymo, and the European black slug. These updates of information will allow WRST to continue with an approach of early detection and rapid response to non-native invasive species establishment.

The agreed upon measures developed through the scoping process in this assessment for non-native species are extent (area) and distribution of infestations. While it is possible to report on the known area and the location of infestations, to make a statement of the condition, there must be something to compare current data to, other than a general statement of ―no exotics or invasive plants." Because the NPS defined reference condition of "pre-exotic species" makes definition of concern for the current condition difficult, a set of criteria that allows for an accurate statement of condition should be developed.

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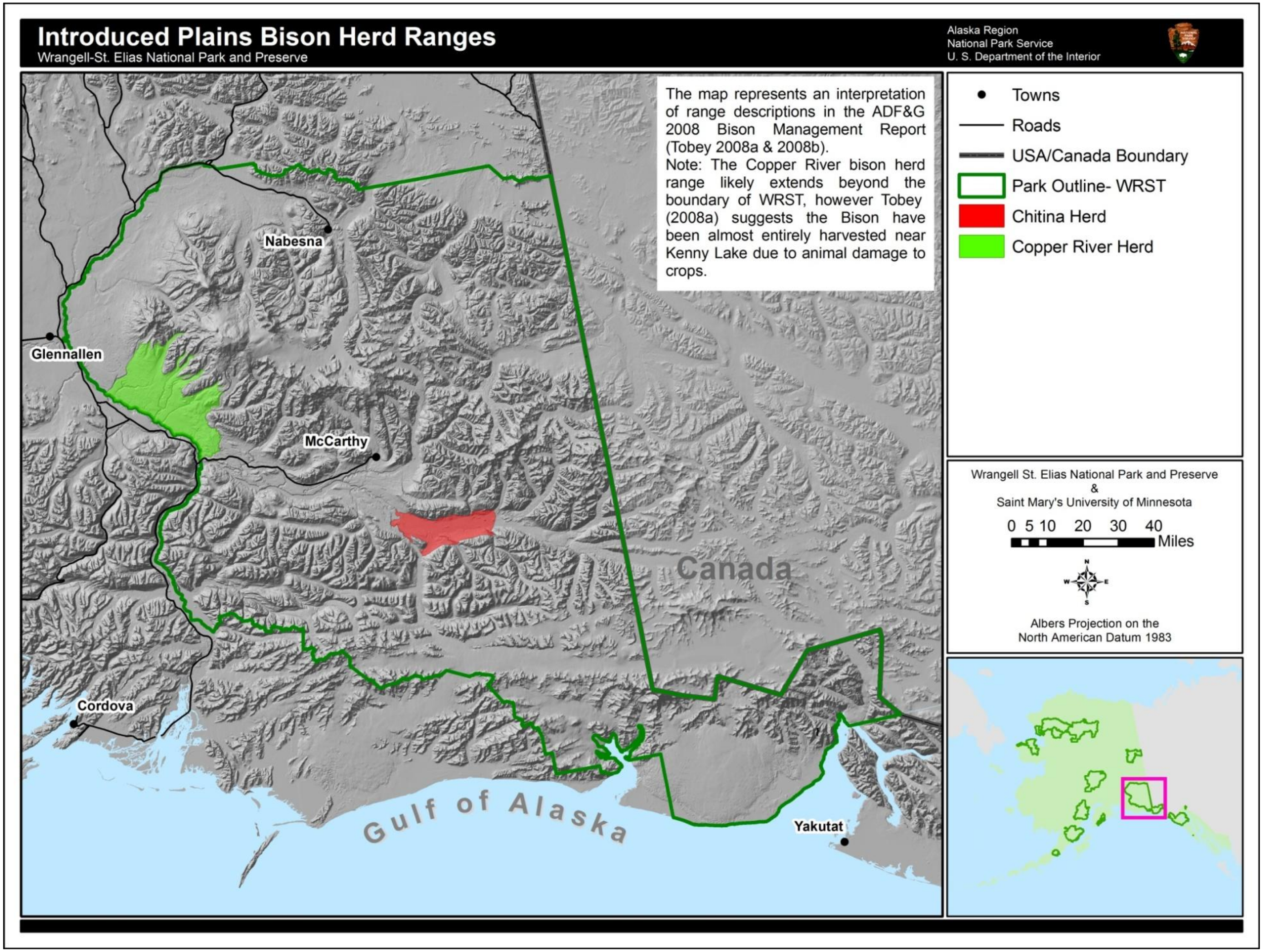
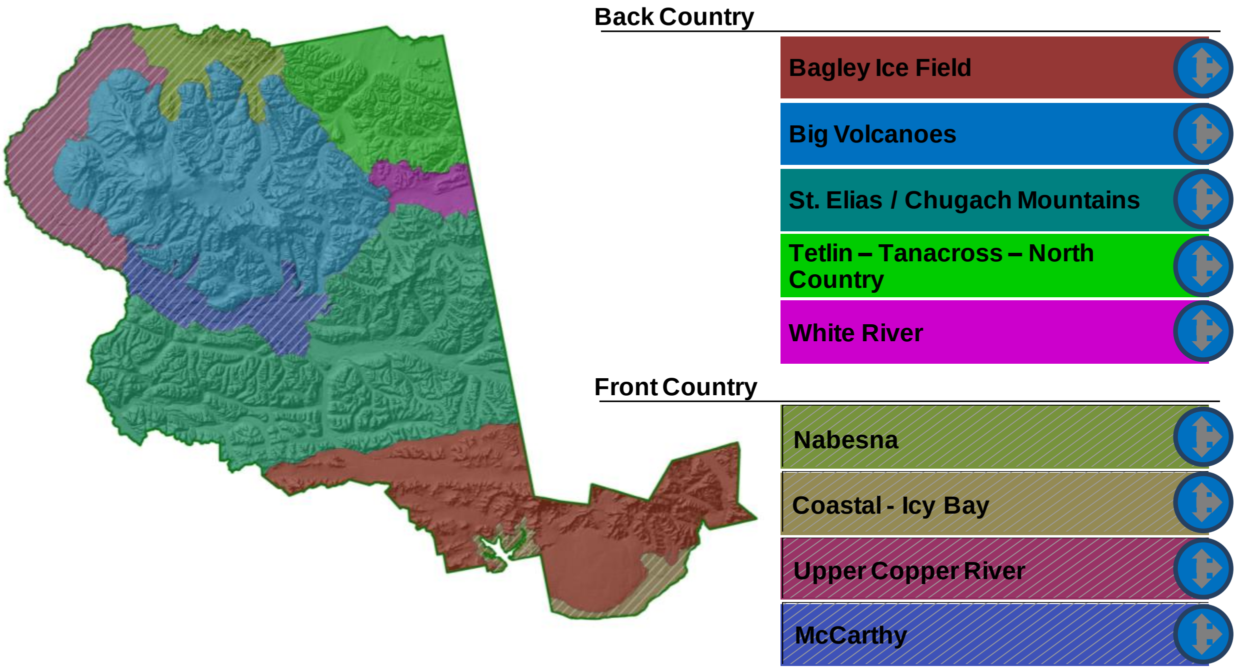


Plate 36. Introduced plains bison range. (Tobey 2008a, 2008b)

4.17 Air Quality

Indicators and Measures

Nitrogen, Sulfur, and Mercury Deposition; Visibility; Ozone



Condition

Due to the lack of current and complete data, it is difficult to confidently make a determination about the condition of air quality at WRST; however, the data that do exist provide no indication that air quality is of concern or is significantly different from historic air quality. Measurements of ozone and nitrogen deposition that exist within the park are reportedly low. Semi-volatile organic compounds (SOCs) in WRST also appear to have not reached levels of concern. It is not possible to determine a trend in air quality due to the lack of recent air quality data.

Background

One of Wrangell-St. Elias's fundamental resources is its scenic beauty. The park is comprised of massive vistas, visually diverse scenery, and natural, undeveloped viewsheds (Wrangell-St. Elias Park and Preserve 2009). In order to maintain the scenic beauty of the park, air quality must also be maintained.

The Central Alaska Network has identified air quality as a ―vital sign" applying only to Denali National Park and Preserve; however, air quality in all National Parks is protected under both the 1916 Organic Act and the Clean Air Act (MacCluskie and Oakley 2005, National Park Service 2006). NPS has identified visibility, atmospheric deposition, and ozone as key air quality indicators and has monitored trends in several parks throughout the United States (National Park Service 2009). Visibility impairments hinder visitors' ability to see and appreciate their surroundings (National Park Service 2009). Acidification and fertilization of soil and surface water resulting from deposition affects ecological health, and ozone affects both human health and vegetation (National Park Service 2009).

In addition to the importance of nitrogen and sulfur deposition, visibility, and ozone levels, park managers are also concerned about mercury deposition. Inorganic mercury becomes highly toxic methylmercury when released into the atmosphere and subjected to naturally occurring processes (Dastoor and Larocque 2004). Methylmercury has the ability to bioaccumulate in aquatic food chains (Dastoor and Larocque 2004). Concern about mercury deposition in Alaska is elevated due to intercontinental transport pathways and sensitive subarctic ecosystems (Denali National Park & Preserve, Andrea Blakesley, pers. comm., 24 February 2010).

WRST is a designated Class II airshed under the Clean Air Act. It is not subject to the strict regulations and monitoring required of a Class I airshed; however, the National Ambient Air Quality Standards (NAAQS) must be met.

Reference Condition

The National Park Service Air Resources Division recommends the following values for determining air quality condition (Table 30). The values indicated as good condition are considered reference condition. These standards take into account the current National Ambient Air Quality Standards (NAAQS).

Table 30. National Park Service Air Resources Division air quality index values.

Condition	Ozone concentration[1]	Wet Deposition of N or S (kg/ha/yr)	Current Group 50 – Estimated Group 50 Natural (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 4th-highest daily maximum 8-hour average concentration averaged over five years.

Data and Monitoring Locations

<u>Locations Within Wrangell – St. Elias</u>

1995 Ozone

In 1995 and 1996 ozone was measured using passive ozone samplers in several national parks to provide baseline data (Ray 1998). The focus of this effort was on Clean Air Act Class I airsheds, but one passive air sample site was measured in Wrangell-St. Elias in 1995 (Ray 1998). One finding was that ozone concentrations vary considerably within the park and between nearby parks (Ray 1998).

WACAP

The NPS Western Airborne Contaminants Assessment Project (WACAP) —was initiated to determine the risk from airborne contaminants to ecosystems and food webs in western national parks of the United States" (Landers et al. 2008). The study included WRST as a secondary park. Only three of the seven ecosystem components sampled at the eight core study parks were sampled at WRST: air, lichens, and conifer needles. Samples were collected in 2005. One air sampler was deployed in the Crystalline Hills, near McCarthy. Conifer needles were sampled at this site and four others. Lichen was sampled at the Crystalline Hills site and two others, for a total of five sample sites. Sites varied in climate and elevation. The contaminants analyzed were primarily semi-volatile organic compounds such as pesticides, combustion byproducts, and polychlorinated biphenyls (PCB).

1990 Baseline Study

In 1990, moss, lichen, spruce, and surface soils were sampled in and near WRST to determine baseline elemental information prior to the construction of a coal-fired power plant near the northwest boundary of WRST (Crock et al. 1993). Three traverses were sampled originating near the power plant location and extending southeast towards Mount Drum, into the park along the west flank of Mount Drum, and northward near the Copper River (Crock et al. 1993).

NPS-SFU

The National Park Service Stack Filter Unit Network (NPS-SFU) was a predecessor to the IMPROVE (Interagency Monitoring of Protected Visual Environments) network described below (IMPROVE n.d.). The network included one site near Wrangell-St. Elias NPP which operated from June 24, 1987 to July 3, 1993. In WRST the stacked filter sampler collected fine (<2.5mm) particulate samples during a 24 hour sampling period, which were analyzed for mass, light absorption, and elemental constituents.

Refer to Plate 37 for air quality sampling site locations.

<u>Regional</u>

IMPROVE

There are five active IMPROVE stations in Alaska, but none are located within WRST. The five locations are: Denali National Park, Simeonof (USFWS), Tuxedni (USFWS), Trapper Creek (Denali NP), and Gates of the Arctic (NPS-Bettles). An IMPROVE station in Petersburg (USFS) ceased operation in the fall of 2009. The IMPROVE network includes aerosol, light scatter, light extinction, and scene samplers (IMPROVE n.d.).

NADP
The National Atmospheric Deposition Program (NADP) is a cooperative effort between many governmental and non-governmental agencies, educational institutions, and private companies to monitor precipitation chemistry (NADP 2009). It includes the NADP National Trends Network (NTN), the Atmospheric Integrated Research Monitoring Network (AIRMoN), the Mercury Deposition Network (MDN), and the Atmospheric Mercury Network (AMNet). There are no NADP network sites located within WRST or within a relevant distance for the condition assessment.

CASTNET
The Clean Air Status and Trends Network (CASTNET) began in 1991 under the Clean Air Act Amendments, and it provides long-term regional environmental monitoring (United States Environmental Protection Agency 2007). The CASTNET system collects data pertaining to sulfur dioxide, sulfate, nitrate, nitric acid, and ammonium (Alaska Department of Environmental Conservation 2002). Each sampler collects data for one-week from ten meters above ground (Alaska Department of Environmental Conservation 2002). There have been four sites in Alaska, but only the Denali site is still active. No CASTNET data have been collected in WRST.

Alaska Network: For several years an Alaska state ambient air-monitoring network has been in place, but the effort has been directed towards larger communities and non-attainment areas (Alaska Department of Environmental Conservation 2002). Sites include Anchorage, Fairbanks, Juneau, the Matunuska-Susitna Valley, and the Kenai Peninsula. Sitka and Ketchikan have historical data but are no longer monitored (Alaska Department of Environmental Conservation 2002).

CAKN
The Central Alaska Network performed a risk assessment regarding foliar injury from ozone on vegetation for parks in the network (Central Alaska Network 2004). The risk assessment was based on the presence of ozone-sensitive plant species, ozone exposure, and soil moisture. Four plant species sensitive to ozone are present in WRST: red alder (*Alnus rubra*), Saskatoon serviceberry (*Amelanchier alnifolia*), quaking aspen (*Populus tremuloides*), and Scouler‘s willow (*Salix scouleriana*) (Central Alaska Network 2004). There were not sufficient ozone exposure or soil moisture data for WRST to determine the risk of foliar injury from ozone.

CAPMON
There are no stations near WRST that are part of the Canadian Air and Precipitation Monitoring Network (CAPMON).

NAPS
The closest station to WRST within the Canadian National Air Pollution Surveillance (NAPS) Network is in Whitehorse, Yukon Territory.

Air Quality Index
The air quality index is calculated by the EPA based on five major air pollutants: ground-level ozone, particle pollution (particulate matter), carbon monoxide, sulfur dioxide, and nitrogen dioxide (U.S. Environmental Protection Agency 2009b). The scale ranges from 0 to 500 (U.S.

EPA 2009b). A lower value indicates better air quality. A value less than 50 is considered good air quality. This index has not been calculated for the Valdez-Cordova census area.

Indicator Results

Due to the diverse geography within Alaska and the great distances to the nearest regional air quality monitoring stations, data from NADP, CASTNET, CAPMON, NAPS, and IMPROVE (except for the NPS-SFU site) were not included in the condition assessment.

<u>Ozone</u>

1995 Ozone

The average hourly ozone concentration for the six weeks of data collected in 1995 is 11.6 ppb (Ray 1998, Table 31).

Table 31. 1995 weekly ozone data from the passive samplers presented as the average hourly ozone concentration for the week (only the weeks with data are shown). (Ray 1998)

	July	August			September		
Week	2	1	2	3	1	2	Mean
Average Hourly Ozone (ppb)	9.9	8.8	6.9	22.4	12.4	9.1	11.6

The ozone sampling effort found similar ozone levels in the three Alaska parks sampled (Noatak National Preserve, Denali National Park and Preserve, and WRST) (Figure 49). The concentrations were considered ―quite low” (Ray 1998). According to the report, ―Based on ozone concentration, the Alaskan parks have excellent air quality during the summer” (Ray 1998).

Deposition

WACAP

The WACAP report found nitrogen concentrations in lichens sampled at WRST to be within background ranges ―indicating that nitrogen deposition is not elevated” (Landers et al. 2008).

<u>NPS-SFU</u>

The data from the stacked filter unit include fine sulfur mass concentrations, but these data have not been analyzed at this time.

Visibility

<u>NPS-SFU</u>

Fine particulate concentrations measured from the stacked filter unit samples are displayed in **Figure 50** below. All samples were below the federal daily standard of 35 $\mu g/m^3$ and the federal annual average standard of 15 $\mu g/m^3$ (US EPA 2010). These standards are not considered reference condition for the park but provide some indication of the air quality.

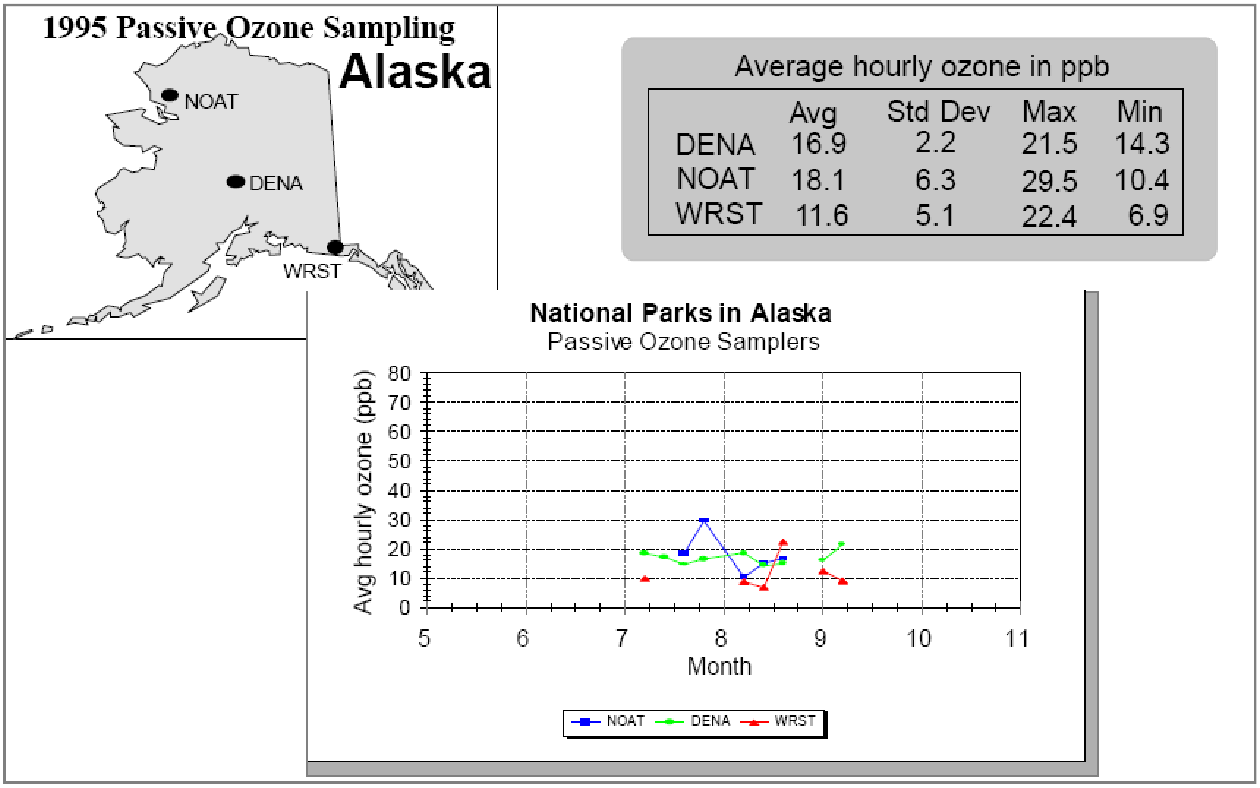


Figure 49. Summary of passive ozone for 1995 in three National Parks in Alaska. (Ray 1998)

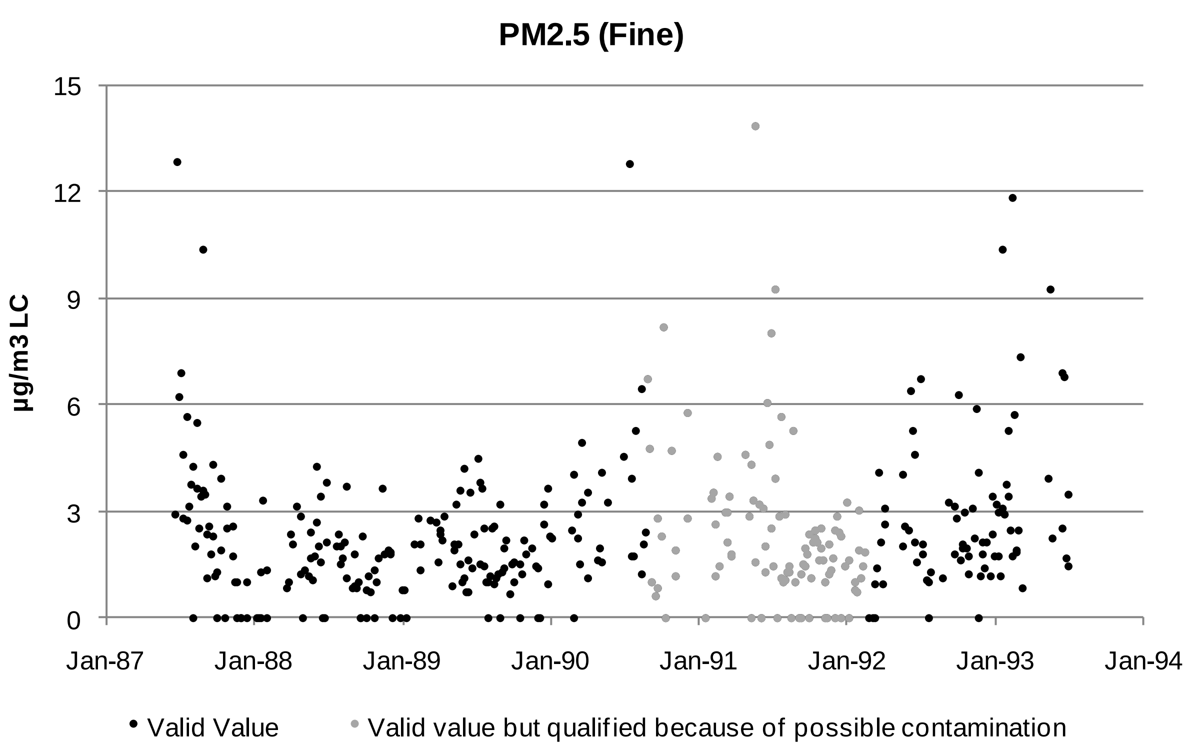


Figure 50. Fine particulate matter, 1987-1993. (CIRA 2009)

Other

WACAP

The Crystalline Hills air sampler reported the lowest number of detected SOCs of all twenty parks in the WACAP study (Landers et al. 2008). The air sampler only detected PAHs (polycyclic aromatic hydrocarbons) and low concentrations of g-HCH (a historic use pesticide). The PAH concentration was near the median of all other parks (Landers et al. 2008).

The vegetation samples from the interior WACAP park sites reported SOC levels at or below the median levels detected in all WACAP parks (Landers et al. 2008). Icy Bay, the non-interior marine site (WRST1), receives high precipitation and reported the highest levels in the park of g-HCH and chlordanes in lichens and conifer needles (Landers et al. 2008). It also had the highest readings for endosulfans, HCB, a-HCH, dacthal, PCBs, and PAHs in lichens (**Figure 51**).

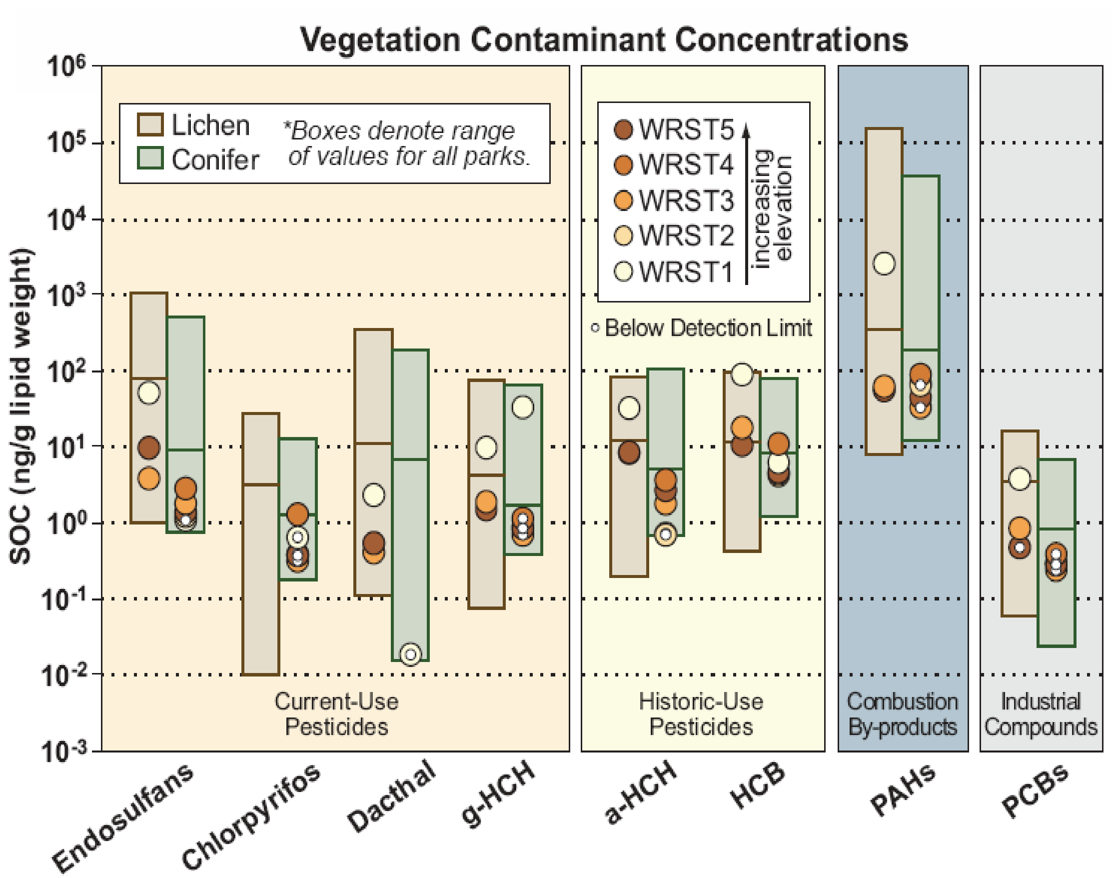


Figure 51. WACAP vegetation contaminant concentrations at WRST sites. The figure is reproduced from Landers et al. (2008).

1990 Baseline Study

The concentrations of Ag, As, Au, Be, Bi, Cd, Eu, Ho, Nb, Sn, Ta, Th, and U in the moss and lichen samples measured as part of the 1990 study were below their limits of determination (Crock et al. 1993). Concentrations of Ag, As, Au, Be, Bi, Cd, Eu, Ho, Nb, Pb, Sc, Sn, Ta, U, and Yb in the white spruce samples were below their limits of determination (Crock et al. 1993). The elements found in detectable levels in some of the white spruce samples were Mo, Nd, Th, and Y (Crock et al. 1993). One soil sample was found to have detectable levels of Mo. No soil samples were found to have determinable levels of Ag, Au, Be, Bi, Cd, Eu, Ho, Nb, Sn, Ta, Th, and U (Crock et al. 1993). Detectable levels of elements do not necessarily indicate pollution. These elements could occur naturally in the environment.

Stressors

Air quality stressors include naturally occurring phenomenon such as volcanoes and smoke from forest fires, as well as local and regional emission sources such as motor vehicles, wood-burning stoves, unpaved roads, windblown dust, construction activities, and industrial facilities (Alaska Department of Environmental Conservation 2002). The sparse population and limited road network in and around the park limits the amount of air pollution from local sources. The potential for large scale logging in some areas of the park creates a potential future stressor to air quality.

In addition to local and regional stressors, there are also stressors that originate from global sources due to global air circulation patterns. These stressors relate to both visibility and deposition. The two main transport pathways are arctic haze and the trans-Pacific transport pathway. Arctic haze, occurring during the winter and early spring, is caused by anthropogenic contaminants becoming trapped within the expanded arctic air mass (Blakesley 2006). Two important contaminants contained in arctic haze are sulfates and sulfur dioxide (Blakesley 2006).

The trans-Pacific transport pathway usually transports small quantities of air pollution from international sources in a seasonal pattern (Blakesley pers. comm.). The WACAP study attributes pesticide deposition in WRST to long-range trans-Pacific transport, primarily due to a lack of significant sources of pesticides within Alaska (Landers et al. 2008). This pathway includes Asian dust events, which usually occur in the spring and carry dust from Asian deserts such as the Gobi and Taklimakan (Alaska Department of Environmental Conservation 2002).

Reporting Zones

Air quality is relevant for all RZs. Table 32 summarizes the RZ locations of the 2005 WACAP sites. All sites sampled within WRST during the 1990 moss, lichen, spruce, and soil study were located in the Upper Copper River RZ. The location of the 1995 passive ozone sampling site is on the border of the McCarthy and St. Elias/ Chugach Mountains RZs. The NPS-SFU was located near Glennallen, outside any RZ.

Table 32. WACAP site locations.

Site	Reporting Zone	Air Sampler	Conifer	Lichen
1	Coastal - Icy Bay	No	Picea sitchensis	Platismatia glauca, Hypogymnia apinnata
2	McCarthy	No	Picea glauca	No
3	Big Volcanoes (near McCarthy)	Yes	Picea glauca	Hypogymnia physodes
4	McCarthy	No	Picea glauca	No
5	McCarthy	No	Picea glauca	Flavocetraria cucullata, Cladina arbuscula

Data Needs

Wet and dry deposition, ozone, and visibility monitoring programs are needed in order to more confidently report on the condition of air quality within the park. More information regarding deposition at Icy Bay would be especially useful. Icy Bay reported higher concentrations of several SOCs compared to the interior WACAP sites. As a high precipitation region, it is more susceptible to wet deposition. The NPS-SFU data set is the longest air quality data set for WRST. A thorough analysis of this data set could provide useful baseline air quality information for comparison to future monitoring results.

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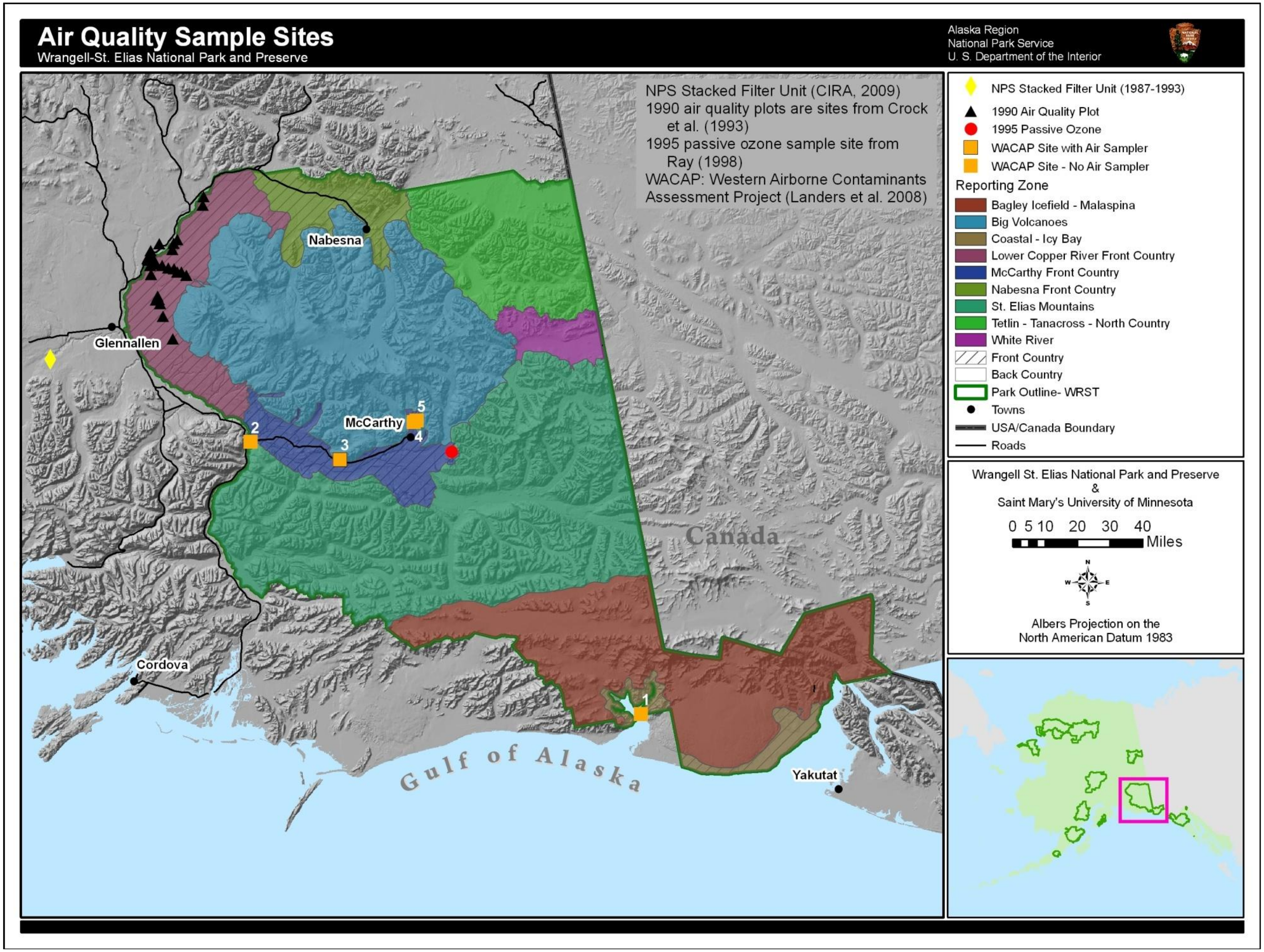
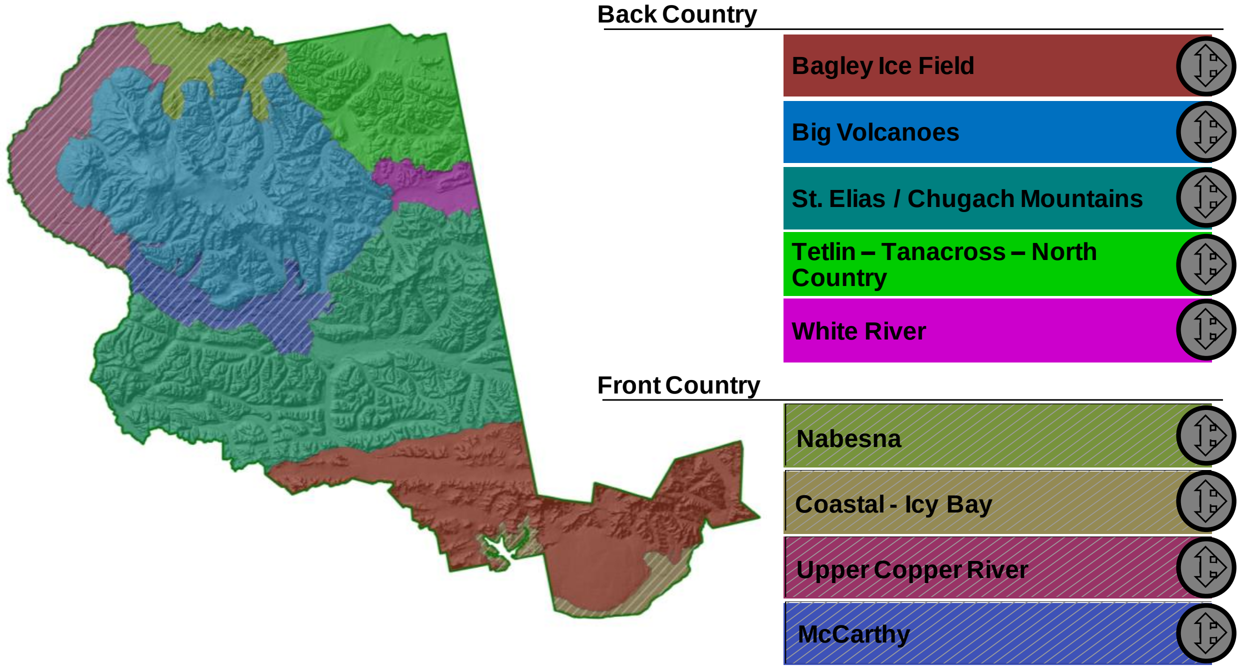


Plate 37. WRST air quality sampling sites. (CIRA 2009, Landers et al. 2008, Ray 1998, Crock et al. 1983)

4.18 Water Quality

Indicators and Measures

Turbidity, dissolved oxygen, temperature, metals, macroinvertebrates



Condition

The condition of water quality in WRST is unknown (Weeks 2003, Hood et al. 2006). The 2000 USGS study performed by Eppinger et al., is the most thorough water quality study in WRST, focusing particularly on mined areas in WRST. While Eppinger et al. (2000) provided insight into the water quality of mined areas in the park, very little research into water quality across the park‘s broad geographical region has been performed. Additionally, the data available in the EPA's water quality STOrage and RETrieval (STORET) database and that collected during the 2001-2002 Freshwater Fish inventory are not analyzed, and therefore are not useful in assessing the condition of the resource.

Assessment of water quality is difficult based on the reference condition established in the framework: water quality measures dominated by natural processes. Eppinger et al. (2000) found that some areas of the park are naturally acidic and metalliferous. In some areas of WRST, carbonate rocks work to buffer contaminants that may be leaching into surface waters from mining operations. Mine tailings in the Kennecott area have high concentrations of many toxins, but because of carbonate rocks, the water quality in the area is good, based on metal and pH levels, when compared to other mined sites in WRST (Eppinger et al 2000).

Background

Over 25% of WRST is covered by glaciers or permanent snowfield, making it one of the largest reserves of freshwater in the Northern Hemisphere (Weeks 2003). Freshwater is vital to the plants, animals, and ecosystems within the park and preserve and aids in the distribution of sediment, organic matter and nutrients across the landscape, which allow the natural systems to remain intact (Weeks 2003). Climate change and other anthropogenic stressors to freshwater in WRST are of particular concern to park staff and are expected to have a significant effect on freshwater systems, not only in WRST but also across the Central Alaska Network (CAKN) (Simmons 2006).

Currently water quality data are limited for WRST (Simmons 2006, Hood et al. 2006, Weeks 2003, Markis 2004 (unpublished)). CAKN has developed a program for monitoring lentic systems and is currently working on a protocol for flowing waters. (Simmons 2009).

Reference Condition

The reference condition of water quality in WRST is defined as ―water quality measures dominated by natural processes."

WRST Water Quality Data Currently Available

The following is from Weeks (2003, page 22), Wrangell-St. Elias National Park and Preserve, Alaska. Water Resources Scoping Report:

"Most of the glacial streams in WRST have a pH near neutral (7.0). Hardness, alkalinity, and heavy metal concentrations vary among streams due to the different geologic formations with which the water comes in contact. Most glacial streams, however, fall in the moderately hard category (75 – 150 mg/L calcium carbonate) and all stream waters show a degree of natural mineralization. High sediment loads and turbidity also characterize these glacially fed systems. Water temperatures in glacial streams remain near freezing throughout the summer due to the daily input of glacial melt water.

The majority of non-glacial streams in the park/preserve have a pH near neutral except for a few streams with pH values less than six, which drain iron sulfide. Similar to the glacial streams, hardness concentrations vary due to varying geology with moderately hard water (75 – 150 mg/L calcium carbonate). Suspended sediment loads are typically low (< 50 mg/L) for these non-glacial systems, with low turbidity except during high flow conditions. Due to the highly mineralized geology, in stream metal concentrations can be relatively high (NPS 1990).

There is little specific information available for the several rivers and streams within the park and preserve boundary."

Baseline Water Quality Data Inventory & Analysis Project

In 1993, the NPS Water Resources Division and the Service-wide Inventory and Monitoring Program initiated the NPS Baseline Water Quality Data Inventory and Analysis Project. The purpose of the project was to take inventory and characterize baseline water quality data from all National Park System Units containing significant natural resources, including analysis of the STORET database. To date, Baseline Water Quality Data Inventory and Analysis is unperformed for WRST (NPS 2010).

Water Quality in Mined Areas of WRST

Eppinger et al. (2000) analyzed ground and surface water data at four historic mine locations and two other sites where mining never occurred. The Kennecott, Bremner, Nabesna, and Gold Hill Mines are all unique in the fact that different types of ore extraction took place at each site. With the exception of the Bremner Mines in the Southwestern portion of WRST, all sites were located in a similar geographical area (Plate 38). However, the study sites varied in deposit types and local geologies (Eppinger et al. 2000).

Kennecott Mine
Surface water samples in the Kennecott area have low metal concentrations compared to worldwide average surface water concentrations. These low concentrations are primarily due to widespread host carbonate rocks and the absence of unstable sulfide minerals. Limestone is widespread throughout the Kennecott area, increasing the buffering capacity of surface waters resulting in pH that is nearly neutral. Even though there are high concentrations of toxic elements in mine waste piles, the absence of acid-generating minerals means that these metals will not be mobilized. Eppinger et al. (2000) states that, ―Kennecott-type deposits are relatively benign to the environment."

Bremner Mines
Historically, the Bremner Mine used mercury to extract gold from ore deposits. Eppinger et al. (2000) did not find high concentrations of mercury in any of the surface waters near the Bremner Mine, but sampling took place during a dry year and whether or not mercury was being mobilized during wet periods was stated as unknown. Other surface water parameters appear to fall under normal regimes but evidence suggests that disturbance of mine waste, either anthropogenic or natural, could result in fluctuations in the current system (Eppinger et al. 2000).

Gold Hill Mines
The Gold Hill Mines are located northeast of the town of Chisana, and encompass an area that is 8 kilometers in diameter, centered on Gold Hill. Waters in this area include Little Eldorado Creek, Bonanza Creek, Coarse Money Creek, Gold Run Creek, and Big Eldorado Creek. During the dry summer of 1997, the USGS did not find inorganic parameters to exceed primary or secondary Alaska Department of Environmental Conservation (AKDEC) Maximum Contaminant Levels (MCL). The same study found pH in the Gold Hill area to equal the secondary MCL and that aluminum and total dissolved solids were just below secondary MCL values. How these values change during wetter periods is unknown (Eppinger et al. 2000).

Nabesna Mines
Water quality parameters in the Nabesna Mine area vary with season and surface flow conditions. Eppinger et al. (2000) found water quality parameters near mine tailings to be poor in the Nabesna Mine area. Arsenic, fluoride, aluminum, copper, iron, and zinc all exceeded AKDEC MCL values in the immediate vicinity mine tailings during at least one sample time between 1994 and 1997. For the five previously listed ions, samples were below AKDEC MCL values once a distance of 850 m from mine tailings was reached. Parameters that exceeded AKDEC MCL values at all sample times were manganese and sulfate (Eppinger et al. 2000).Cabin Creek downstream of the Nabesna mine is a 303d listed stream segment. Mitigation measures including ditching have been implemented and a monitoring plan is being developed; however, until the contaminated soils can be addressed the stream will remain impaired.

Orange Hill and Bond Creek Areas
The Orange Hill and Bond Creek areas studied by Eppinger et al. (2000) were not mined. These areas had multiple parameters that exceeded drinking water standards established by AKDEC and EPA. Evidence suggests that these waters have been acidic and metalliferous for several tens

of thousands of years. These metal rich, acidic waters are not necessarily harmful, offering unique ecosystems where certain life forms can thrive. Low pH soils also provide habitat for rare plants and can serve as mineral licks for animals (Eppinger et al. 2000).

Quality of Coastal Waters in WRST

The following summary is from Hood et al. (2006), Assessment of Coastal Water Resources and Watershed Conditions at WRST National Park and Preserve, Alaska:

"Water quality in coastal watersheds and coastal areas of WRST is not monitored. Due to the remote location and low level of human activity, it is assumed that water quality within the coastal areas of WRST is in good condition. Unlike northern and central areas of WRST, coastal watersheds have been subject to little mineral exploration and development. The only source of information on the water quality of coastal rivers and streams within WRST is a 1989 NPS field survey on the environmental impacts of a sand and gravel mining operation near the mouth of Independence Creek, immediately south of the WRST boundary and approximately 100 m (328 ft) from the high tide line in Icy Bay (Cook 1990). WRST staff collected information on water temperature, conductivity, pH, dissolved oxygen, hardness, arsenic, lead, iron, total suspended solids and discharge in the drainage slough behind the camp and 60m (197 ft) from the mouth of Independence Creek. Measured iron concentration was 20.5 mg/l, which is twenty times the EPA standard for freshwater aquatic life and may indicate the presence of an upstream ore deposit (Cook 1990). Total suspended solids were also high, at 1050 mg/l, which was explained by the warm weather at the time of sampling. Melting of the Independence Glacier, from which Independence Creek originates, provides the stream with higher suspended particle loads. All other parameters measured (Figure 52) were within normal ranges set by the EPA and the State of Alaska.

Site	Drainage behind mine camp	60m from mouth of Independence Creek
Water Temperature (°C)	16.0	13.0
Turbidity (NTU)	13.0	252.0
Conductivity (UMHOS)	245.0	80.0
pH	7.39	7.27
Dissolved Oxygen (mg/l)	5.0	8.0
Alkalinity (mg/l)	143.0	46.0
Hardness (mg/l)	170.0	56.0
Settleable solids (mg/l)	0.2	0.7
Width (ft.)	14.0	41.2
Depth (ft.)	0.700	0.784
Velocity (ft./s)	0.00	2.59
Discharge (CFS)	0.000	119.962
Arsenic (mg/l)	0.0060	0.025
Iron (mg/l)	0.592	20.500
Lead (mg/l)	0.0030	0.0060
Total Suspended Solids	3.4	1050.0

Figure 52. Water quality from two locations near Icy Bay mine site 21, August 1989 Analysis of metal and total suspended solids was done by Northern Testing Laboratory, Anchorage, Alaska. (Cook 1990)

Because groundwater studies have not been carried out along the coastline of WRST, specific information for this area is not available. The nearest groundwater study site is in the northern central areas of WRST (NPS 1990). The NPS study does not provide any data, but it qualitatively states that groundwater in that region of WRST has naturally high concentrations of metals, particularly iron, due to contact with highly mineralized surfaces and restriction of water circulation by permafrost (NPS 1990). Some groundwater was found in the area to be saline due to underlying marine sedimentary deposits (NPS 1990)."

CAKN Flowing Waters

The CAKN flowing waters program is part of the CAKN Vital Signs program developed in 2005 (MacCluskie and Oakley 2005). The purpose of the flowing waters portion of the Vital Signs program is to detect trends in important components of lotic ecosystems, including hydrologic regime, geomorphology, water quality, and the distribution and abundance of freshwater fish, benthic macroinvertebrates, and diatoms (Simmons 2006). Currently, the flowing waters program is in the protocol development stage, which includes refining field protocols and logistics, determining data collection sites and gathering preliminary (baseline) data for future comparison (Simmons 2009). The lack of baseline data, the size, and remoteness of the CAKN units, and the difficulty and cost of accessing remote sites (Simmons 2006) have all contributed to the long development time of the flowing waters program. Upon completion, this program will capture the effects of system altering processes including climate warming, associated glacial melting and other potential stressors, natural or anthropogenic (Simmons 2006).

Stressors

NPS staff noted many stressors to water quality in WRST, including climate change, mining, recreation/residential/commercial development, logging, OHV use, and oil and gas exploration.

Of the listed stressors, climate change and mining are the only two that have WRST specific documentation.

Climate is a primary driver of ecological change and therefore an important part of CAKN monitoring efforts (Sousanes 2007). Evidence suggests that positive feedback from climate change will result in continued warming of high latitude climates because of changes in summer albedo, vegetation, glaciers, and length of the snow free season (Chapin et al. 2005, Serreze et al. 2000). Increased glacial melting will alter many parameters in the streams of WRST, such as flow rates, temperature regimes, and sediment load (Oswood et al. 1992). Additionally, permafrost thawing has altered the hydrology of many parts of Alaska as evidenced by the drying of surface waters (Osterkamp 2005). A goal of the CAKN flowing waters protocol is to address the effects that a warming climate will have on the aquatic ecosystems in WRST, which currently is largely unknown (Simmons 2006).

Eppinger et al. (2000) explained that the effects of historical mines on water quality vary with bedrock geology and mineral deposit type. In the Kennecott area, mines have little effect on the water quality because of the abundance of carbonate rocks, the absence of acid-generating minerals, and the lack of metals that mobilize at high pH (Eppinger et al. 2000). Waters in some areas that are rich in pyrite deposits in WRST have high acid and metal environments even when mining is not present (Eppinger et al. 2000). In addition, weather affects the pH and metal levels of waters near mines. For example, waters near the Nabesna mine have low metal concentrations and near neutral pH values during dry periods, but wetter periods exhibit lower pH values and high metal concentrations (Eppinger et al. 2000).

Data Needs
Water quality data for WRST is incomplete. Two NPS documents, Assessment of Coastal Water Resources and Watershed Conditions at WRST National Park and Preserve, Alaska (Hood et al. 2006) and WRST National Park and Preserve, Alaska, Water Resources Scoping Report (Weeks 2003), acknowledge that data pertaining to water quality are limited or non-existent. Additionally, data that are available in the STORET databases are unanalyzed (NPS 2010).

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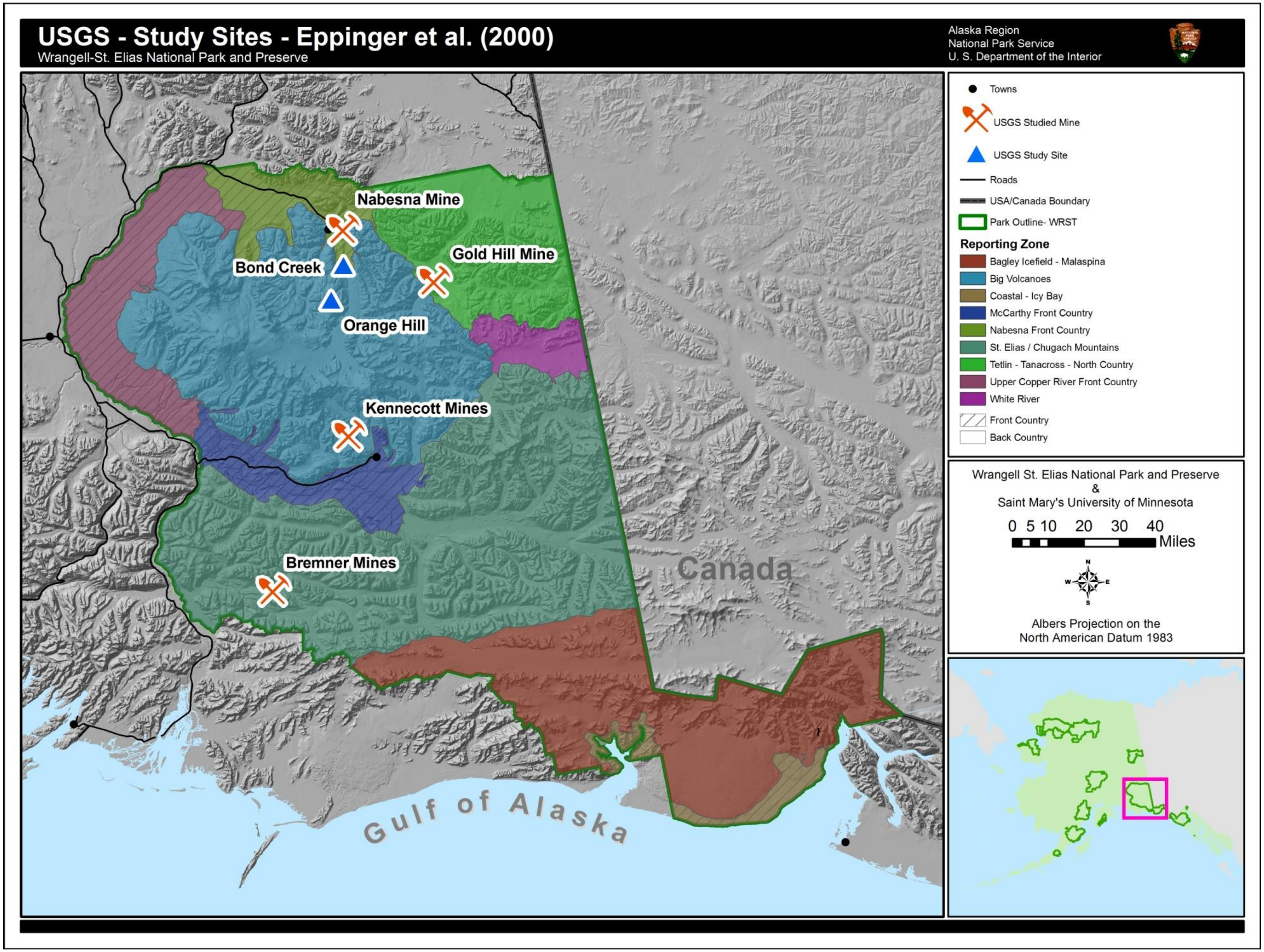
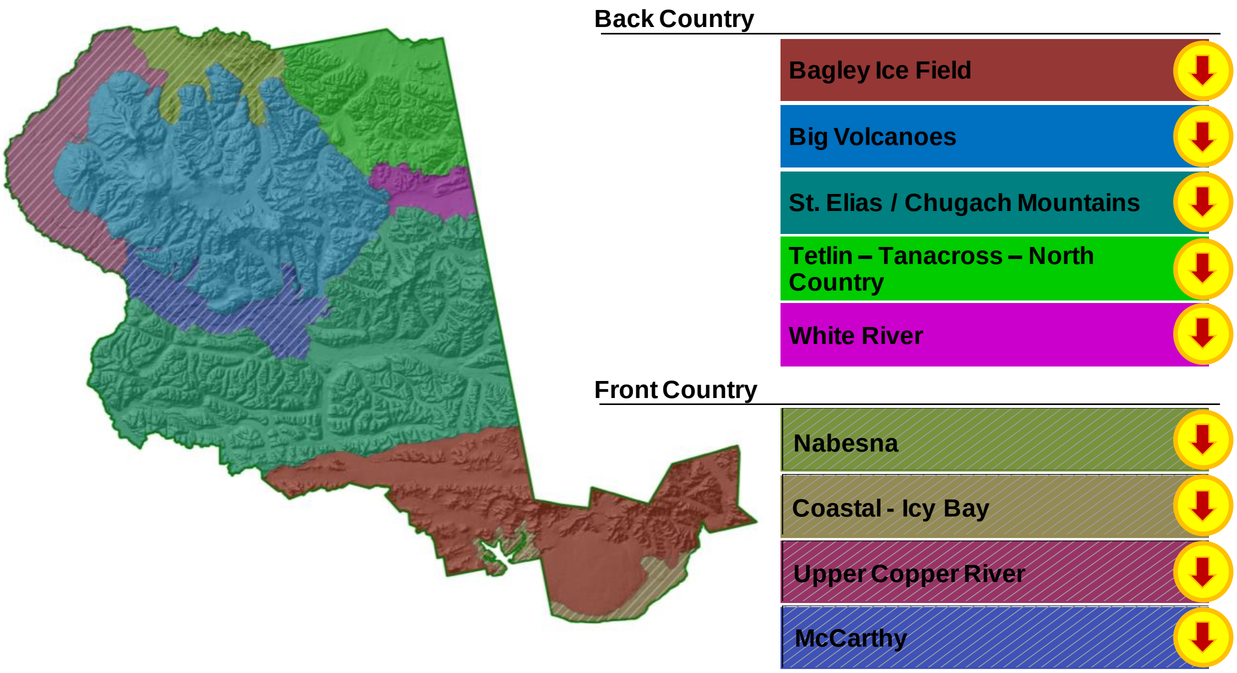


Plate 38. USGS mine study sites. (Eppinger et al. 2000)

4.19 Climate

Indicators and Measures
Temperature, Precipitation



Condition
The Central Alaska Network has reported evidence of possible significant long term climate change (Sousanes 2006). Unusually mild winters throughout much of Alaska in recent years and a substantial increase in temperatures during the 1990s is interpreted by many experts as a sign of large scale warming of the Earth‘s surface (Redmond and Simeral 2006). Warmer temperatures have been reflected in dramatic melting of snow and ice, thawing of permafrost and snowfields, and shorter seasons of river and lake ice (MacCluskie and Oakley 2006). On the northern margin of the Bagley Icefield, warming is thought to be more intense than the Medieval Warm Period or any other time in the last 1,500 years and is evident by extensive glacier retreat (Loso et al. 2007).

Concern in scientific communities regarding regional and global climate trends are substantial enough to elevate the condition of climate in WRST to moderate concern with a declining trend. In the 2006 National Park Service Alaska Park Science Strategy, climate change was identified as one of the top five environmental stressors impacting Alaska‘s parks (Marcy 2006). Several NPS staff, scientists, and interested parties were interviewed as part of the development of the Alaska Park Science Strategy. The consensus of a wide variety of respondents was that ―climate change is changing habitats, use of areas, accessibility, biotic communities, diseases and causing other effects that will change the characteristics of parks as well as the type of management action required to maintain park values and mission" (Marcy 2006, page 64).

Background
The extensive land area and significant elevation gradients of WRST create a varied climate throughout the park. The park includes coastal, transition, and interior climate regimes (Sousanes 2006). Southeast portions of the park contain areas that receive some of the most precipitation anywhere in the world (Redmond and Simeral 2006). Estimated precipitation in these regions ranges from 9,000-12,000 millimeters (900-1200 cm) per year (Redmond and Simeral 2006). Other areas of the park receive far less precipitation. The mountain peaks in the central part of the park receive 2000-3000 mm (200-300 cm) per year, and areas on the north side of these mountains receive 200-300 mm (2-3 cm) (Redmond and Simeral 2006). Annual precipitation patterns within the park also vary. The coastal area receives peak precipitation in the fall and early winter, while interior areas of the park receive the highest amounts of precipitation in the summer (Sousanes 2006).

Changes in climate have been observed in Alaska (MacCluskie and Oakley 2005). Melting snow and ice, thawing of permafrost and permanent snowfields, and reductions in snowfall amounts and river and lake ice seasons reflect general trends toward warming temperatures (MacCluskie and Oakley 2005). Climate is a primary driver of ecological processes (Sousanes 2006). Changes observed in the Central Alaska Network include decreases in useable moisture for plant growth, increases in fire occurrence and intensity, reductions in slope stability which result from thawing permafrost, and changes in glaciers (MacCluskie and Oakley 2005, Molnia 2007). WRST is a showcase park for glacial landscapes, and changes in these landscapes will be of long-term importance for resource managers (Loso et al. 2007). The importance of climate was recognized by the Central Alaska Network, which has included climate as a ―vital sign" in their inventory and monitoring plan (MacCluskie and Oakley 2005).

Past and Present Monitoring
There are three main types of climate monitoring stations in or near WRST. These are Cooperative Climate Stations (COOP), snow monitoring stations, and remote automated weather stations (RAWS). The stations in or near WRST according to Keen (2008) are represented on Plate 42. The periods of record for the climate stations in or near WRST range from one to 88 years (Keen 2008).

COOP Monitoring
The National Weather Service (NWS) Cooperative Observer Program (COOP) is a network of trained volunteers and contracted weather and climate observers. Created in 1890 under the Organic Act, this program provides meteorological data to define the climate in the United States, measure long-term changes in climate, and to support forecast, warning, and other public service programs (National Weather Service n.d.). Agencies such as the National Weather Service, Federal Aviation Administration, and the National Park Service also report their data to this program (Keen 2008). Data usually include daily maximum and minimum temperatures, snowfall, and 24-hour precipitation totals.

Snow Monitoring Stations
The Natural Resources Conservation Service (NRCS) operates snow course and snowpack telemetry (SNOTEL) stations (Keen 2008). Manual measurements of snow depth and snow water equivalent are usually made around the first day of the month during the winter and spring

at snow course sites. At SNOTEL stations, equipment including pressure sensing snow pillows, precipitation gauges, and air temperature sensors automatically collect data (Keen 2008).

Remote Automated Weather Stations

Various federal and state agencies operate remote automated weather stations (RAWS). The data are managed by the National Interagency Fire Center (NIFC) and archived by the Western Regional Climate Center (Keen, 2008). The Central Alaska Network (CAKN) Inventory and Monitoring program operates five remote automated weather stations (RAWS) in WRST.

CAKN is in the process of establishing a more detailed climate monitoring network with particular focus on high elevation locations (Central Alaska Network, Pam Sousanes, Physical Scientist, phone conversation, 16 February 2010). The lower elevation sites will continue to be monitored, but there is a special interest in determining differences in climate and trends at higher elevations. This improved monitoring network should allow for better tracking of climate trends in the future. Remote automated weather stations for the CAKN network in WRST are currently located at Chicken Creek, Chitutu, May Creek, Gates Glacier, Tebay, and Tana Knob.

A study by Davi et al. (2003) investigated temperature variability using maximum latewood density and tree-ring data in the Wrangell Mountain region. Their model reconstructed warm-season temperatures from 1593 to 1992 and accounted for 51% of the temperature variance from 1958 to 1992. In general, the results showed warming during the mid 1700s, cooling during the late 1700s and early 1800s, and warming during the 20th century. (Davi et al. 2003). The 20th century was the warmest of the four centuries modeled (Davi et al. 2003).

Reference Condition

The reference conditions for climate are the temperature and precipitation normals for years 1971-2000. The temperature and precipitation normals are defined as the arithmetic mean computed over three consecutive decades (NCDC 2008). The National Park Service Alaska Region Inventory and Monitoring Program in partnership with the Oregon State University PRISM Climate Group generated monthly and annual temperature and precipitation spatial data sets for 1971-2000. The annual temperature and precipitation normals are depicted spatially on Plate 39, 40, 41.

In addition, 1971-2000 monthly normals for temperature and precipitation have been published for stations in or near WRST, which have sufficient data for calculation. This includes twelve stations with temperature and precipitation data. The National Water and Climate Center also has calculated average snow depth and snow water equivalent (SWE) using the 1971-2000 time period for 14 snow courses in or near WRST (Plate 43). The following tables and figures represent the temperature and precipitation normals and the average snow depth and SWE for these stations for 1971-2000 (Figure 53,Figure 54, andFigure 55; Table 33, Table 34, andTable 35). Note the different patterns in temperature and precipitation between the coastal locations (Cordova, Valdez, and Yakutat) and the more interior locations (Glennallen, Gulkana, Nabesna, Northway, Paxson, Slana, Tok, and Tonsina).

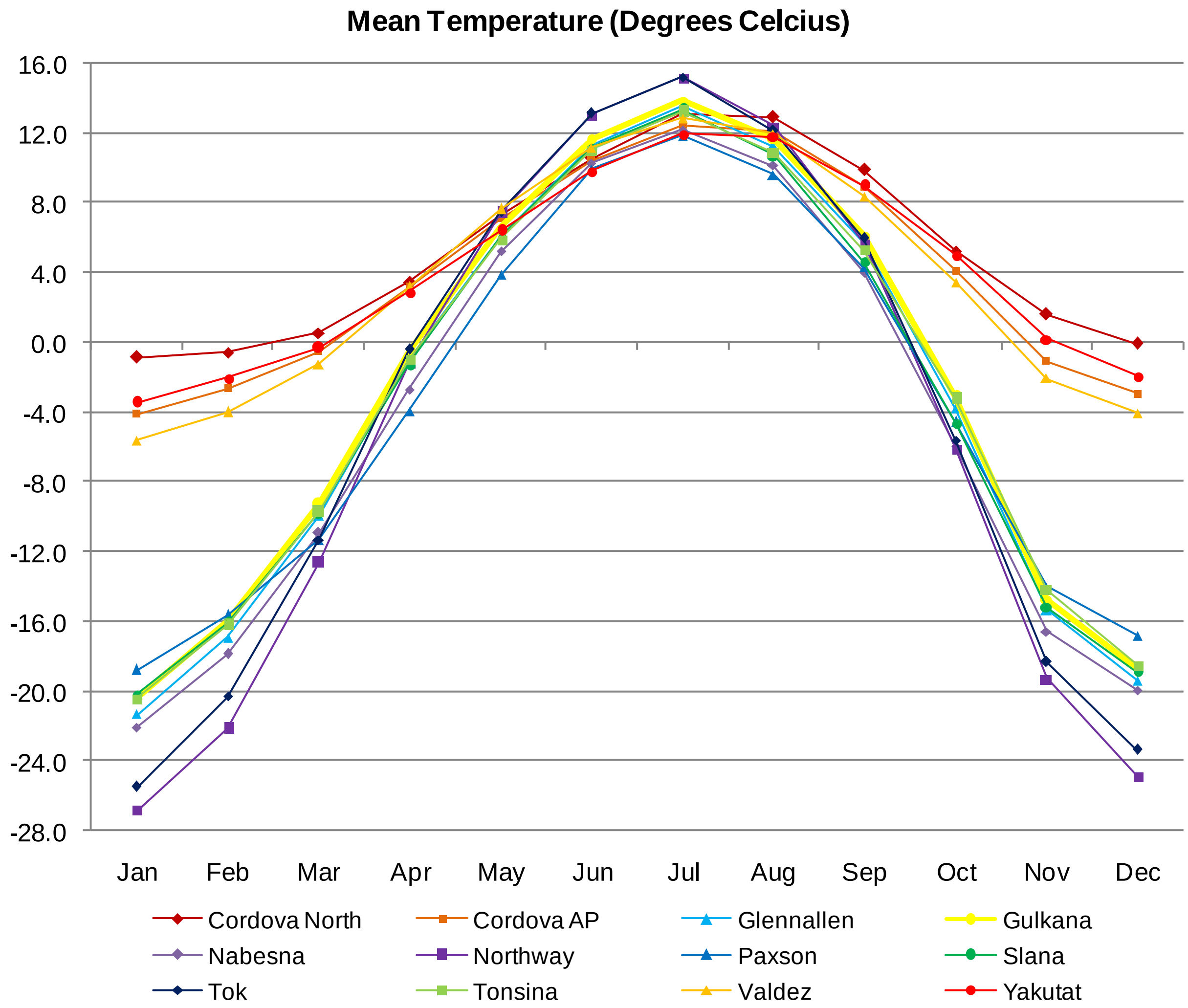


Figure 53. Mean monthly temperature normals (degrees Celsius), various Alaska sites, 1971-2000. (Keen 2008)

Table 33. Temperature normals (degrees Celsius) for stations in or near WRST, 1971-2000. (Keen 2008)

Month	Northway	Nabesna	Tok	Paxson	Slana	Glennallen	Tonsina	Gulkana	Valdez	Cordova AP	Yakutat	Cordova North
Jan	-26.8	-22.1	-25.5	-18.8	-20.2	-21.3	-20.4	-20.4	-5.6	-4.1	-3.4	-0.8
Feb	-22.2	-17.9	-20.3	-15.7	-16.1	-16.9	-16.2	-16.0	-4.0	-2.7	-2.0	-0.6
Mar	-12.6	-10.9	-11.3	-11.3	-9.8	-9.9	-9.7	-9.3	-1.2	-0.5	-0.3	0.6
Apr	-1.2	-2.7	-0.4	-3.9	-1.2	-0.9	-0.9	-0.5	3.2	3.2	2.9	3.4
May	7.4	5.2	7.5	3.9	6.1	6.1	5.9	6.6	7.7	7.1	6.4	7.3
Jun	13.1	10.3	13.2	10.0	11.2	11.4	11.1	11.7	11.2	10.5	9.8	10.6
Jul	15.2	12.2	15.2	11.9	13.4	13.6	13.3	13.9	12.9	12.5	12.0	13.1
Aug	12.4	10.2	12.2	9.6	10.8	11.3	10.9	11.7	12.0	12.2	11.8	12.9
Sep	5.7	4.1	6.0	4.3	4.7	5.7	5.3	6.2	8.4	8.9	9.0	9.9
Oct	-6.1	-5.9	-5.6	-4.6	-4.6	-3.8	-3.2	-3.1	3.4	4.2	5.1	5.3
Nov	-19.3	-16.6	-18.3	-14.0	-15.2	-15.4	-14.2	-14.7	-2.1	-1.1	0.2	1.6
Dec	-24.9	-19.9	-23.4	-16.8	-18.9	-19.4	-18.5	-18.7	-4.1	-2.9	-1.9	-0.1
Annual	-4.9	-4.5	-4.2	-3.8	-3.3	-3.3	-3.1	-2.7	3.5	3.9	4.2	5.3

Table 34. Precipitation normals (millimeters) for stations in or near WRST, 1971-2000. (Keen 2008)

Month	Tok	Northway	Glennallen	Gulkana	Nabesna	Tonsina	Slana	Paxson	Valdez	Cordova AP	Cordova North	Yakutat
Jan	8.6	6.1	14.2	11.4	6.1	21.8	12.4	23.9	152.9	181.4	262.4	334.8
Feb	4.6	5.6	13.5	13.2	7.9	21.3	14.0	17.3	140.5	165.4	248.2	279.1
Mar	3.3	5.1	9.4	9.1	4.1	11.4	13.2	18.0	114.0	153.9	219.2	289.8
Apr	3.6	5.1	5.6	5.6	7.9	7.1	8.4	15.5	90.2	144.0	202.9	274.3
May	11.4	25.1	12.4	15.0	19.1	11.9	21.8	27.9	78.2	158.5	203.5	248.4
Jun	50.5	48.3	36.1	39.1	70.6	31.5	52.1	67.3	76.5	138.9	166.6	182.1
Jul	58.4	58.4	41.7	46.2	69.3	44.5	71.6	77.2	97.5	142.5	180.8	200.2
Aug	21.6	35.1	45.0	45.7	44.2	36.6	58.4	81.3	168.1	239.3	297.4	337.1
Sep	18.5	22.6	29.2	36.6	25.9	35.6	49.5	75.4	243.6	363.2	482.9	530.4
Oct	15.2	12.4	26.9	25.9	14.0	33.0	26.7	54.9	217.9	320.5	419.6	609.6
Nov	13.0	7.9	19.3	17.0	11.7	29.7	21.3	29.2	140.0	193.0	257.8	385.3
Dec	9.7	6.4	30.5	24.6	10.2	32.3	23.4	31.5	192.8	244.3	367.0	402.6
Annual	218	238	284	290	291	317	373	519	1,712	2,445	3,308	4,074

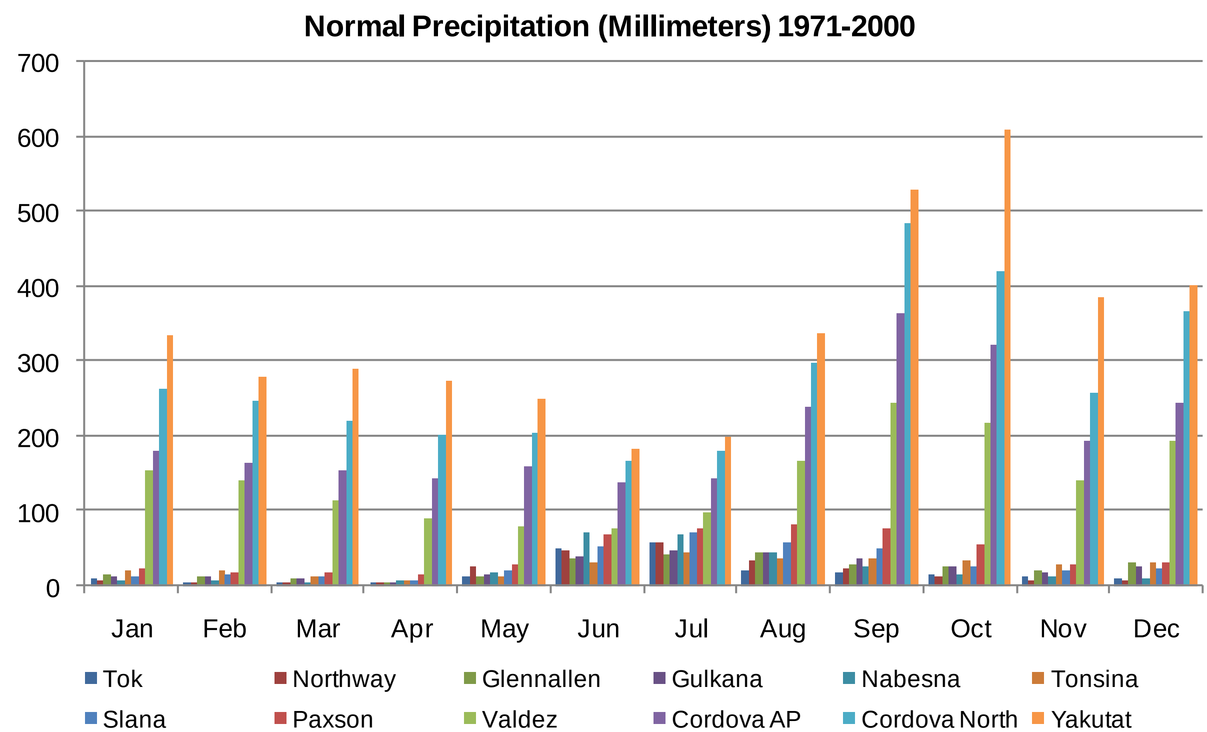


Figure 54. Normal precipitation (millimeters) for stations in or near WRST, 1971-2000. (Keen 2008)

Table 35. Snow course depth average (centimeters) and snow water equivalent (SWE) average (centimeters), 1971-2000. National Water & Climate Center. (Keen 2008) January depth and SWE are only available for Dadina Lake (Depth: 48.3, SWE: 7.6) and Sanford River (Depth: 45.7, SWE: 8.1).

	Elevation	February		March		April		May	
Snow Course	**(Meters)**	**Depth**	**SWE**	**Depth**	**SWE**	**Depth**	**SWE**	**Depth**	**SWE**
Chisana	1012	55.9	8.6	55.9	9.1				
Chistochina	661	45.7	7.6	55.9	8.9	55.9	10.4	10.2	3.0
Chokosna	472			53.3	8.1	55.9	9.9		
Dadina Lake	658	61.0	10.4	73.7	13.0	68.6	15.0		
Haggard Creek	774	61.0	11.4	68.6	14.2	73.7	16.0	45.7	13.2
Jatahmund Lake	664	40.6	5.8	45.7	7.4	45.7	8.1		
Kenny Lake School	396	35.6	6.6	45.7	8.6	43.2	9.4	7.6	2.3
Mentasta Pass	741	61.0	12.2	66.0	14.7	71.1	17.0	40.6	12.2
Paxson	808	71.1	14.0	78.7	16.8	81.3	19.8	55.9	17.5
Sanford River	695	61.0	10.7	71.1	13.7	71.1	15.7	38.1	10.2
Tok Junction	503	43.2	6.6	48.3	8.1	48.3	9.1	7.6	2.3
Tolsona Creek	610	48.3	8.1	55.9	9.7	55.9	10.4	12.7	5.3
Tsaina River	503	127.0	31.8	142.2	39.9	144.8	44.7	104.1	37.1
Worthington Glacier	640	157.5	42.2	172.7	54.9	182.9	63.2	154.9	62.5

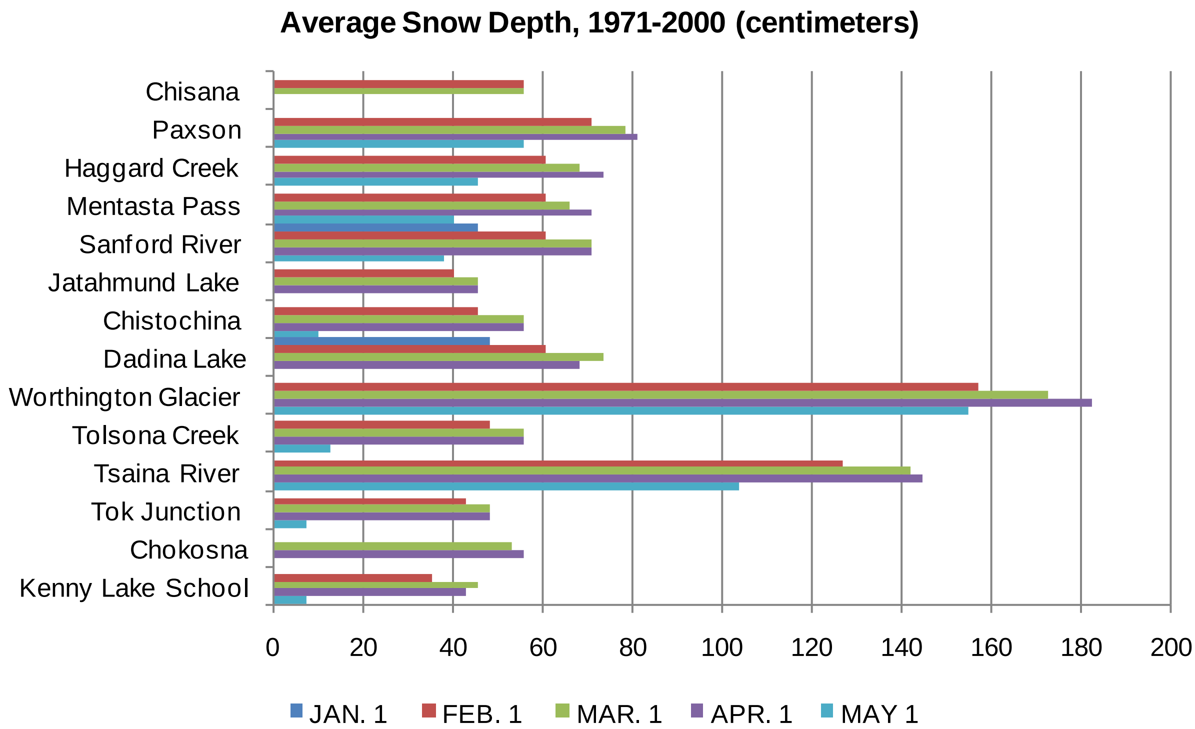


Figure 55. Average snow depth (centimeters), 1971-2000. National Water & Climate Center. (Keen 2008) Snow course locations are arranged from lowest elevation (bottom) to highest elevation (top).

Current Status and Trend

There is an important distinction between climate and weather. Weather is the behavior of the atmosphere during a period of minutes to months (NASA 2005). Climate is the long-term pattern of weather in a given location. Climate is constantly fluctuating on multiple temporal scales (Redmond and Simeral 2006). These fluctuations present challenges in determining climate trends because there are a variety of possible trends depending on the period of time analyzed. 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 36).

Table 36. 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 the region is the Pacific (inter) Decadal Oscillation (PDO). Mantua et al. (1997) formally identified this pattern of climate variability in a study relating climate oscillation to salmon production. The cycle alternates between positive and negative phases and relates to sea surface temperature in the northern Pacific Ocean. A positive phase is associated with a relatively strong Aleutian Low, which moves warmer air into the region (Wendler and Shulski 2009). Phase shifts occurred in 1925 (negative to positive), 1947 (positive to negative), and 1977 (negative to positive) (Mantua et al. 1997). The PDO index, which is based on monthly anomalies in sea surface temperature of the North Pacific, is depicted in Figure 57.

The Pacific Decadal Oscillation effects regional climate, especially during the winter months (Hartmann and Wendler 2005, Redmond and Simeral 2006). Hartmann and Wendler (2005) compared several climatic variables in Alaska during the cold phase from 1951 to 1975, and the warm phase from 1977 to 2001. They found the PDO shift in 1976 was responsible for a significant portion of the warming trend noticed in Alaska between 1950 and 2000.

Hartmann and Wendler divided Alaska into six climatic regions for analysis including interior and southeast regions overlapping substantial portions of Wrangell-St. Elias (Figure 56). The correlation coefficients (r) between mean annual temperature and the PDO index were 0.715 in the southeast region and 0.663 in the interior region. Both values were significant at a probability greater than 99%. All regions experienced statistically significant increases in mean winter surface air temperature from the 1951-1975 period to the 1977-2001 time period, but the greatest difference in mean seasonal temperature (+3.1ºC) occurred between the time periods in the interior region during the winter (Hartmann and Wendler 2005). Temperature differences in mean surface air temperature are included in Table 37.

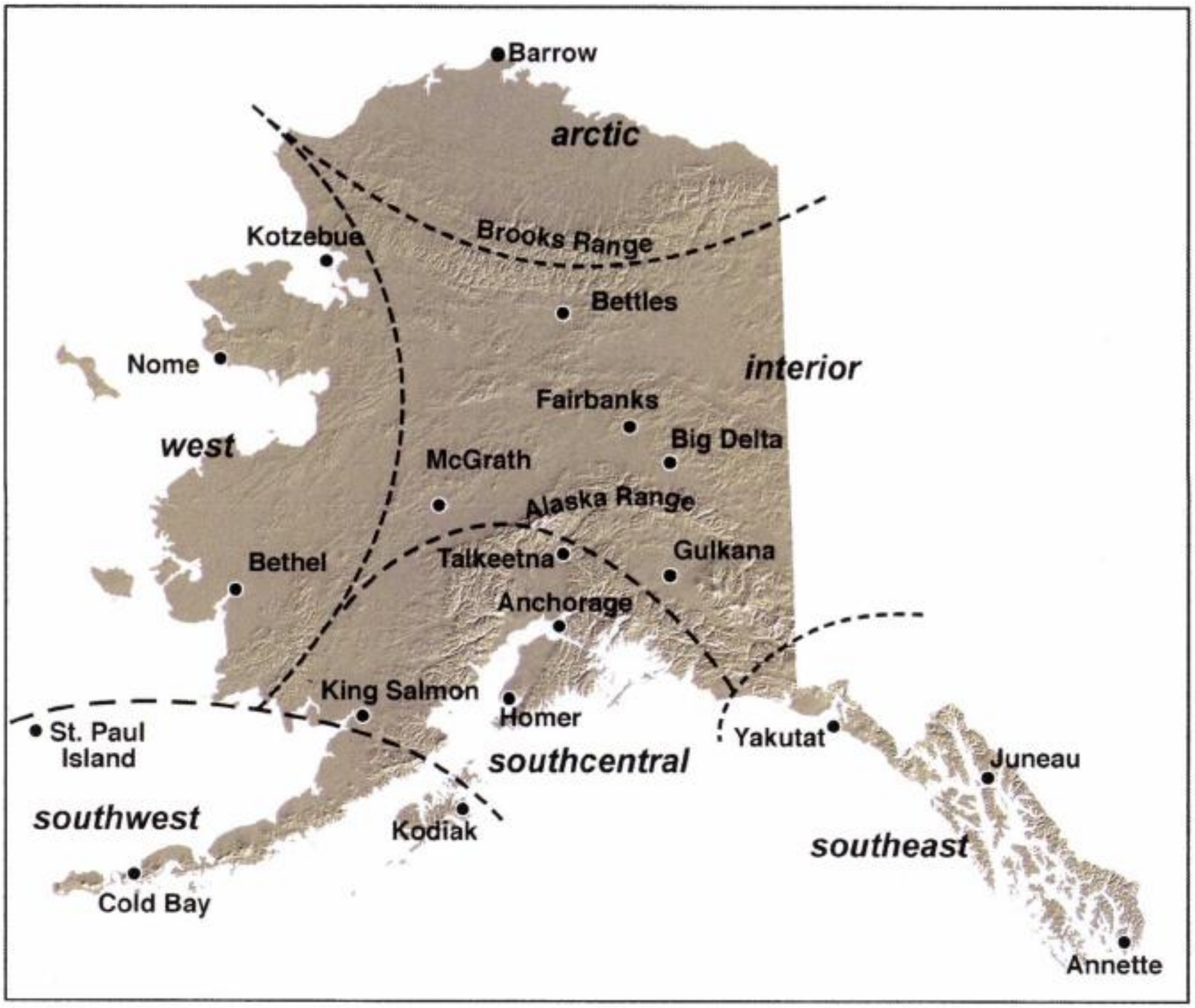


Figure 56. First-order National Weather Service stations and the climate regions of Alaska. From (Hartman and Wendler 2005)

Hartmann and Wendler found the total annual precipitation increased in the southeast and interior regions. Although total precipitation increased in the southeast region, snowfall decreased significantly. This could be explained by the increase in temperature from the cold to warm phase of the PDO. Mean winter temperatures in the southeast are near freezing, so the increase in temperature would result in more precipitation falling as rain instead of snow (Hartmann and Wendler 2005). Annual snowfall increased in the interior region (Hartmann and Wendler 2005).

Table 37. Change in mean surface air temperature, total precipitation and snowfall (from 1951-1975 to 1977-2001) for southeast and interior regions. Adapted from (Hartmann and Wendler 2005). Bold indicates significance at a probability greater than 95%. Shading indicates significance at a probability greater than 99%.

	March, April, and May	June, July, and August	September, October, and November	December, January, and February	Annual
Temperature					
Southeast	**+1.4ºC**	**+0.7 ºC**	+0.4 ºC	**+1.7 ºC**	**+1.1 ºC**
Interior	**+1.7 ºC**	**+0.5 ºC**	+0.2 ºC	**+3.1 ºC**	**+1.4 ºC**
Total Precip.					
Southeast	+4%	+6%	+8%	+7%	+7%
Interior	+4%	+7%	+7%	+12%	+7%
Snowfall					
Southeast	**-49%**	-	-18%	**-34%**	**-36%**
Interior	-8%	-	**+21%**	**+20%**	+14%

The following figures display annual average temperature (Figure 57) and total precipitation (Figure 58) for Gulkana, Yakutat, and Northway Airport in addition to the PDO index. Only years with limited or complete data sets are included. Gulkana and Yakutat station records are included due to their designation as first-order National Weather Service stations. First-order stations are operated by certified observers and have the best continuity of station location and data quality (Hartmann and Wendler 2005). Northway Airport is also included in the figure because of its proximity to the northeast portion of WRST and its relatively long record. The locations of these stations can be found on Plate 43.

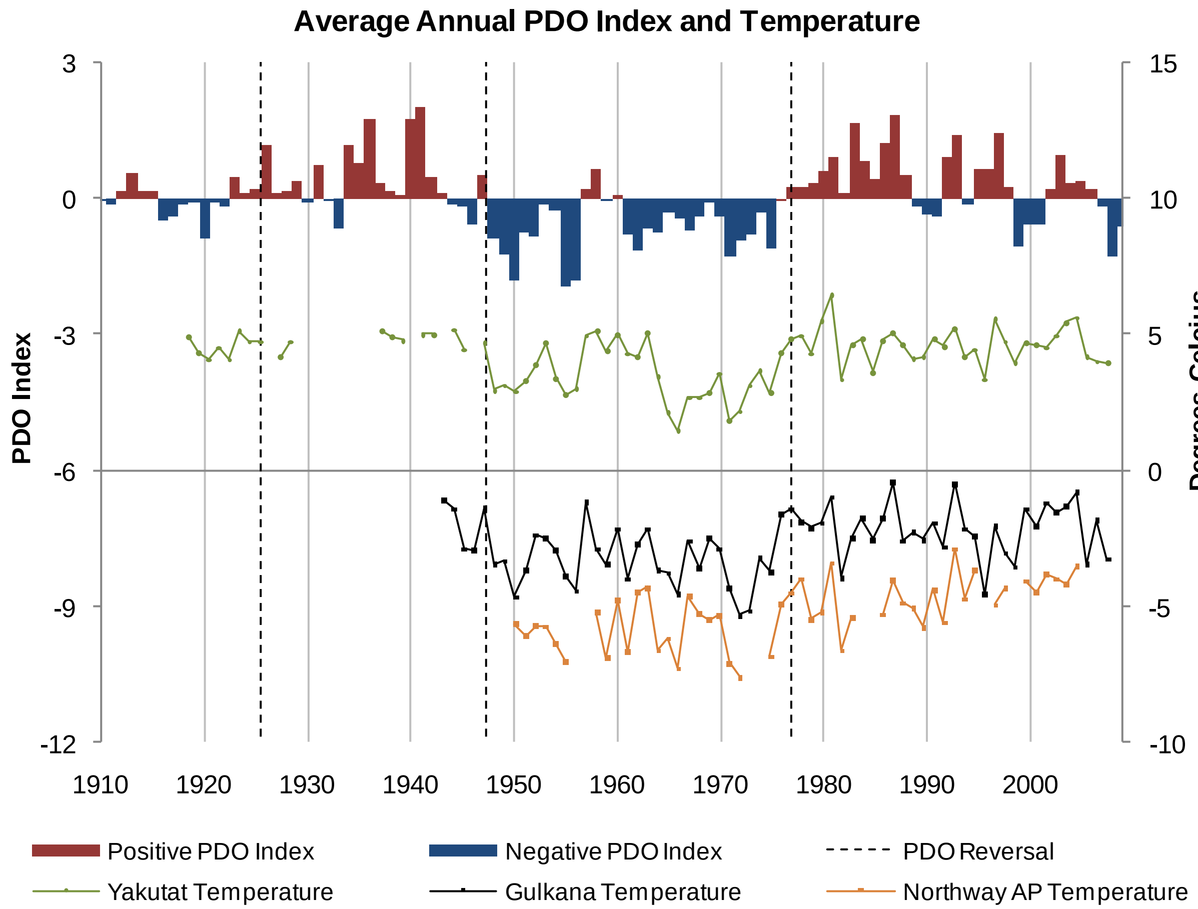


Figure 57. Annual average PDO index and annual average temperature for Gulkana, Yakutat, and Northway Airport. (Mantua 2010, Alaska Climate Research Center 2010a,b, Western Regional Climate Center 2006) Vertical dashed lines represent reversals in PDO polarity in 1925, 1947, and 1977.

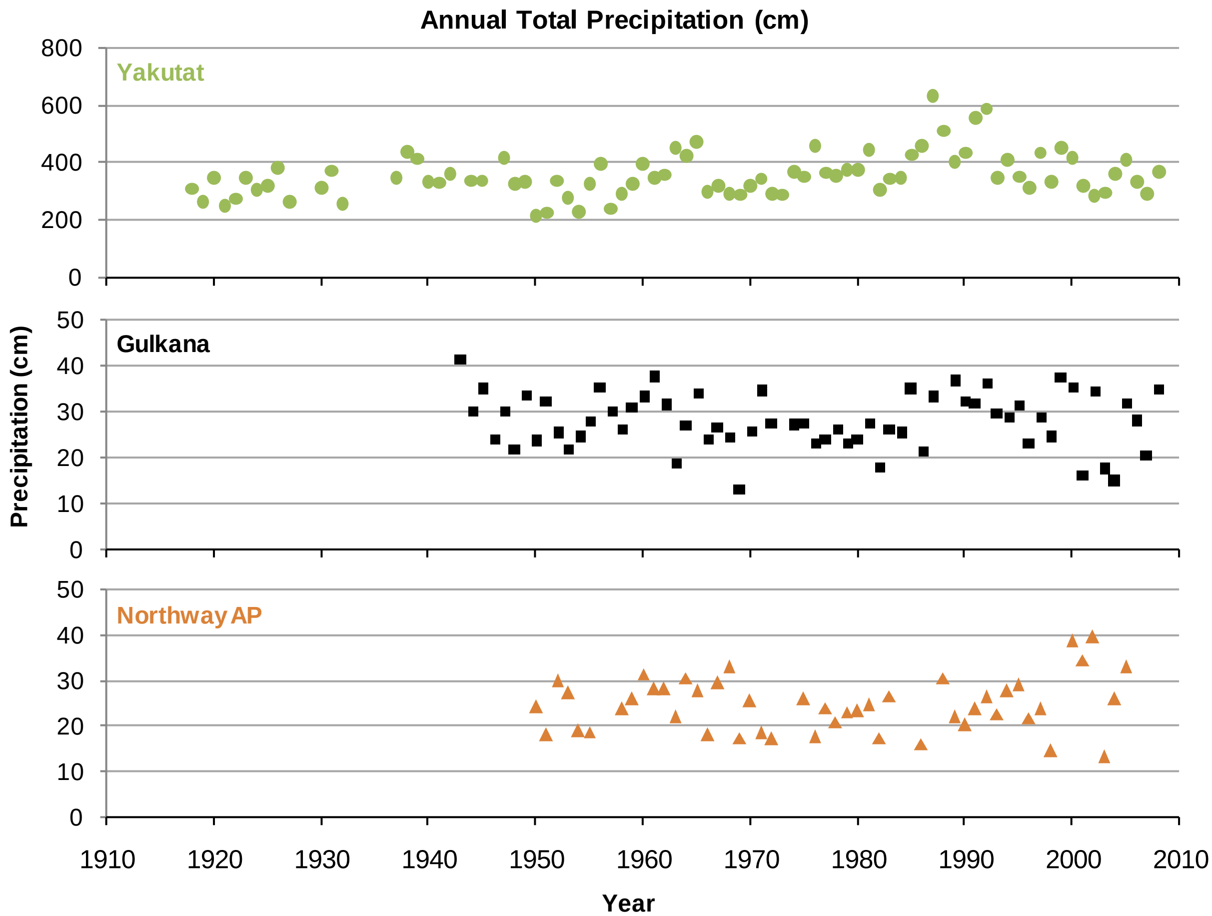


Figure 58. Total annual precipitation for Yakutat (top), Gulkana (middle), and Northway Airport (bottom). Note the larger precipitation scale for Yakutat. (Alaska Climate Research Center 2010a,b, Western Regional Climate Center 2006)

Stressors

There is a scientific consensus that a general warming trend in global climate has some anthropogenic cause (Morris 2007). Concentrations of carbon dioxide and other greenhouse gases such as methane, nitrous oxide, and halogen-containing gases have increased in the atmosphere because of human activity (Denman et al. 2007). Human sources of carbon dioxide include fossil fuel combustion, cement manufacturing, deforestation, biomass burning, and some agricultural practices (Denman et al. 2007). Human sources of methane include energy production from coal and natural gas, waste disposal in landfills, raising ruminant animals, rice agriculture, and biomass burning. Certain agricultural practices such as application of nitrogen fertilizer and raising cattle as well as some industrial activities contribute to increases in nitrous oxide concentrations (Denman et al. 2007).

Natural events and changes in landscape features also affect climate. Davi et al. (2003) found major volcanic eruptions coincided with multiple severely cold warm-seasons in their temperature record modeled from tree-ring data. Another change potentially affecting climate in interior Alaska is the decline of sea ice in the Arctic Ocean (CAKN n.d.). In addition to anthropogenic sources, methane is released through natural processes such as thawing permafrost and ebullition (bubbling) from northern lakes (Anisimov 2007, Walter et al. 2007). This potentially results in a positive feedback loop of climate warming increasing permafrost thaw leading to more methane release (Anisimove 2007, Walter et al. 2006).

Reporting Zones

Plate 42 and Plate 43 display climate monitoring sites with RZs. Thirty-year temperature and precipitation normals for those sites that appear on Plate 43 are included in the reference condition section. For distribution of average temperature and precipitation throughout the park see Plates 40, 41, and 42.

Data Needs

Continued monitoring of climate stations will provide important information for assessing the condition of climate. Estimating temperature records by analyzing ice cores from the park would better inform knowledge of the long term natural climatic variability.

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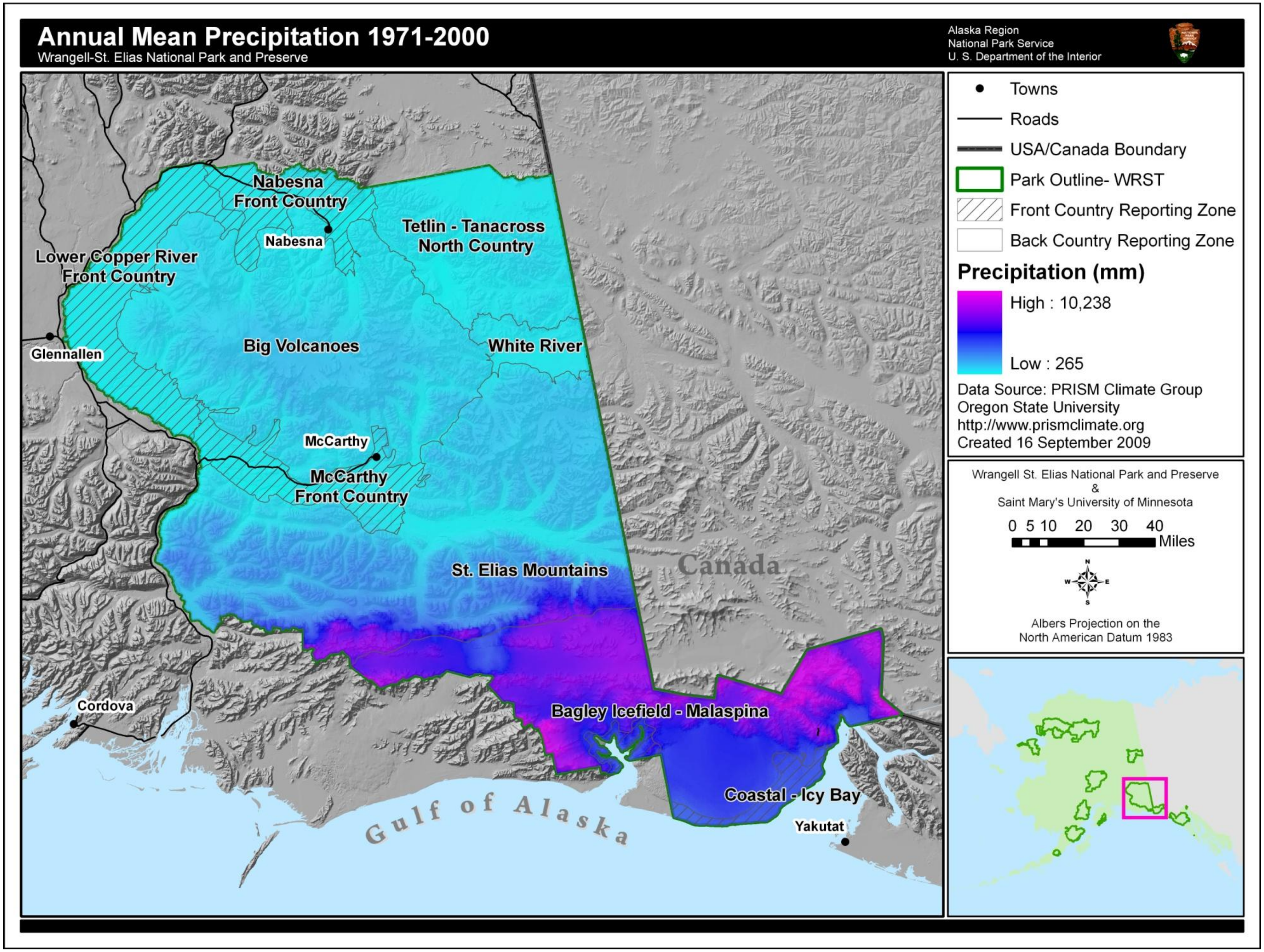


Plate 39. Annual Mean Precipitation, WRST, 1971-2000. (PRISM Climate Group 2009)

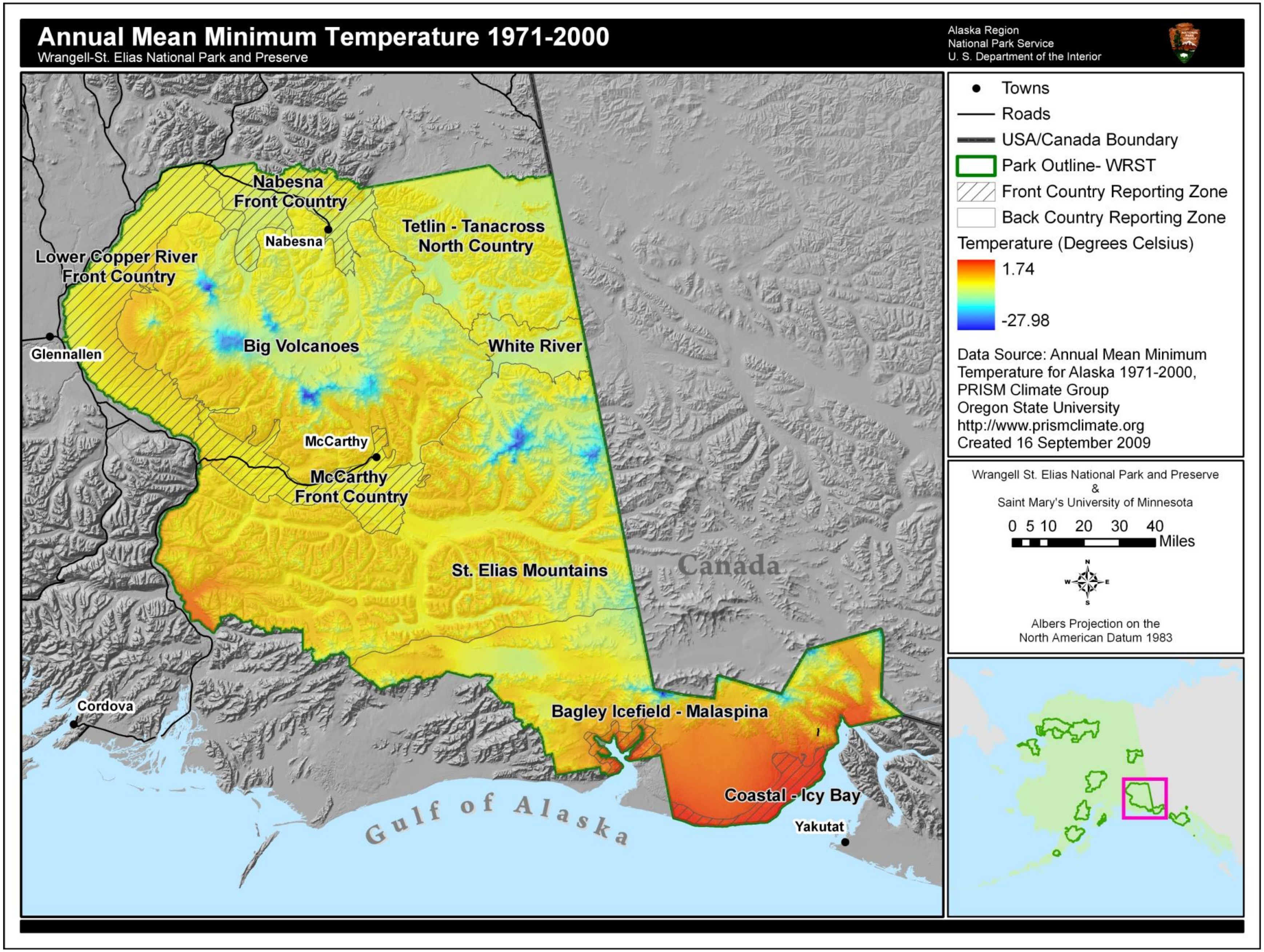


Plate 40. Annual Mean Minimum Temperature, WRST, 1971-2000. (PRISM Climate Group 2009)

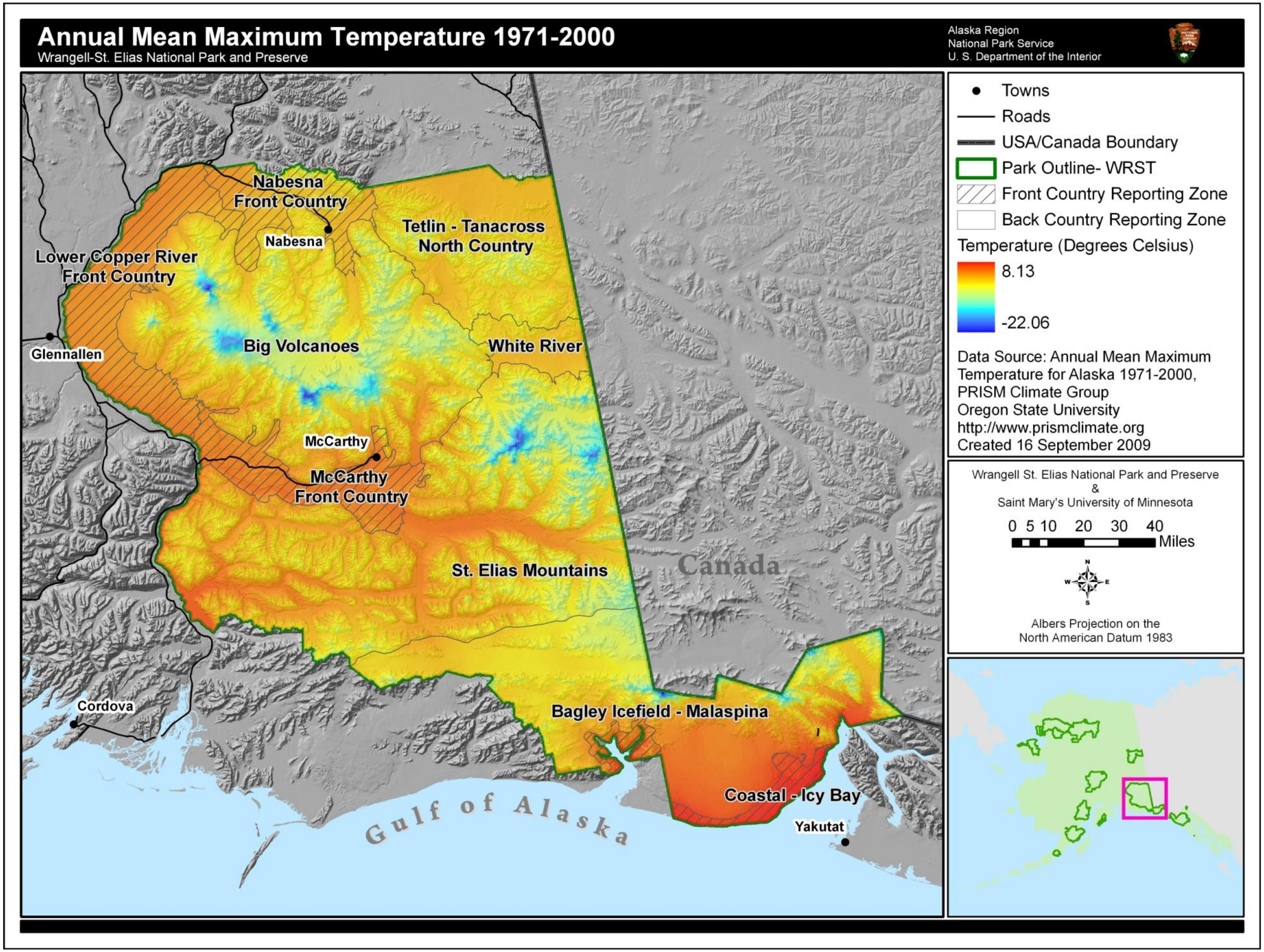


Plate 41. Annual Mean Maximum Temperature, WRST, 1971-2000. (PRISM Climate Group 2009)

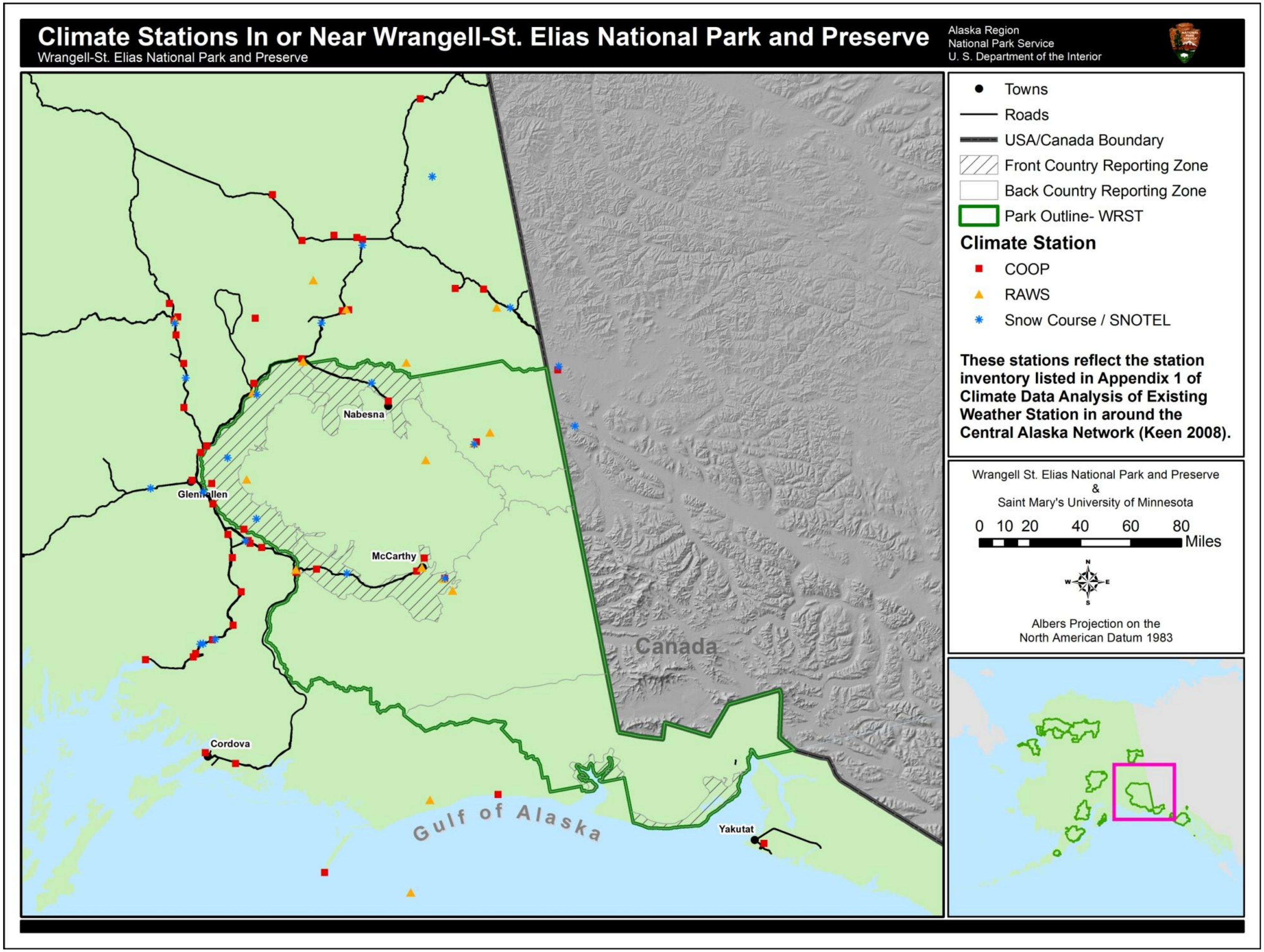


Plate 42. Climate Monitoring Locations in and near WRST. (Keen 2008)

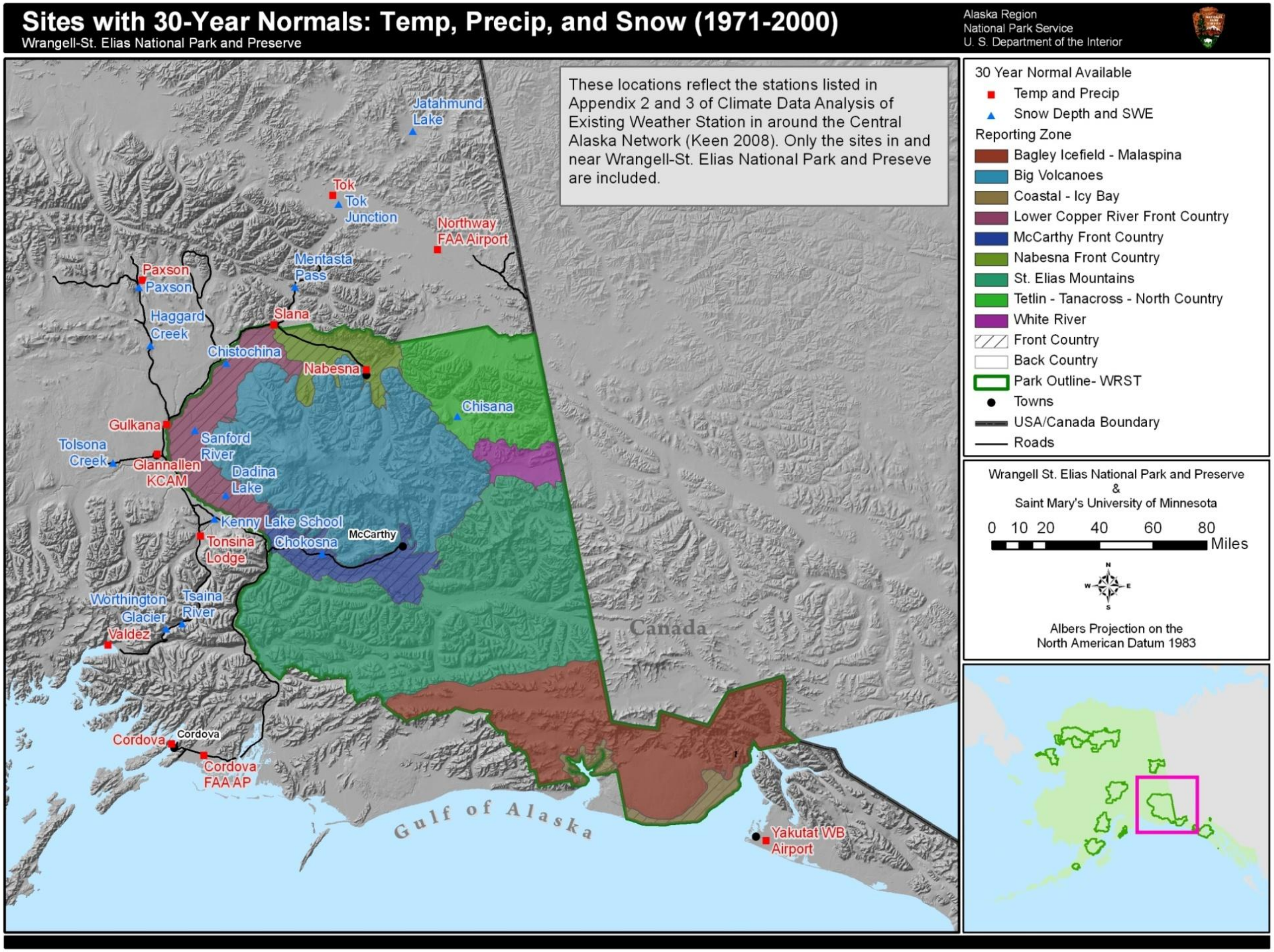
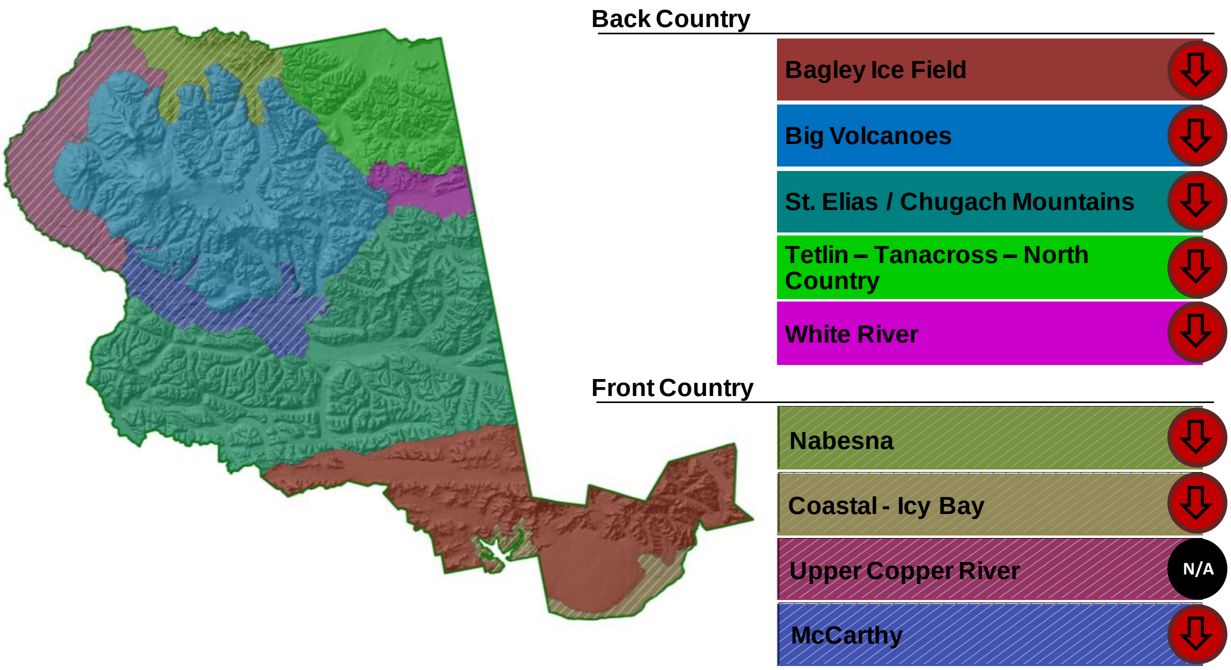


Plate 43. Climate monitoring locations in and near WRST with calculated 30-year normals, 1971-2000. (Keen 2008)

4.20 Glacial Features

Indicators and Measures

Changes in glacial extent



Condition

Glaciers cover approximately 20% of the land area in WRST, making it the largest aggregation of glaciers in North America. Glaciers are responsible for shaping the hydrology of WRST. Most major rivers in WRST originate from glacial runoff, making glacial melt patterns important to many of the species of plants, fish, and wildlife in the park. The condition of glaciers across WRST is of significant concern, based on the changes in glacial extent over recent time. A recent 2007 study found that 98% of Alaskan glaciers, of which 99.9% are terrestrial, were receding (Molnia 2007). This included nearly all terrestrial glaciers in the three mountain ranges located in WRST: Wrangell, St. Elias, and Chugach (Molnia 2007).

Background

WRST holds the largest aggregation of glaciers in North America, with nearly 20% of the land area in WRST covered by glaciers. The Malaspina Glacier alone, in southeast WRST, is larger than the size of Rhode Island (Weeks 2003). Due to the extent of glaciers in the park, WRST is one of the highest priority sites for investigating climate and glacier interactions in the world (Weeks 2003). Glaciers are also a focal point of most park visits; Kennicott Glacier is the most visited site in WRST (Scott 2009). In addition, many guide services offer glacier viewing from helicopters or small planes.

Most of the rivers in WRST begin as glacial runoff. As a result, glaciers exert a major influence on the hydrological cycle of the park. Highest river flows in WRST correspond to late summer when glacial-melt is at its peak (Weeks 2003). Glacial rivers carry large sediment loads at peak flows, which enable them to carve the landscape and move and deposit significant volumes of material in various locations. This results in the typically braided channels of most major rivers in WRST. Glacial rivers are generally low in productivity due to the cold water and high sediment loads.

Reference Condition

The reference condition of glaciers in WRST is the historical natural record of glacial extent prior to climate change. The date climate change began is ambiguous, but much research and monitoring has occurred since the Landsat baseline decade (1972-1981) that provide evidence of the condition of specific glaciers since that time.

Mountain Range Specific Summaries

Chugach Mountain Range Glaciers

The eastern Chugach Mountain Range, characterized by its large mass of connected glaciers, runs east to west across southern WRST (Field 1975). During the Landsat baseline decade, most glaciers in the Chugach Mountain Range were receding and the few that were advancing were located in Western Prince William Sound (Molnia 2007). Since the Landsat baseline decade, most glaciers in the Chugach Mountains have continued to recede (Molnia 2007).

St. Elias Mountain Range Glaciers

The St. Elias Mountain Range runs parallel to the Gulf of Alaska coast through central WRST. This mountain range is host to the three largest temperate glaciers in North America: Bering Glacier (>5000 km^2), Malaspina Glacier (~5000 km^2), and Hubbard Glaciers (Molnia 2007). Over 50 glaciers in the St. Elias Mountain Range are greater than 8 km in length (Molnia 2007). Many of the other glaciers associated with the St. Elias/ Chugach Mountains are tidewater glaciers (glaciers that terminate in the sea, ending in an ice cliff from which icebergs are discharged) (Bates and Jackson 1987, Molnia 2007). Movement trends of the St. Elias Mountain glaciers are variable. Hubbard Glacier, the largest tidewater glacier in Alaska, has been advancing for the last 100 years at a rate of approximately 22m/yr (Molnia 2007). On the other hand, Tyndall Glacier, another tidewater glacier, was documented as being approximately 700m thinner compared to its reported thickness in 1959 (Molnia 2007).

Wrangell Mountain Range Glaciers

The Wrangell Mountain Range, which holds many of the highest peaks in North America, also hosts roughly 50 outlet glaciers of lengths greater than 8 km (Molnia 2007). Outlet glaciers are ice channels, constricted by bedrock on either side, that flow out of an ice sheet. Mount Wrangell is currently the only active volcano in this range (Molnia 2007). Since an earthquake in 1964, studies have shown that the heat flow from Mount Wrangell is at least 1000 times greater than the Earth's average geothermal heat flux (Benson et al. 1975, Benson and Follet 1986). The heat emitted from Mount Wrangell is responsible for all glacial melting at the summit caldera (Benson and Follet 1986). Three of Mount Wrangell's outlet glaciers have been advancing since 1964 at rates between 5-18 km/yr (Sturm 1995, Sturm et al. 1991); all others have been receding or thinning (Molnia 2007).

Gulkana Glacier

For the last 50 years, the USGS has been monitoring the Gulkana Glacier, which is located just northeast of WRST in the Alaska. The study of the Gulkana Glacier has coincided with the monitoring of South Cascade Glacier, Washington and Wolverine Glacier, Alaska (near Anchorage). The USGS has focused on documenting the net mass balance of these glaciers, measured as the difference between the mass gain through accumulation of snow and the mass loss through ablation (Josberger et al. 2007). Ablation is the combined water loss of glacial water due to melt and runoff, icebergs, and water vapor (Josberger et al. 2007).

To date, this study has drawn two major conclusions. First, all three glaciers have lost mass since the initiation of monitoring began in the late 1950s (USGS 2009). Second, glacier mass loss has accelerated during the last 15 years, also recording the highest melt years on record (USGS 2009). Additionally, the rate of volume loss has been substantially greater at Gulkana Glacier than the other two sites; which could be due to mountain ranges blocking incoming precipitation (Josberger et al. 2007).

Stressors

The stressor to glaciers as identified by NPS managers is primarily climate change. Climate change can affect different types of glaciers in a variety of ways. With increasing temperatures, terrestrial glaciers typically recede and tidewater glaciers exhibit mixed reactions.

Data Needs

In the last 40 years, technological advancements have enabled a vast expansion in the knowledge of glaciers and their history. Continued monitoring of glaciers in and near WRST is important because of the role glaciers play in the ecological processes of the park and preserve.

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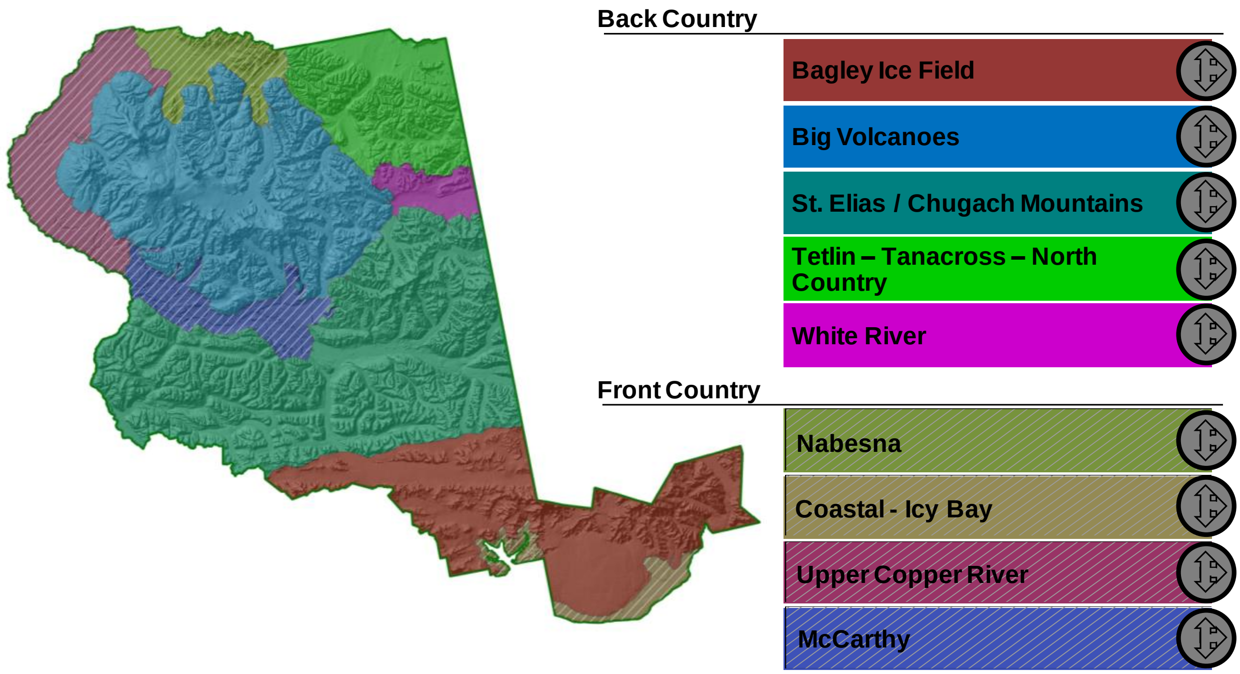
4.21 Hydrology

Indicators and Measures

Flood Frequency and Duration, Annual Peak Flows



Due to lack of data, the condition of hydrology in WRST is unknown. No data exist that quantify flood frequency and duration in WRST. Annual peak flow data are also limited, despite the existence of 161 USGS gauge sites near WRST (Plate 44). Of the 161 sites, only 54 have annual peak flow data and most of that data is historical, from the 1950s and 1960s. There are only six sites in the WRST area that have recorded data since 2000, only one of which has greater than 15 total years of data that are relevant to WRST.

Background

Over 25% of the land in WRST is covered by glaciers or permanent snowfields, making it one of the largest reserves of freshwater in the Northern Hemisphere (Weeks 2003). In WRST, there is greater than 30,000 hectares of lakes and ponds and greater than 20,000 km of NHD flowlines (Table 38, Table 39). Freshwater is vital to the plants, animals, and ecosystems within WRST. In particular it is responsible for the distribution of sediment, organic matter, and nutrients across the park, allowing the natural systems to remain intact (Weeks 2003). Climate change and other anthropogenic stressors to freshwater in WRST are of particular concern to park staff and are expected to have a significant effect on freshwater systems, not only in WRST, but also across the Central Alaska Network (CAKN) (Simmons 2006).

Table 38. WRST lakes and ponds summary. (NHD Analysis)

Area name	Acres	Hectares
Nabesna:	18, 464.0	7,472
Yakutat:	31,098	12,585
Valdez:	10,537	4,264
Mt. St. Elias:	3,138	1,270
McCarthy:	18,046	9,303
Icy Bay:	31	13
Gulkana:	8,245	3,337
Cordova:	443	179
Bering Glacier:	6,159	2,492
Total:	77,697	33,442

Table 39. Summary of NHD flowlines in WRST.

Strahler's Rank	Count of Segments	Average Shape Length (m)	Sum of Shape Length (m)	Flowline Length(Miles)	Flowline length (km)
1	13,026	1,091	14,212,935	8,832	14,214
2	5,664	859	4,864,546	3,023	4,865
3	2,796	867	2,423,695	1,506	2,424
4	1,724	740	1,275,448	793	1,273
5	824	628	517,343	321	517
6	257	614	157,714	98	158
Total	24,291	N/A	23,451,682	14,572	23,451.36

Reference Condition
The hydrologic reference condition, as defined in the WRST NRCA Framework, is "natural flood frequency and intensity prior to climate change."

Flood Frequency and Duration
No information exists that quantifies flood frequency or duration for WRST.

Annual Peak Flows
Plate 44 shows the USGS gauge sites located on rivers in and around WRST. Of the 161 sites shown, 54 record annual peak flow data. Of these, only six have data recorded since 2000 and only three of those have greater than 15 total years of data. Only one of the three sites that meet the above criteria is located in WRST. USGS sites 15212800 and 15208100 measure annual peak flows of small waters southeast of WRST, and have average annual flow values 38.9 CFS and 407.75 CFS respectively. USGS site 15470300 at Little Jack Creek near Nabesna is located within the boundary of WRST. Average annual peak flow at Little Jack Creek (1975-2007, n = 26) is 115.9 CFS (Figure 59). Throughout the recording history of this gauge, annual peak flow in Little Jack Creek has ranged from 13 CFS (1998) to 263 CFS (2007).

Although not meeting the previously listed criteria, USGS gauge site 1521400 on the Copper River at the Million Dollar Bridge near Cordova provides information about flow levels for the entire Copper River watershed. Data at this site are limited, with 11 annual peak flow measurements available; only three of which have been recorded since 1995 (Figure 60). The average annual peak flow for this site is 296,000 CFS, ranging from 234,000 CFS (1994) to 444,000 CFS (2006). The three most recent annual peak flow measurements, 2005, 2006, and 2006, have averaged 347,333 CFS.

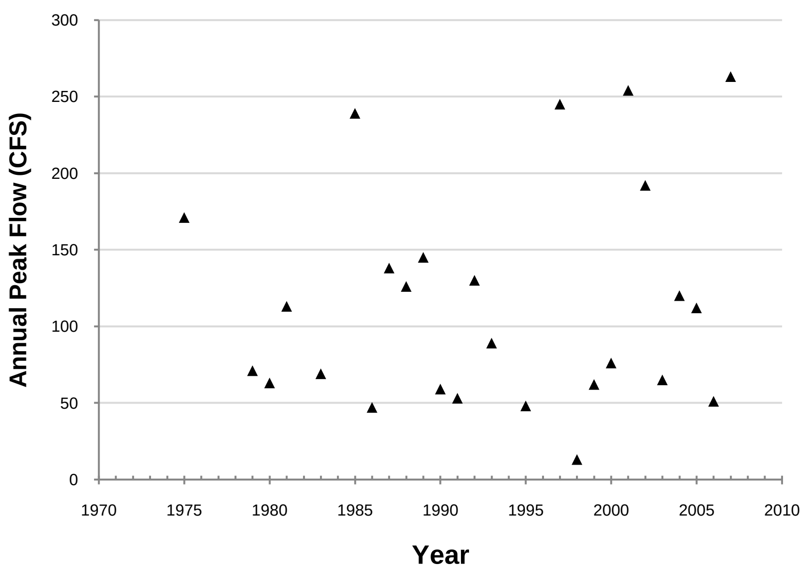


Figure 59. Annual peak flow data for USGS gauge site 15470300, Little Jack Creek near Nabesna, AK, 1975-2008.

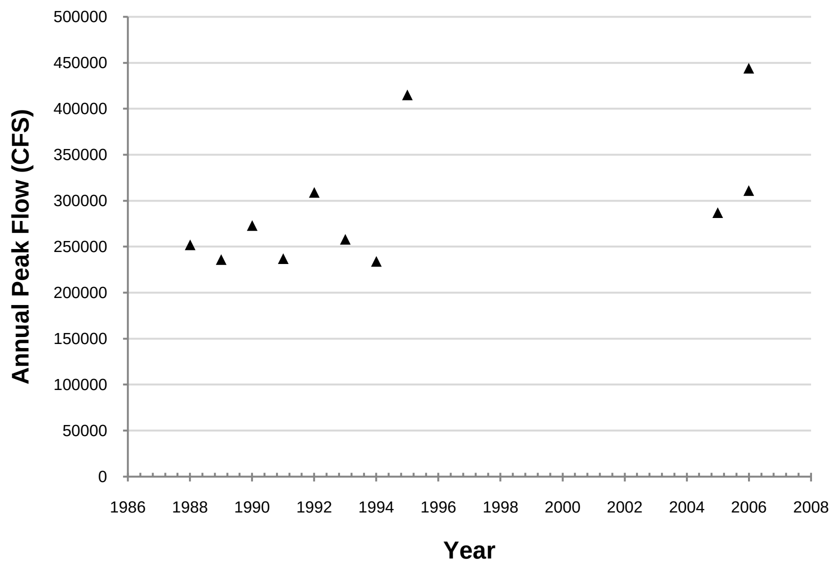


Figure 60. Annual peak flow data for USGS gauge site 1521400, Copper River at the Million Dollar Bridge near Cordova, AK, 1988-2006.

Stressors

Climate change and culverts are the two stressors to hydrology that WRST staff documented in the framework development of this NRCA. Climate change could affect the hydrology of WRST in many ways. Permafrost thawing can change the hydrology of stream systems by altering sediment, stream flow, and temperature regimes in adjacent streams (Oswood et al. 1992). Permafrost thawing can also alter lake levels, which, consequently, have been decreasing in WRST and in Southeastern Alaska due to the increased water holding capacity of thawed soils (Loso et al. 2007). Additionally, if glacial melting continues, altered peak stream flow levels and flood frequencies can be expected. Ice dammed water release, or glacial outbursts, are also a concern because of their potential to alter surface water flows in glaciated regions.

Culverts alter surface water flow in WRST, but to date no research has determined the magnitude of the effect on flow regimes in the park. Currently, 28 culverts have been identified along McCarthy Road and 33 along Nabesna Road (CRWP 2009) (Plate 45).

Data Needs

Data regarding flood frequency is not available. A wealth of TEK information about floods may be available, but it is unexplored to date. As previously stated, annual peak flow data are limited; only one USGS gauging site in the park has more than 15 years of data in addition to having data for since 2000.

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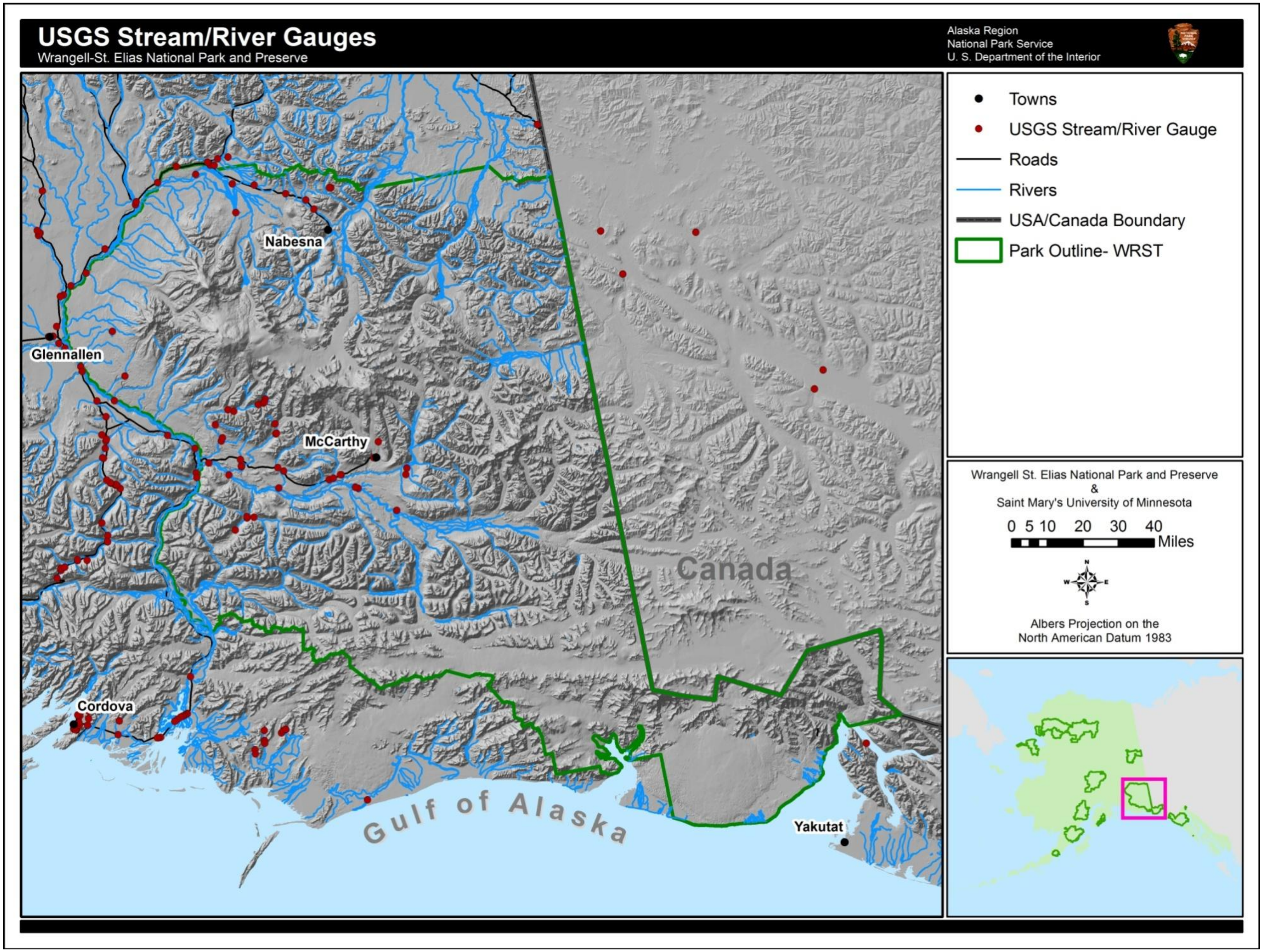


Plate 44. USGS stream and river gauge sites, WRST.

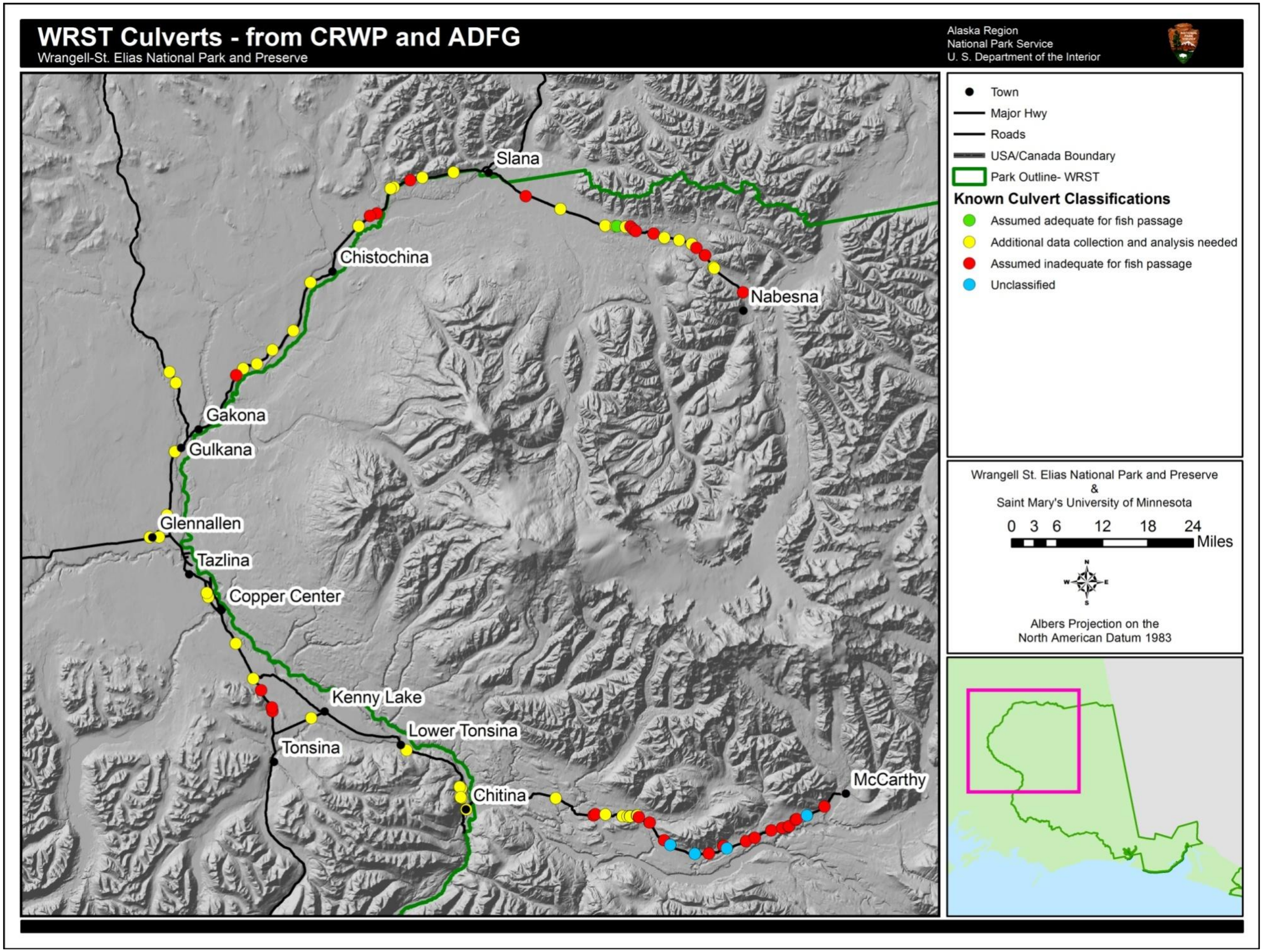
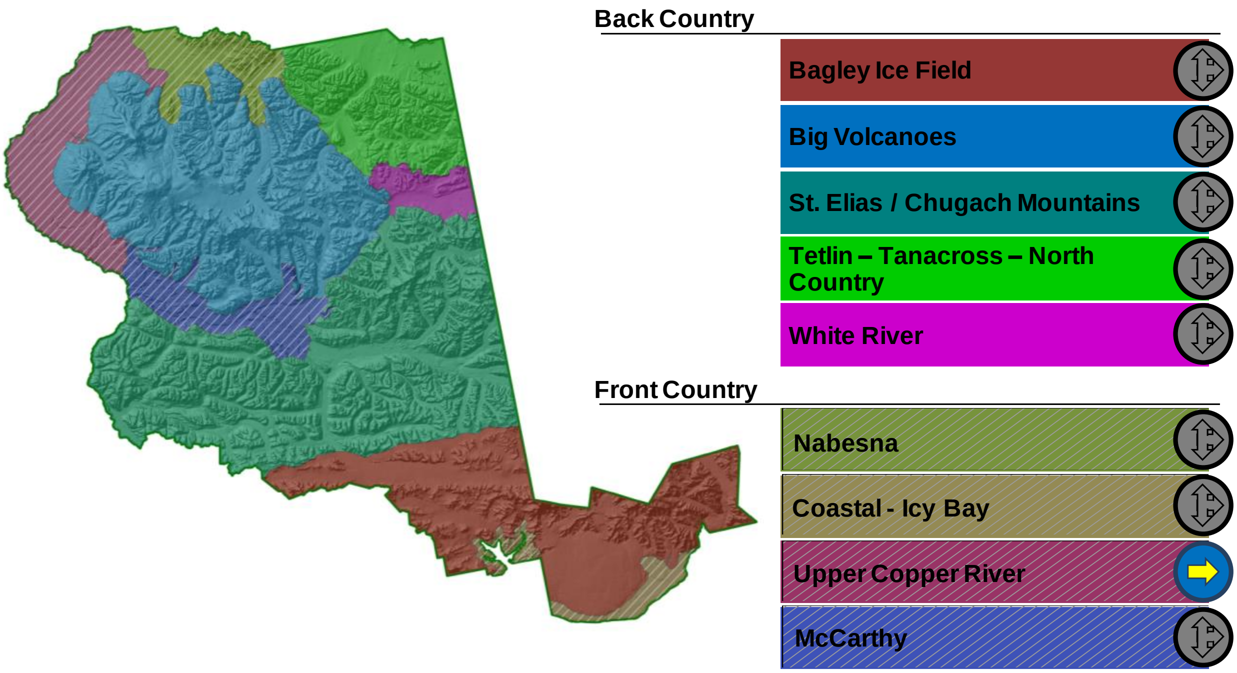


Plate 45. Known culvert locations in WRST along McCarthy Road, Nabesna Road, and the Alaska Highway. (NPS PDS 2009, CRWP 2009)

4.22 Subsurface and Geothermal

Indicators and Measures

Disturbance of and Intrusion in Active Geothermal Areas



Condition

Not enough information is available to present a comprehensive assesment of the geothermal resources of WRST. However, the mud volcanoes between Mount Drum and the Copper River have received research attention because of potential future geothermal development. Current conditions are indicated by studies examining temperature and chemical data of mud and gas releases by all three mud volcanoes in the area. No documentation of potential stressors such as trail development or visitation pressure is available. While historic OHV trails and seismic lines may provide some access to the areas adjacent to the mud volcanos, the majority of the land surface surrounding these geothermal features is under private ANCSA (Alaska Native Claims Settlement Act) Native ownership and information on visitation is unavailable. The mud volcanoes are not currently exploited as an energy resource and no evidence of visitation suggests a good condition with a stable trend in the Lower Copper RZs. Although geothermal resources exist throughout many of the RZs of WRST, no detailed information is available and, therefore, condition is unknown.

Background

The area within WRST referred to as the Wrangell volcanic field contains several warm springs and a summit crater with fumaroles. The most documented, are the warm springs in the western Wrangell Mountains, called mud volcanoes, because of interest in the potential development of geothermal energy. These mud volcanoes have built up mud mounds as high as 91 m (300 ft) and as wide as 2,438 m (8,000 ft.) in diameter. They continue to produce warm, carbon dioxide-enriched saline mud, possibly the result of degassing from a deep-seated magma body below (Winkler et al. 2000). These mud volcanoes are the subject of this assessment.

Motyka et al. (1983) mapped locations of hot springs, volcanic vents, thermal water areas, and areas of volcanic rock. Subsequently, these were converted into digital GIS layers by Alaska Department of Natural Resources, Division of Geological & Geophysical Surveys (DGGS) (Plate 46). The hot springs GIS layer shows known hot springs in which surface water temperature measured a minimum of 15°C during reconnaissance work. The volcanic vents layer shows the locations of 27 known volcanic vents in WRST; however, no additional information other than location is provided. Thermal water is considered to be ground water of sufficient temperature for direct heat applications. This polygon layer represents an area that is favorable for discovery of thermal water at shallow depth (less than 1000m). The area of thermal water in WRST is the third largest in the state of Alaska. Finally, the volcanic rock layer simply represents Quaternary or Quaternary-Tertiary volcanic rock areas.

According to DGGS, most geothermal areas in Alaska have been investigated closely with the exception of reconnaissance surveys conducted during the 1979 to 1982 period. There are six hot springs documented in WRST (Table 40).

Table 40. Hot springs in WRST. (Motyka et al. 1983)

Name	Surface Manifestation
Lower Klawasi mud volcano	warm springs
Upper Klawasi mud volcano	warm springs
Shrub mud volcano (not on map)	*not documented*
North Crater Mt. Wrangell	summit crater fumaroles
Copper Glacier	warm springs
>100*	*not documented*

*This hot spring was identified as ">100" in the 'NAME' attribute of the GIS data.

Information available on the six hot springs in WRST is primarily focused on the Klawasi Group, also referred to as the Drum group by Patrick et al. (2004). This group is composed of three large and active mud volcanoes (Shrub, Lower Klawasi, and Upper Klawasi) that are located approximately 27 km (17 mi) east of Glennallen near the west slope of the Pleistocene volcano, Mt. Drum (McGimsey & Wallace 1999, Plate 46). Although the Klawasi group is completely within the administrative boundaries of WRST, the majority of the land in this area is in private ownership primarily held by an ANCSA Native corporation. In addition, a small amount of nearby land is in Federal ownership outside of the Park Service (NPS PDS 2009a), (Plate 47). According to the Alaska Volcano Observatory, the Klawasi mud volcanoes are not seismically monitored, but the USGS and NPS are responsible for monitoring their general activity.

Reference condition
Reference condition for Geothermal Resources is the current state of geothermal resources. See below for discussion of the current information on active geothermal resources in WRST.

Specific Site Summaries

Shrub

Shrub mud volcano rises approximately 100 m (340 ft) above surrounding terrain and is composed of deposits derived from the underlying glaciolacustrine sediments of the Basin (Richter et al. 1998). Low-level mud and minor gas emissions have historically been almost constant at the other two mud volcanoes. However, Shrub was virtually inactive for decades with only minor discharge observed in the mid-1950s (Nichols and Yehle 1961). In 1955 and 1956, Nichols and Yehle (1961) reported that Shrub had small gassy pools in a basin 30 feet below the summit. The summit was described as dry in 1981 by Motyka et al. (1989), then, during the spring of 1997, Shrub began to vigorously erupt CO_2-rich gas and warm saline mud (McGimsey and Wallace 1999). Mud and gas eruptions ranged from bubbling mud to violent discharges of mud and gas, sending material up to 10 m above the vents (Richter et al. 1998).

The USGS and NPS monitored activity at Shrub and Upper Klawasi volcano in 1997 and 1998, and site investigations of the volcano indicated that it discharged warm mud, water, and CO_2 rich gas from 1996 to 2000 (Sorey et al. 2000). In addition, new features developed between 1998 and 1999, including a 54°C gassy hot spring on the north flank of the volcano and several small thermal and non-thermal features at the main vent area (Sorey et al. 2000). These features were named and water samples are reported at five locations in the vicinity of Shrub and one at the Upper Klawasi (Table 41) (Sorey et al. 2000). No measurements were taken at Lower Klawasi during site investigations. Although this represents the most recent field measurements of Shrub, Patrick (2004) determined that thermal bands on Landsat 7 ETM+ and new ASTER sensors could be used as a reliable thermal monitoring data set for warm mud volcanism. Patrick (2004) specifically estimated mud temperatures, active mud areas, and heat flux for Shrub and Upper and Lower Klawasi mud volcanoes, and suggest that regular acquisition and analysis of these data may be effective in detecting increased activity and mitigating potential hazards.

Continued monitoring may be important, as Richter et al. (1998) found that some lethal atmospheric concentrations of CO_2 caused vegetation damage and killed birds and snowshoe hares near the Shrub mud volcano in 1997. Richter et al. (1998) suggest that deaths are due to streams of CO_2 discharge and warn that they are very dangerous, even fatal to humans, because they can occur without warning and are invisible. There is a potential for sudden, large volume releases of CO_2 from vents at the summit on the northern side of Shrub mud volcano (Sorey et al. 2000). Since the closest towns, Glennallen and Copper Center, are approximately 15 km from the Drum mud volcanoes, activity poses no significant risk to population centers (Patrick et al. 2004).

Table 41. Chemical analyses for water samples collected in June 1999 and July 1973 at Shrub and Upper Klawasi mud volcanoes. Parameters corrected for field conditions, assuming pH values for CO[2] saturation at 0.9 atmoshperes (i.e. for an elevation of 3,000 feet above sea level). (Sorey et al 2000)

Site	T (°C)	pH	Alkalinity (mg/L)	CO_2 (mg/L)	DIC[1] (mg/L)
Shrub MVA[2]	48	7.2	7,440	818	1,690
Shrub FVA[3]	49	7.22	9,640	818	2,120
Shrub MGPA[4]	54	7.23	9,640	800	2,100
Shrub cold spring	6	6.82	7,720	2,490	2,200
Upper Klawasi	23	7	8,860	1,430	2,140
Shrub spring[5]	18	7.02	10,000	1,670	2,420

[1] Discharge of inorganic carbon
[2] Main Vent area
[3] Fissure Vent area
[4] Mud/Gas Pit area
[5] Sample collected from mineral spring near summit in July 1973 by Ivan Barnes (U.S. Geological Survey).

Upper and Lower Klawasi

The Upper and Lower Klawasi mud volcanoes are 90 m and 45 m in height above the surrounding land. They have diameters of approximately 1.7 km and 2.1 km, and contain summit craters with diameters of 45 and 53 m, respectively (Nichols & Yehle 1961). These mud volcanoes have been active for at least 40 years, periodically erupting mud, saline water, and CO_2 –rich gas. However, through comparison of aerial photos taken in 1938 to recent ground photos, the Lower Klawasi may be in an extended period of continuous activity dating back before the 1950s (Patrick et al. 2004).

Researchers have collected temperature, chemical, and discharge data on some the mud and gas discharges (Sorey et al. 2000). Temperature and discharge rates of Upper and Lower Klawasi mud volcanoes as presented by Patrick et al. (2004) and displayed in Table 42. Shrub mud volcano had the highest temperature recording (48-54 degrees C) of the three in the Klawasi group, similar to the bottom-hole temperatures of deep exploration wells near Glennallen (Motyka et al. 1989), whereas Upper and Lower Klawasi have produced historic surface fluid temperatures between 17-31 degrees (Table 42).

Stressors and threats

The WRST NPS resource staff created an initial list of possible stressors and potential threats to geothermal resources in the park. These include: trail development and visitation; non-federal land management or use; and development and exploitation of geothermal energy resources.

Trails identified in the area consist primarily of historic use OHV trails (NPS PDS 2009b). Seismic lines are also present in the area and are sometimes traveled by subsistence users (NPS, Eric Veach WRST Chief of Resources, pers. comm.). It is likely that the seismic lines could provide access to the mud volcanoes given that they overlap historic trails shown in blue (Plate 47). The historic use OHV trails appear to provide access to the Lower and Upper Klawasi mud volcanoes (Plate 47). No trail condition or development data are available.

Table 42. Field observations of Klawasi mud volcanoes. (Patrick et al. 2004)

Year	Temperature (°C)	Discharge rate (l/min)	Reference
Upper Klawasi			
1954	31		Nichols and Yehle (1961)
1960	31	8–19	Nichols and Yehle (1961)
1981	13		Motyka et al. (1986)
1982	17	110	Motyka et al. (1986)
1985	19		Motyka et al. (1986)
1998	29–31		Sorey et al. (2000)
1999	23–26		Sorey et al. (2000)
Lower Klawasi			
1956	28		Nichols and Yehle (1961)
1960	20–22	19–38	Nichols and Yehle (1961)
1981	20		Motyka et al., 1986
1982	20	110	Motyka et al. (1986)
1985	22		Motyka et al. (1986)

Specific information on land management and existing land use in areas surrounding the mud volcanoes is unavailable; however, a possible threat of disturbance exists due to the potential for geothermal energy development. Economides et al. (1982) suggested that the Copper Valley is an ―attractive candidate” for geothermal development, but sufficient reservoirs must be discovered. DGGS notes that more recent geochemical and isotopic investigations of the mud volcano fluids show that the reservoirs feeding the Klawasi mud volcanoes are likely of moderate temperature (100-200 degrees C) and the land ownership in this area is divided among the local Native Corporation, the state of Alaska, and the National Park Service.

Geothermal resources in Alaska are classified in terms of their potential energy production by the DGGS, using three classification categories based on surface water temperature. These classifications include: low (<90 degrees C); moderate (90 degrees C – 150 degrees C); and high (> 150 degrees C) (Rapp et al. n.d.). The high temperature category is usually applied to generation of electric power and the moderate to low categories are used for direct heat sources, such as central heating and ground-source heat pumps. However, some recent advances in technology may allow for electrical generation from the moderate temperature resources (Papp et al. n.d.).

―Wrangell-St. Elias National Park and Preserve may contain ‗blind‘ geothermal resources beneath the Wrangell volcanic field. The Copper River Basin, to the west of Mt. Wrangell, contains mud volcanoes that could be an indication of geothermal activity and are of interest due to their proximity to population centers. In an assessment of Alaska‘s geothermal resources carried out from 1979 to 1982, the AK Division of Geologic and Geophysical Surveys noted that the western Wrangell Mountains could be a promising region for finding and developing geothermal resources.” (Amanda Kolker). However, as stated earlier, ―no geothermal exploration or development is planned for this area at this time.” (Kolker pers. comm.)

Data needs

Visitation information, land use, and geothermal energy development information is needed to understand the condition and potential impacts or use of geothermal resources in WRST. More information about other WRST hot-springs, such as the Copper Glacier and the 27 volcanic vents indicated by Motyka et al. (1983), would help create a more complete understanding of these unique resources.

Quite often geothermal areas are sites of diverse vegetation and wildlife due to the proximity of higher temperatures that can promote species range extensions and create unique habitat conditions. The Copper River Vegetation Study (NPS PDS 2009c) is spatially coincident with Lower Klawasi mud volcano, but does not appear to represent a detailed vegetation inventory specific to the mud volcanoes area. Also, no information was available on fauna specific to these active geothermal features, other than the mention of dead birds and snowshoe hares and browned vegetation from carbon dioxide exposure around the Shrub mud volcano by Sorey et al. (2000).

Monitoring of mud volcano activity could be accomplished using remote sensing technologies.

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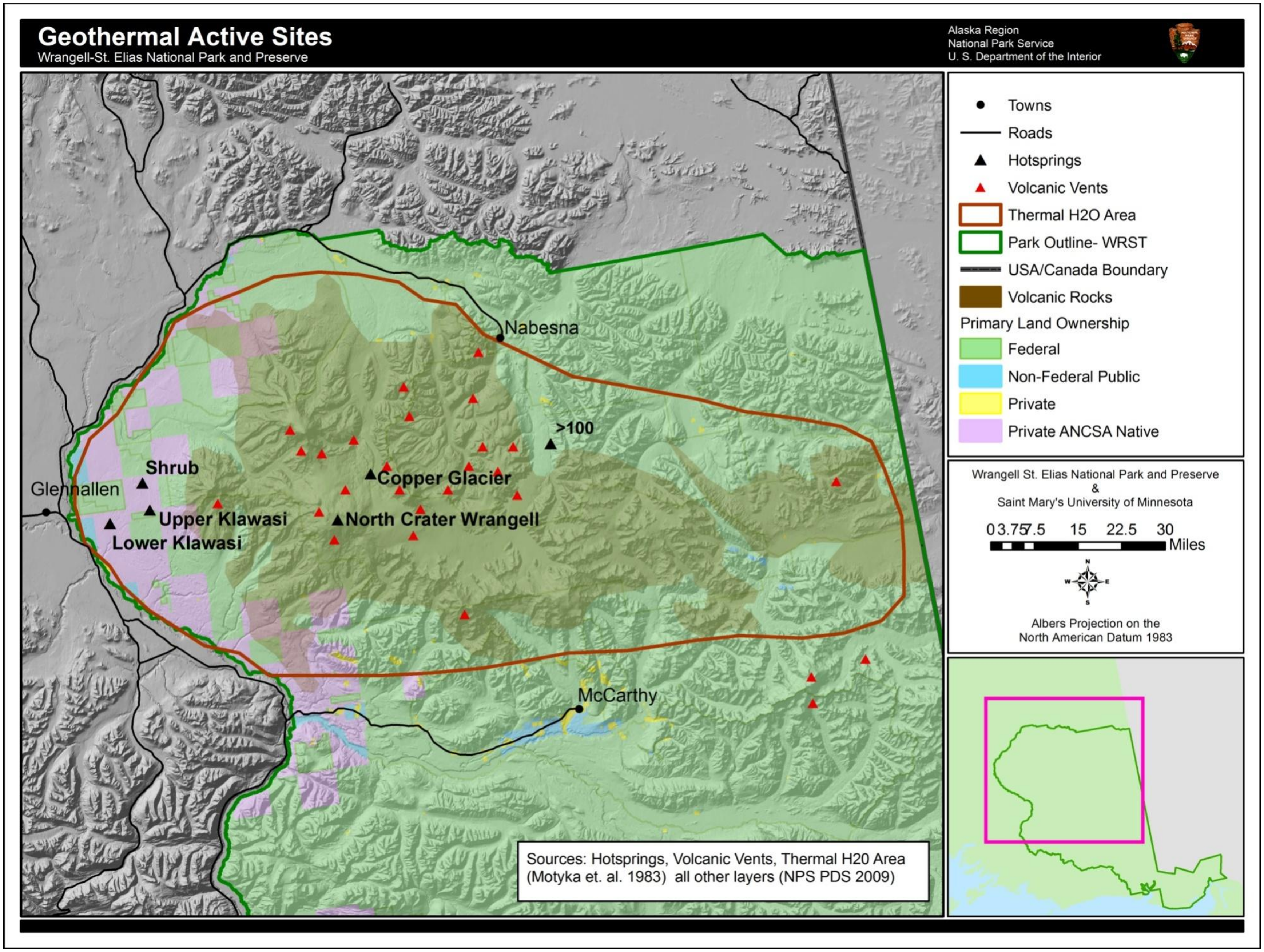


Plate 46. Geothermal active sites. (Mytoka et al. 1983)

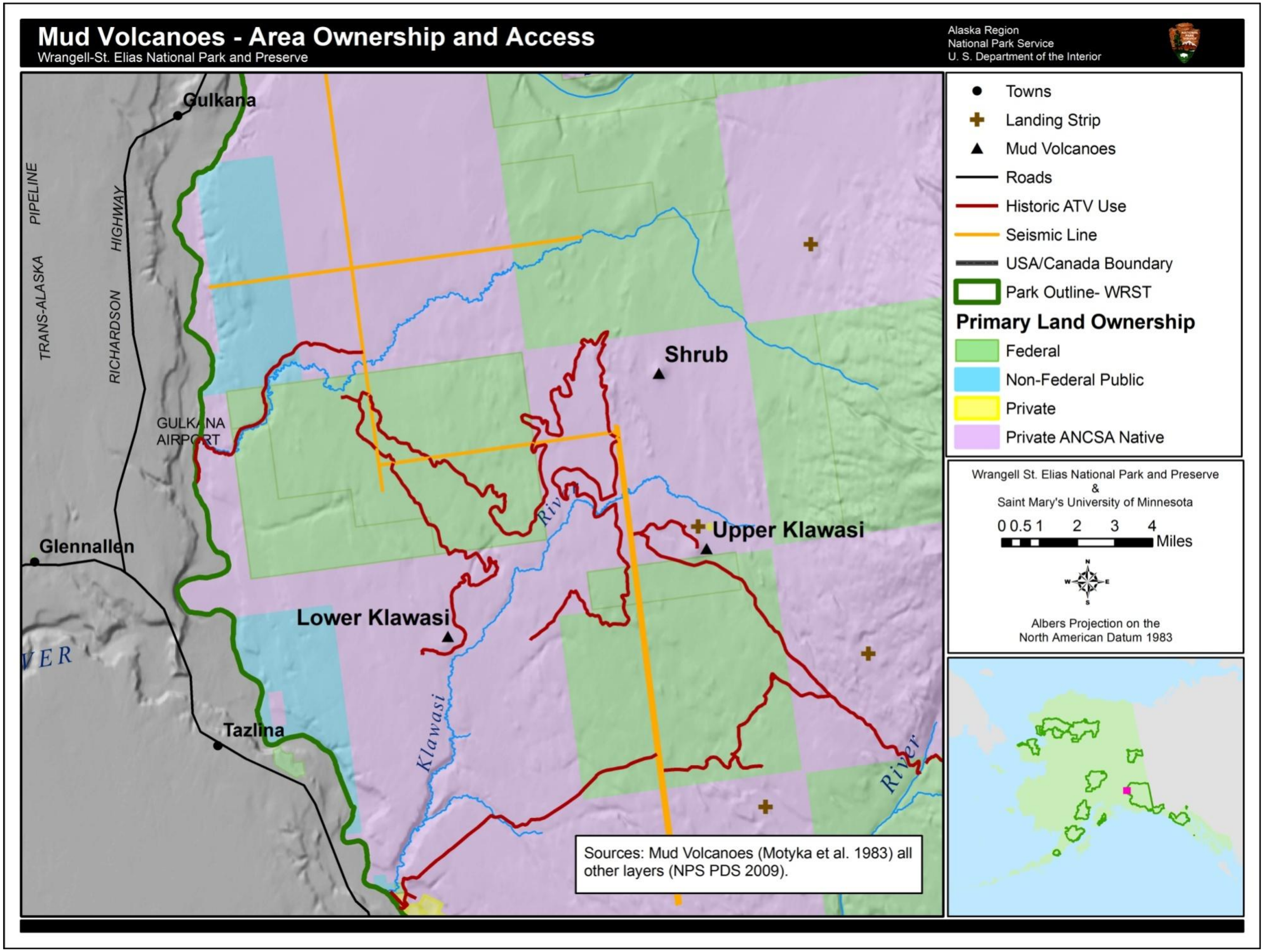
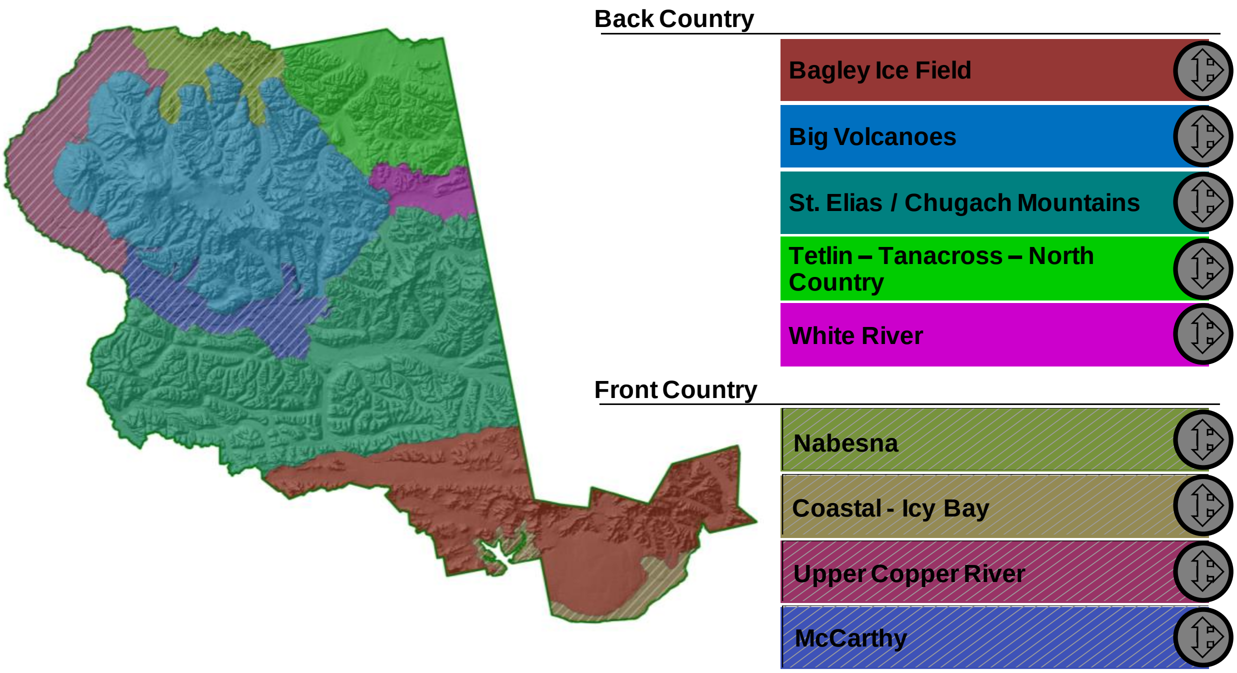


Plate 47. Mud volcanoes - area ownership and access. (Motyka et al. 1983)

4.23 Soils and Permafrost

Indicators and Measures

Number and Distribution of Thermokarst Features, Lake Level Changes



Condition

Data specific to the condition of permafrost within WRST is limited. The available spatial data are generalized and inadequate to determine the condition and accurate extent of this natural resource component. The condition of permafrost and associated thermokarst features is inferred from studies and observations completed in and outside the park boundaries. Permafrost warming and degradation has been observed in multiple sites in Alaska (Serreze et al. 2000, Jorgenson et al. 2001, Yoshikawa and Hinzman 2003, Osterkamp 2005, Romanovsky et al. 2010); however, studies in other areas of Alaska may not be appropriate for use in assessing the status of permafrost in WRST. There has been documented change in lake size and abundance in a portion of WRST, but the role of permafrost degradation in this change is unknown. It is possible that increased soil water holding capacity and opportunities for water drainage due to thawing permafrost contributed to this change.

Background

Permafrost is soil or rock that remains frozen (below 0°C) for two years or more (NPS 2006). It can occur within one to ten feet below the surface soil and be up to two hundred or more feet deep (NPS 2006). Permafrost affects the growth of forests in that the depth of the active zone, or the upper layer of soil that seasonally thaws, determines which trees and plants can survive and how well they can develop (Figure 61). Jorgenson and Osterkamp (2005) state that “Permafrost degradation associated with a warming climate is second only to wildfires as a major disturbance to boreal forests.” A shallow active layer underlain by permafrost contains soils saturated with water and low in nutrients. This typically results in slow growth rates and a stunted appearance for vegetation on these sites (NPS 2006). Permafrost is a “vital sign” for the Central Alaska Network Inventory and Monitoring Program (MacCluskie and Oakley 2005).

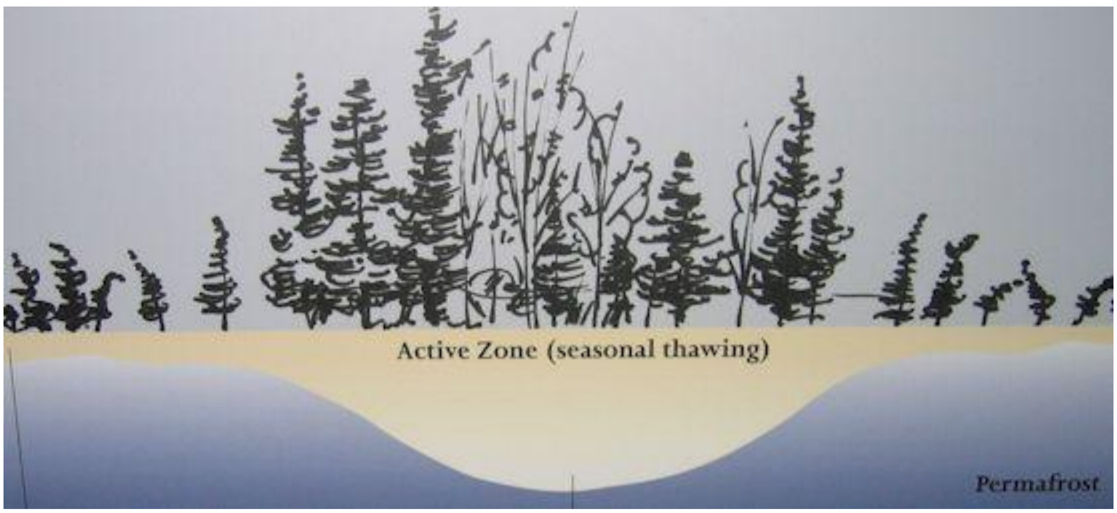


Figure 61. Forests become more developed where the active zone is deeper. (From NPS 2006)

<u>Thermokarst</u>

NPS program managers have chosen to monitor thermokarst features across the landscape (Karle and Jorgenson 2004) instead of employing site-specific methods such as borehole measurements or permafrost observatories to assess changes to permafrost. Thermokarst is surface subsidence resulting from thawing permafrost (Karle and Jorgenson 2004). Thermokarst features, including channels, pits, troughs, potholes, ponds, and drunken forests, can vary in size, location, hydrology, soil, ice content, and amount of thaw settlement (Appendix H, I) (Karle and Jorgenson 2004, Osterkamp 2005b). This subsidence can alter ecosystems, sometimes resulting in the conversion from one ecosystem to another (e.g. terrestrial system to an aquatic or wetland system) (Jorgenson et al. 2001, Karle and Jorgenson 2004). Thermokarst also has important implications for fluxes in energy, moisture, and gases across the ground surface-air interface (Osterkamp 2005b).

<u>Lake Levels</u>

Permafrost is an important driver of hydrology (Oelke et al. 2003). Distribution of permafrost affects the size, abundance, and distribution of aquatic resources in WRST, including shallow lake systems (MacCluskie and Oakley 2005). These aquatic resources support an abundance of wildlife, including waterfowl, shorebirds, and sources of food for subsistence users (Karl et al. 2009). Increased temperatures of ground and water bodies results in the growth of taliks, which are unfrozen areas of soil positioned between sections of frozen soil or between the permafrost and active layer (Riordan 2005). If a talik grows to the point where it penetrates through the permafrost or merges with neighboring taliks, paths are created for water drainage, and standing water maybe dispersed by sub-surface drainage (Yoshikawa and Hinzman 2003, Riordan 2005).

Reference Condition

The reference condition for permafrost in WRST is the extent of permafrost, thermokarst features, and shallow lake levels during the 1950s. This timing is consistent with the escalation of global climatic warming and should provide the opportunity to measure the impacts of changing climatic conditions on permafrost and related features. Historical aerial imagery from the mid 1950s exists for determining the reference condition. Riordan (2005) used this imagery to document change in lake size and abundance in a Copper River study area. The imagery was also used in a study by Karle and Jorgenson (2004) comparing permafrost mapping methodology in a 10 x 10 km area within the park. A park-wide effort to map permafrost, thermokarst features, and lakes using the 1950s imagery has not yet been conducted; therefore, the reference condition is unknown for nearly the entire park.

Number and Distribution of Thermokarst Features

Karle and Jorgenson (2004) conducted a study comparing permafrost mapping methodology using a sample site in each CAKN park. The 10 x 10 km WRST test site used in the study is located along the Chetaslina River within the Copper River Basin Ecoregion (center at approximately 61° 51‘ 00” N, 144° 40‘ 00” W) (Karle and Jorgenson 2004, Nowacki et al. 2001). On-screen delineation of thermokarst features was completed using 1957 black and white imagery (1:40,000 scale) and 1997 color infrared imagery (1:40,000 scale). The thermokarst features were then classified based on the degree of vegetation establishment. Point-sampling using 100 systematically distributed points was conducted these images to determine the abundance of thermokarst. Spectral classification (ERDAS 8.6) was also investigated using the 1997 CIR imagery and 2002 Landsat TM satellite imagery.

This study described significant differences in the ability of the techniques to detect thermokarst features (Table 43). In addition photo interpretation was complicated due to the presence of morainal kettle basins, which can appear similar to low-lying thermokarst features. This was resolved by using a stereoscope with paired aerial photography to identify morainal features associated with the kettle basins (Karle and Jorgenson 2004). A more detailed discussion comparing the various imagery sources and analytical techniques, as well as figures depicting the results can be found in Karle and Jorgenson (2004).

Table 43. Extent of permafrost degradation within the WRST test site by year and analytical technique. Degradation stages were classified as degradation-moraine (DM), degradation-active (DA), stabilization-initial (SI) and stabilization-advanced (SA). (Karle and Jorgenson 2004)

Year	Image Type	Analysis	Percent Area of Degradation Stage					Accuracy of Spectral Classification (%)
			DM	DA	SI	SA	Total	
1957	BW Photo	PI	1.5	0	2.0	0.7	4.2	-
1957	BW Photo	Point Sampling	1	0	0	1	2	-
1997	CIR Photo	PI	1.5	0	0.4	1.3	3.3	-
1997	CIR Photo	Point Sampling	1	0	0	1	2	-
1997	CIR Photo	Spectral	ND[a]	1.4	2.3[b]	0.4[b]	3.9	22
2002	Landsat	Spectral	ND	0.2	2.0	2.1	4.3	31

[a] Degradation of glacier ice in moraines lumped with SA.

[b] Denotes that the SI and SA categories overlap

Lake Level Change

Changes in lake size and extent have been documented in the park (McGuire et al. 2003, McGuire 2004, Riordan 2005). Riordan (2005) documented the drying of shallow lakes and overall reduction in water area in WRST. The size and number of lakes in the Copper River Basin were measured based on aerial and satellite imagery from approximately 1950 to 2000. The Copper River Basin study area experienced a 28% reduction in water area over this time period and a loss of 55 water bodies (101 to 46) (Riordan 2005). Reductions in water area and number of water bodies were found in other regions of Alaska as part of the same study (Riordan 2005, CAKN Inventory and Monitoring Program 2008). No analysis was completed correlating the change in lakes to permafrost degradation, but permafrost degradation was identified as a possible contributor. A shallow lakes monitoring effort in the Central Alaska Network began in 2006 (Larson 2006). Initial efforts were focused in Denali National Park and Preserve (Larson 2006), but monitoring began in WRST in the summer of 2009. Data from WRST have not yet been analyzed.

Additional Permafrost Monitoring

Permafrost Maps

There have been multiple efforts to map the extent of permafrost in Alaska. None of these efforts have been specific to WRST nor do they include extensive field verification. However, they do provide a general indication of the probable extent and distribution of permafrost. Table 44 displays area of permafrost by RZs in WRST.

Table 44. Square kilometers of permafrost types by reporting zone and for WRST. (USGS 1996)

	Bagley - Malaspina	Big Volcanoes	Coastal - Icy Bay	Upper Copper River	McCarthy	Nabesna	St. Elias/ Chugach Mountains	TTNC	White River	Entire Park
Lowland and Upland Area underlain by moderately thick to thin permafrost	0	11	0	1,855	691	328	8	210	0	3,104
Lowland and Upland Area underlain by numerous isolated masses of permafrost	0	74	0	548	635	381	484	370	223	2,715
Mountainous Area underlain by discontinuous permafrost	0	13,010	0	941	600	1,181	5,328	4328	806	26,195
Mountainous Area underlain by isolated masses of permafrost	6,988	0	139	0	263	0	10,565	0	0	17,955
UNKNOWN-Coastal	2,466	0	829	0	0	0	0	0	0	3,295

Circum-Arctic Map of Permafrost and Ground Ice Conditions
In an effort to create a unified international map of permafrost distribution and properties, the International Permafrost Association compiled the Circum-Arctic Map of Permafrost and Ground Ice Conditions (Heginbottom et al. 1993). Permafrost extent was classified into four categories based on the percent of ground underlain by permafrost: Continuous (90-100%), Discontinuous (50-90%), Sporadic (10-50%), and Isolated Patches (0-10%) (Heginbottom 1993). Land areas generally free of permafrost were also noted. Plate 48 depicts the extent of this spatial data set within the WRST park boundary.

Permafrost Characteristics of Alaska: In conjunction with the Ninth International Conference on Permafrost, a new map of permafrost in Alaska was published (Jorgenson et al. 2008). The map was developed using a rule-based model incorporating annual air temperatures and surficial geology. Borehole ground temperatures, estimated ground ice volumes in the upper 5 meters of permafrost, pingo distribution, and ice wedge distribution were also mapped (Jorgenson et al. 2008). The size of the map is not appropriate for inclusion in this report, but readers are encouraged to review it for the most current estimate of permafrost distribution in WRST.

Boreholes
Beginning in 1977, a series of permafrost observatories with boreholes were established along a north-south transect of Alaska (Osterkamp 2005). There is a site in Gulkana, near the south end of the transect, on the northwest border of WRST. Results from this site indicate the discontinuous permafrost found at this location has been warming slowly since monitoring began in 1983 (Figure 62) (Osterkamp 2005). This warming was attributed to relatively warm air temperatures and thicker-than-normal snow cover (Osterkamp 2005).

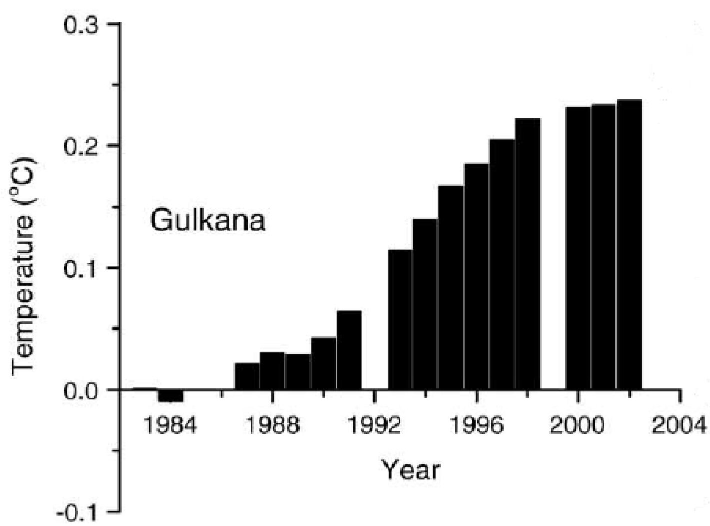


Figure 62. Temperature differences between annual measurements at the 20-m depth and that of 1985 for the Gulkana site. (From Osterkamp 2005)

Additionally, permafrost at the Gulkana site has been thawing from the bottom up at a rate of 4 cm per year from 1989-2002 and 9 cm per year from 2000-2002 (Osterkamp 2005, Figure 63). This rate is larger than theoretically expected (Osterkamp 2005). Possible reasons are larger-than-normal heat flow from the nearby Mt. Wrangell volcano, pores not saturated with ice, or pores containing significant amounts of unfrozen water (Osterkamp 2005).

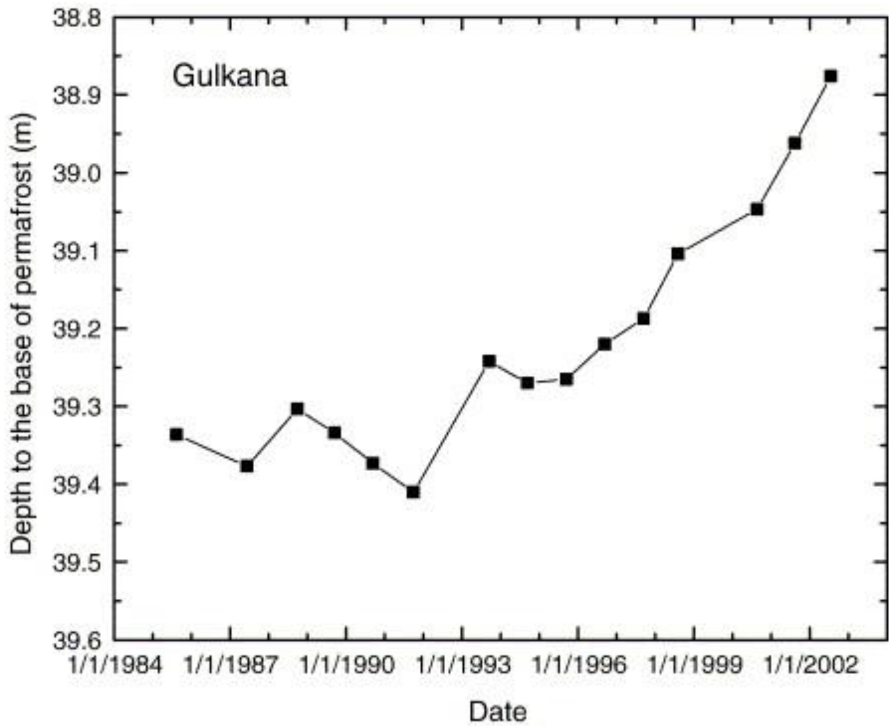


Figure 63. Depth to the bottom of permafrost (0° C), Gulkana, 1984-2002. (From Osterkamp 2005)

A permafrost observatory at the Gakona High Frequency Active Auroral Research Program (HAARP) site began in 2004 (Romanovsky et al. 2010). Permafrost in this area is considered widespread and extremely sensitive (Romanovsky et al. 2010). Boreholes were established in natural conditions and within a gravel pad that had experienced significant human disturbance. Investigations of horizontal and vertical permafrost distribution were also made using DC Resistivity. This investigation found stable permafrost in the forest with a lower boundary approximately 50-60 meters deep (Romanovsky et al. 2010).

The permafrost map by Jorgenson et al. (2008) indicates the existence of a borehole near McCarthy with a permafrost depth of 183 meters. Additional boreholes that are depicted on the map near the park range from 20 to 60 meters of permafrost depth.

<u>Frost Tubes</u>

Dr. Kenji Yoshikawa worked with several schools in Alaska to develop a coordinated permafrost monitoring program using frost tubes (Yoshikawa 2010). Frost tubes are used to measure the timing and depth of soil freezing. At least four of the participating schools are located within approximately 50 kilometers of WRST: Glennallen School, Kenny Lake School, Northway School, and Nelnah Bessie John School in Beaver Creek. The data are not analyzed in relation to WRST permafrost; however, these data could be a useful resource to better understand the nature and extent of permafrost near the park.

Soil Temperature
A percentage of the climate monitoring stations in WRST collect soil temperature data. Known locations include Chicken Creek, Gates Glacier, Tebay, and Tana Knob. 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 have not been analyzed at this time.

Stressors
Climate is the main driver of permafrost change. Air temperature, snow cover, and soil moisture all affect the temperature of permafrost (Osterkamp 2005). After a cooler period during the 3rd quarter of the 20th century, many weather stations in Alaska have reported an increase in air temperature of 1 to 2 degrees Celsius. This temperature increase and documented warming of permafrost in Alaska is cause for concern (Osterkamp 2005). In addition to increased air temperatures, fire can also affect permafrost dynamics (Jorgenson et al. 2001). Removal of the plant canopy and a substantial portion of organic matter by fire increases soil temperature (Jorgenson et al. 2001). Discontinuous permafrost, which is the main type found in WRST, is warm enough that a temperature increase of a few degrees could trigger substantial thawing (Osterkamp 2005). Some areas are within a degree of thawing (Osterkamp 2005b). The permafrost at the Gulkana borehole site is within 0.8 degrees Celsius of thawing (Osterkamp 2005b).

Off-highway vehicles (OHVs) are considered a customary and traditional means of transportation in WRST; however, research and monitoring has indicated their use can increase in the development of thermokarst features in permafrost soils (MacCluskie and Oakley 2005). When the surface vegetation and organic soil is compressed or disturbed by OHV traffic, the insulative properties of the materials are changed, which can lead to changes in permafrost thaw depth (Racine and Ahlstrand 1991). Racine and Ahlstrand (1991) investigated the impact of OHV traffic in a test site located along the northern edge of the park between Slana and Nabesna. One hundred and forty test lanes were established, each with an assigned vehicle, traffic intensity, and traffic timing. Various amounts of change in thaw depth were found depending on the traffic pattern and vehicle tested (Racine and Ahlstrand 1991, Figure 64).

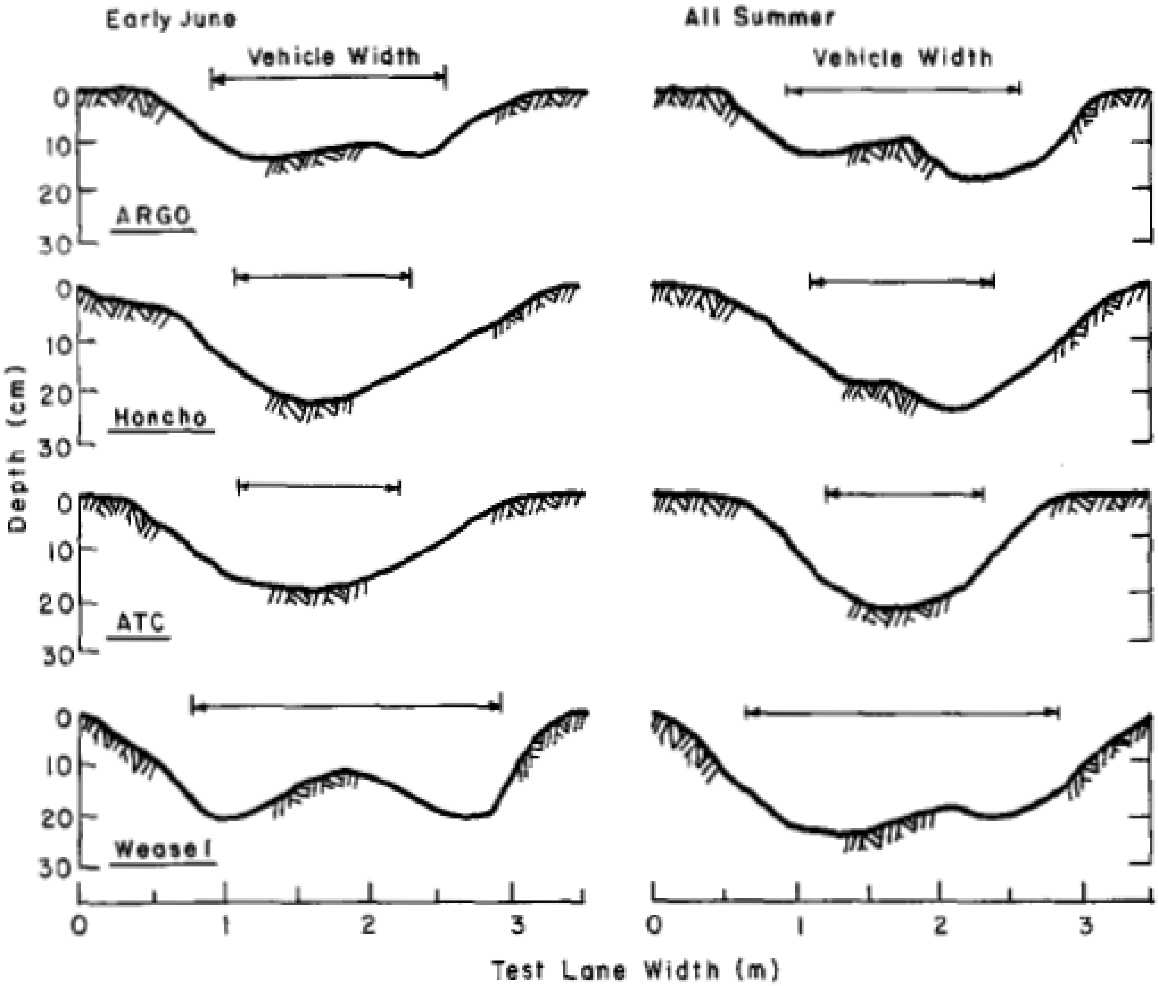


Figure 64. August 1987 frost table depression profiles beneath off-road vehicle test lanes obtained by probing from a reference line. All eight profiles represent 150-pass test lanes produced during: A) early June 1985 and B) 15 passes each week for ten weeks from early June to early September 1985. Vertical exaggeration is 5 times the horizontal. Figure from Racine and Ahlstrand (1991).

Reporting Zones

Extent of permafrost distribution is summarized by RZ in Table 44 above and depicted on Plate 48.

Data Needs

Data specific to the condition of permafrost within WRST is lacking. Following a review of existing permafrost monitoring projects and techniques, Karle and Jorgenson (2004) developed recommendations for monitoring permafrost in the Central Alaska Network. Karle and Jorgenson recommended a combination of (1) an initial assessment of the risks of permafrost degradation, (2) establishment of a field monitoring network in high risk areas, and (3) quantifying changes in regional extent and distribution of thermokarst using remote sensing. Detailed recommendations regarding experimental design and methodology to complete each of these three components are included in Karle and Jorgenson (2004). Further monitoring recommendations are included in Osterkamp (2005b). A coordinated monitoring of permafrost as part of the CAKN Inventory and

Monitoring Program will begin in 2011 (DENA, Guy Adema, physical scientist, phone conversation, 25 Feb 2010).

There are several studies that may contribute to the knowledge of permafrost in or near WRST. Osterkamp (2005b) recommended a thorough review of gray literature regarding permafrost, including USGS reports, state geological survey reports, Alaska Department of Transportation drilling logs, water well logs, drill logs from oil exploration, and information from the private sector. A significant landcover mapping project for WRST was completed in 2007, and the database developed for this project may contain useful data related to permafrost (Stumpf 2007). The usefulness of soil temperature data collected at climate monitoring stations and Yoshikawa‘s school frost tube data could also be explored to provide a broader picture of permafrost condition in and around the park.

In addition to an inventory of current thermokarst features and lake levels, a review of aerial imagery from the 1950s is needed to accurately determine reference condition for permafrost in WRST.

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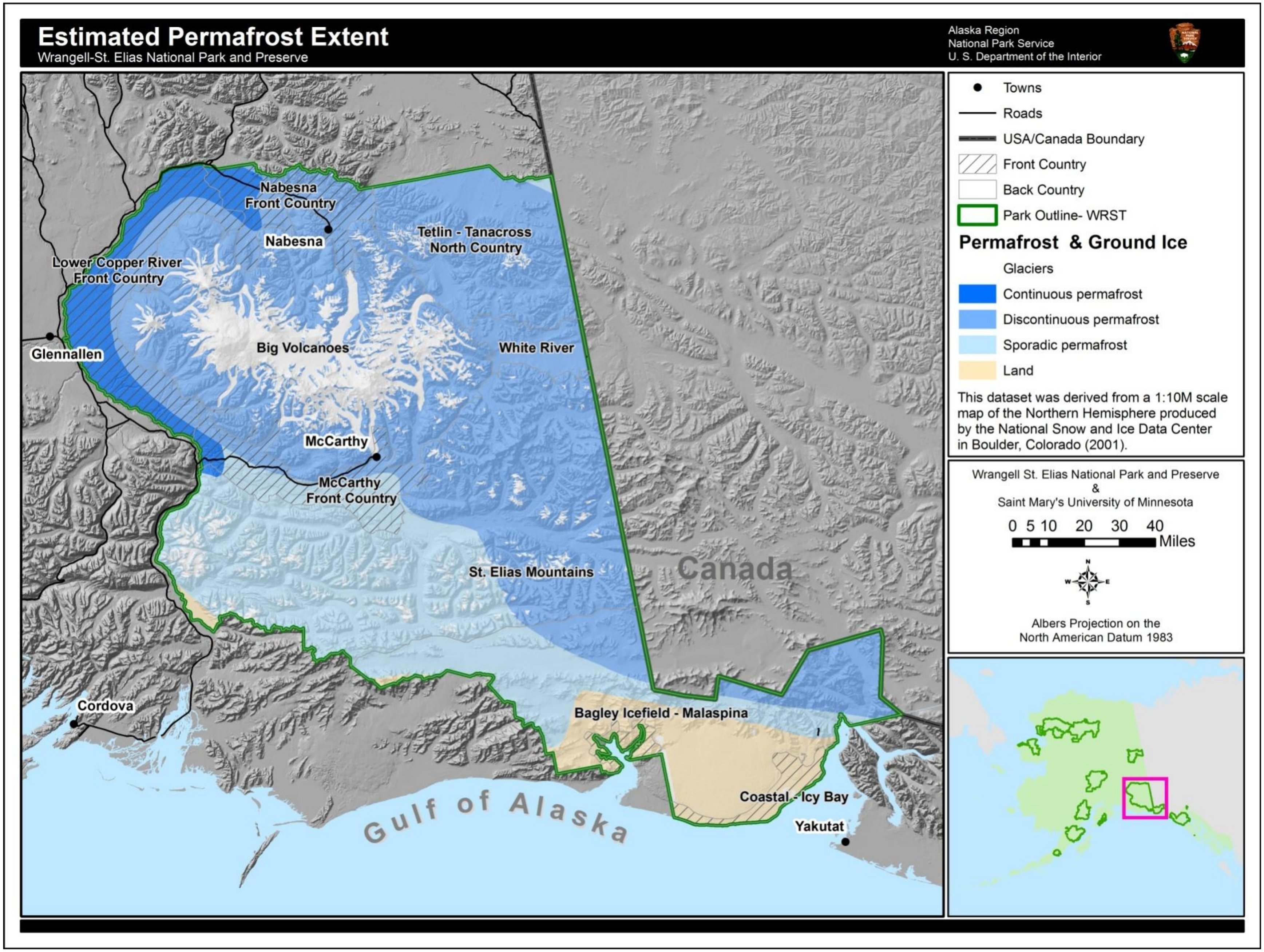
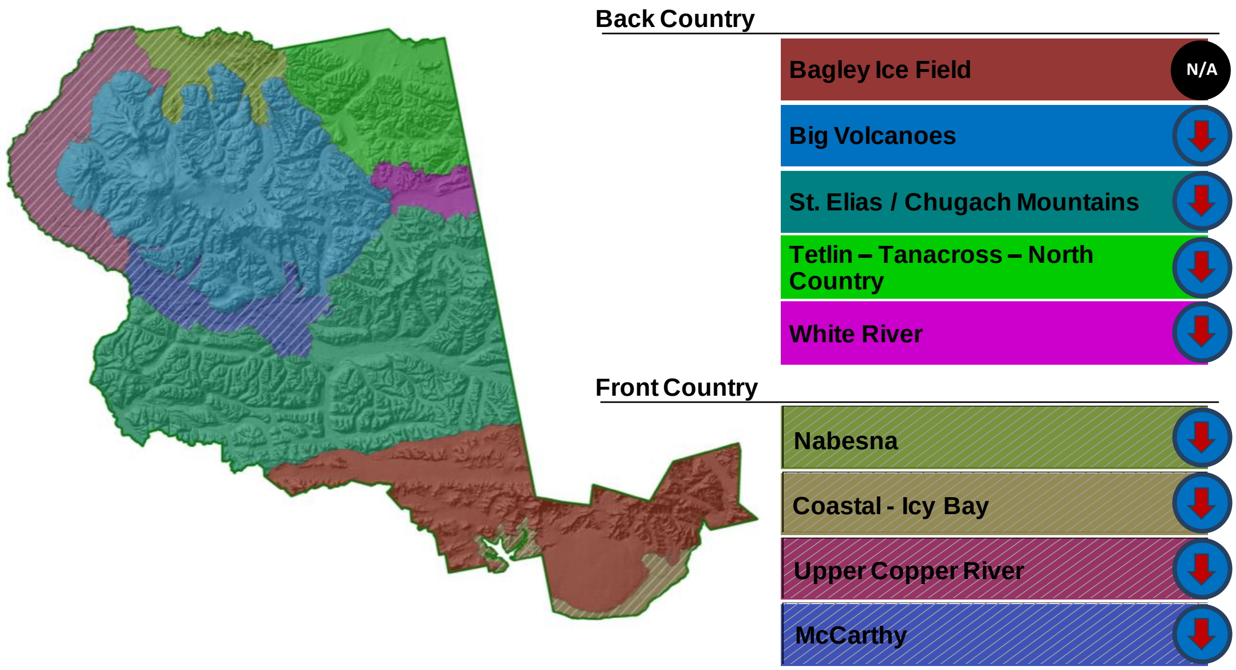


Plate 48. Estimate of permafrost extent. (Brown et al. 2001, NPS-PDS 2009)

4.24 Consumptive Use

Indicators and measures
Fish Harvest Distribution & Trends, Wildlife Harvest Distribution & Trends



Condition
The opportunity for the harvest of fish and wildlife in WRST is of cultural, social, and economic value to subsistence users. Harvest also represents a stressor to fish and wildlife populations, and management is required to sustain healthy populations in the Preserve and healthy and natural populations in the Park. The status of fish and wildlife harvest in WRST can be examined through a variety of information sources including ADFG salmon permit data and harvest reports, NPS federal salmon harvest permit data and reports, ADFG wildlife harvest and management reports, community household harvest surveys, and NPS-administered federal permit data. These data can help resource managers understand harvest levels, harvest locations or areas, and provide indications of levels of harvest pressure on given resources.

The primary resource harvested in the area surrounding WRST is salmon, with the vast majority of these being sockeye salmon (Weeks 2003, ADF&G 2009a). Although fewer are harvested, non-salmon fish are also important to subsistence users (Simeone and Kari 2005). Non-salmon fish harvest numbers and location information are limited, whereas salmon harvest information is available for many years in the Copper River. Most salmon harvest relevant to WRST, in terms of number of fish harvested, occurs outside the Park and Preserve boundaries in the Copper River and in two large tributaries of the Copper River, the Gulkana and Klutina Rivers (Sommerville 2008).However, many of these fish originate from within WRST, therefore overall harvest is of interest to resource managers (NPS, Barbara Cellarius Subsistence Specialist, pers. comm.). Since salmon are a shared resource, with several different groups harvesting fish in multiple areas, under various state and federal regulations, describing and understanding harvest as it relates specifically to WRST is complex.

Commercial harvest of sockeye salmon has increased in the Copper River District over the few decades and the escapement past Milles Lake Sonar at the mouth of the Copper River has also increased (Lewis et al. 2008). The composition of salmon harvest in the Copper River District under various regulations has changed over the last 30 years with the creation of personal use fishery harvest regulations and the more recent establishment federal subsistence fisheries.

Federal subsistence harvest accounts for a small proportion of harvest compared with commercial and state subsistence harvests. Generally, state regulated subsistence harvest of sockeye salmon has increased in the Glennallen Subdistrict from the late 1980s to the mid 2000s. Federal subsistence in the Glennallen Subdistrict has varied from 2002, the initial year that federal permits were issued, with a low of 8,000 fish, to a high of approximately 19,900 fish in 2006 (McCormick 2009). Personal use sockeye harvest has increased and federal subsistence harvest has varied with a peak in 2006, and lower harvests in 2007 and 2008, compared to the earlier part of the decade.

In the case of major wildlife species harvested, harvest levels have declined for three of the large mammals harvested in WRST. Caribou harvest has nearly completely ceased due to regulations imposed in response to significant caribou herd population declines. Dall‘s sheep harvest has significantly declined over the last decade (Moderow 2006b). However, there has been a similar decline in the number of hunters during this same time period, while Dall‘s sheep hunter success rates have remained relatively stable. One of the factors that may be playing affecting the decline in sheep harvest is changes in the harvest season and limits (i.e., the sex and horn configuration). Mountain goat harvest has also declined, from a high of 46 animals in 1986, to a low of nine animals in 2002 (Moderow 2006a).

Other important species have remained stable or been highly variable over the last three decades. Moose harvest estimates, the number of hunters, and hunter success rates have remained stable from 1983 to 2007 in WRST (Moderow 2006b). Brown bear harvest in WRST and has been variable from 1960 to 2005, averaging 27 bears harvested per year (Moderow 2006b). Black bear harvests were limited; an estimated total of 19 bears were harvested from 1975 to 1998 (Moderow 2006b). Long term furbearer harvest data are limited only to lynx (*Lynx Canadensis*) and otter (*Lontran candadensis*). From 1984-2003, harvest of both lynx and otter varied greatly; in some years has many as 259 lynx were harvested, while in other years as few as 12 were harvested. A range of one to 16 otter were harvested annually over the same period of record.

It is clear that opportunities to harvest fish and wildlife continue in WRST, but the primary concerns regarding these opportunities include recent declines in harvest of Dall‘s sheep and mountain goat, and some increases in overall numbers of fish harvested and the number of individuals harvesting salmon in the Copper River watershed. Specific assessment of harvest opportunities that improve and update the understanding of household subsistence and of community use may require a regular cycle of community harvest surveys. Information not currently gathered (i.e., estimates of catch or harvest per unit effort) may provide further detail for subsistence harvest opportunities. Given the large and diverse areas represented by each of the reporting zones, and that multiple species of fish and wildlife resources are important to WRST, expressing the overall observations of harvest as a condition with an associated graphic is problematic. However, the condition of fish and wildlife harvest remains good with harvest for nearly all major species continuing. Concerns about the harvest pressure on sockeye salmon, and the declines in harvest of Dall's sheep and mountain goat, led to the assignment of a declining trend in condition (down arrow) for all RZs in which harvest of these species may take place. All reporting zones, except the Bagley Ice Field RZ, may be affected by some declines in harvest. The Bagley-Ice Field RZ, however, is dominated by year-round snow and ice and therefore harvest is not likely to occur here, earning it a not-applicable designation.

Introduction

Harvested resources in WRST include various species of salmon, fresh water fish, moose (*Alces alces*), caribou (*Rangifer tarandus*), Dall's sheep (*Ovis dalli dalli*), mountain goat (*Oreamnos americanus*), black and grizzly bears, migratory birds, ptarmigan, grouse (*Lagopus lagopus*), snowshoe hare (*Lepus americanus*), furbearing animals, berries, mushrooms, and dead and green logs for construction and firewood (NPS 2007). The 1987 Upper Copper/Tanana household survey (ADGF 2009a) is the most representative survey in terms of number of communities represented that have access to harvest resources within the boundaries of WRST. Using the number of pounds harvested, fish were the most harvested resource in a survey for communities in the area of WRST (Copper Basin/Upper Tanana Survey), followed closely by large land mammals, and then by small land mammals, vegetation, berries, upland game birds, and migratory birds (ADF&G 2009a) (Figure 65). Similarly, using total pounds harvested by resource, Wolf (2004) found that sockeye salmon, moose, and caribou were the top three consumptive use species, respectively, for Gulkana, Alaska (a community within a few miles of boundary of WRST).

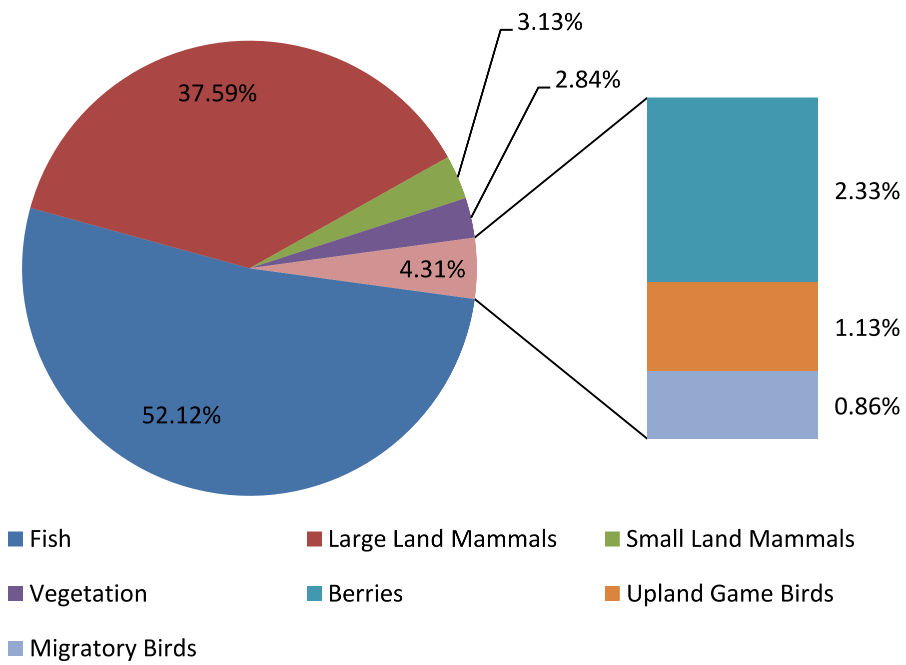


Figure 65. Percent of estimated pounds harvested in each resource category for the communities of Chisana, Chistochina, Chitina, Copper Center, Dot Lake, Gakona, Glennallen, Gulkana, Kenny Lake, McCarthy Road, Mentasta, Northway, Slana, Tanacross, Tazlina, Tetlin, Tok, and Tonsina in the 1987 Copper Basin/Upper Tanana survey (ADF&G 2009a).

The most significant consumptive use concerns in WRST relate to the management of harvested fish and wildlife, salmon and large mammals in particular (MacCluskie and Oakley 2005). In order to manage this harvest, NPS needs to understand all consumptive use of park resources, including harvest of fish and wildlife under both state subsistence and sport regulations (NPS, Barbara Cellarius, Subsistence Specialist, pers. comm.). Given management concerns, the focus of this assessment is on fish and wildlife harvest, examining federally regulated subsistence harvest and state regulated sport, subsistence, and personal use harvest. The consumptive use of fiber, including harvest of dead or downed trees, standing live timber less than 3 inches in diameter, and the non-commercial harvest of live standing timber is also of management interest, however this was not specifically examined in this document because of limited quantifiable data (Cellarius pers. comm.). That is, the consumptive use of fiber is generally a data gap for this assessment. The only source of information that mentions fiber harvest is community harvest survey data. Surveys primarily report two categories, the number of pounds of berries and the number of pounds of general vegetation by household.

Data used for the assessment of fish and wildlife harvest come from multiple sources: ADF&G harvest reports, ADF&G Division of Subsistence community surveys, federal harvest numbers from NPS, and various other studies. While available data applied well to the full-park or GMU level, it often did not represent the most current picture of harvest at the community level, as only a few recent community surveys have been conducted. In addition, harvest records of large land mammals are often indistinguishable between what occurs within the boundaries of WRST and what occurs outside the boundaries of WRST, due to geographic harvest reporting units, Uniform Coding Units (UCUs), not coinciding with park and preserve boundaries.

The harvest of large land mammals such as moose, caribou, Dall‘s sheep, mountain goat, and brown bear are reported almost exclusively through ADF&G harvest tickets and are subsequently entered into the ADF&G harvest database. However, hunting permits are used to capture harvest of moose and mountain goats under federal subsistence regulations and are also entered into the ADF&G harvest database. There are also questions about the accuracy of reported harvest in the ADF&G harvest database. Moderow (2006a) found cases of under-reported harvest when comparing a 1987 household survey with the ADF&G harvest database. In the case of brown bear, Wilder (2003) stated that actual take could be double that wich was reported, primarily due to unreported defense of life and property kills.

In the case of fish, data are available for the harvest of salmon under all broad regulatory categories: subsistence, commercial, sport, and personal use. However, resident fish harvest data are limited.

Management

Regulation of harvest in WRST and the adjacent area is complicated, and consumptive use management requires that traditional uses are coupled with resource preservation and traditional National Park values, which includes recognizing humans as a part of nature instead of apart from nature (Arnberger 2003). There are two general classifications of consumptive use harvest in WRST: subsistence and sport. Subsistence harvest can be broken down into the two general categories of federal and state subsistence.

Federal subsistence harvest plays an important role in the lives of native and non-native residents in and adjacent to WRST (Snitzler & Cellarius 2007). The Federal Subsistence Board (FSB), comprised of six members representing NPS, USFWS, BLM, Bureau of Indian Affairs, and the USFS, sets regulations and seasons for species harvested under federal subsistence. In WRST, NPS enforces federal subsistence regulations for all species. Migratory birds and marine mammal regulations are under USFWS jurisdiction and enforcement, but are also enforced by NPS law enforcement. ANILCA mandates that NPS manages WRST to "protect the resources related to subsistence needs," and to ―preserve wilderness resource values and related recreational opportunities including but not limited to" sport hunting and fishing" (ANILCA sections 101 a, b, c). ANILCA states that subsistence uses of fish and wildlife by rural residents of Alaska have priority over sport, commercial, and personal use. NPS is dedicated to providing continued opportunities for rural residents to harvest fish, wildlife, and plant resources under subsistence on federal land and water established by ANILCA. ANILCA directs NPS to maintain populations of and habitat for fish and wildlife, to maintain healthy populations on preserve lands, and natural and healthy populations on park land. NPS allows sport hunting and fishing on preserve land and only sport fishing on park land within WRST. Figure 66 shows the different designations of land in WRST.

State subsistence regulations in Alaska are set by the Alaska Board of Fisheries and the Alaska Board of Game, with the assistance of the ADF&G Division of Subsistence, Division of Commercial Fisheries, and the Division of Wildlife Conservation. The federal subsistence priority is for rural residents, whereas the state's subsistence priority is for all state residents, both rural and non-rural. Similar to federal mandates described by ANILCA, the Alaska State Constitution gives subsistence use of fish and game by Alaska residents priority over other uses.

Established state subsistence is secondary to federal subsistence in most cases within the WRST boundary. Exceptions include Native corporation conveyed lands, small private inholdings, University of Alaska lands, and State of Alaska lands within the park boundary. Federal subsistence users also have harvest priority in navigable waters adjacent to WRST. However, state subsistence salmon harvest occurs in the Copper River, which is adjacent to WRST. The superintendent of WRST is responsible for managing the salmon fishery on the Copper River.

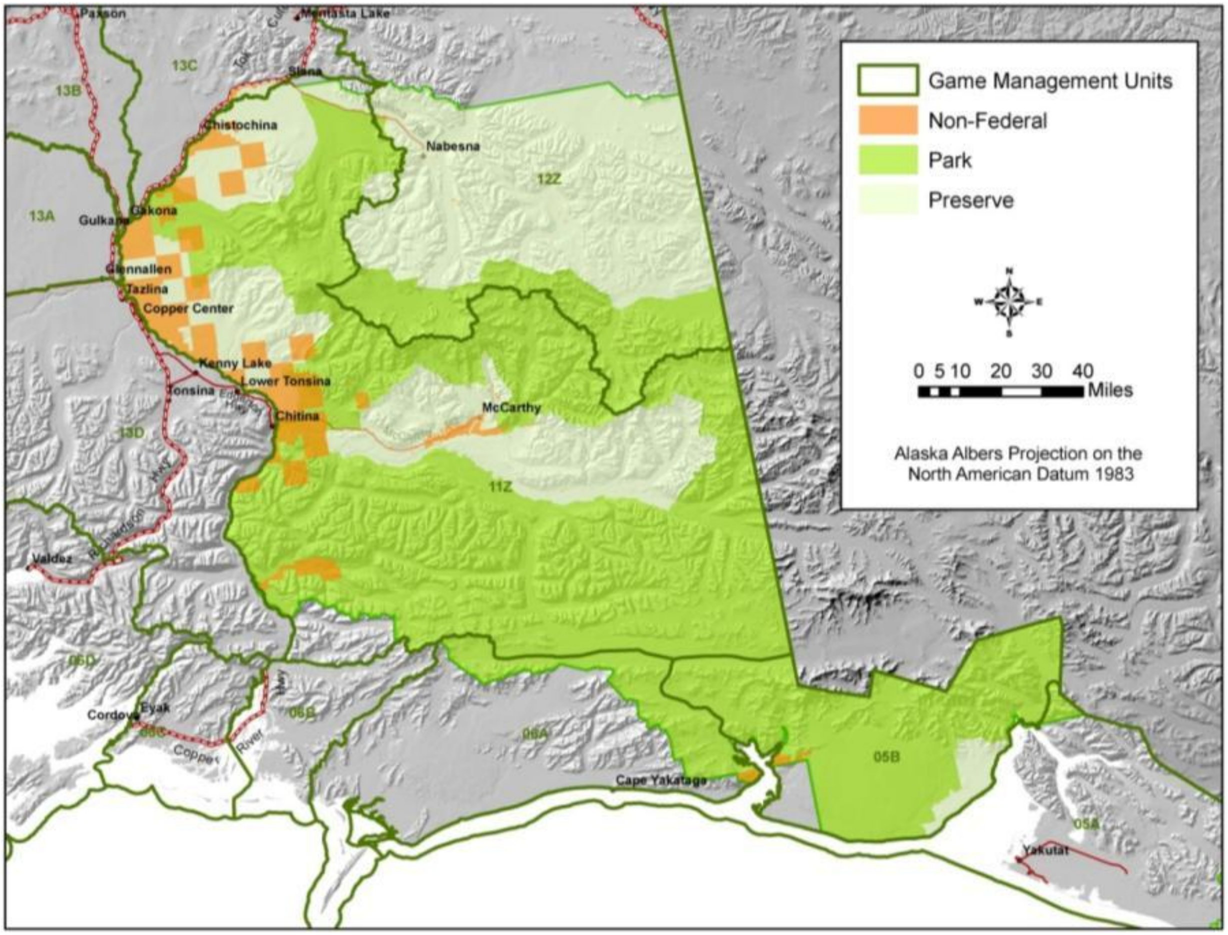


Figure 66. Regulatory boundaries in WRST. Note: This map is intended to provide an overview of the main regulatory boundaries in WRST, not to provide the sufficient detail to specifically locate lands, non-federal lands, or access easements.

Fish

Important fish species harvested

Although salmon harvest by subsistence and personal use fishers is far greater than non-salmon fish, both salmon and non-salmon fish are important to subsistence users and sport fishers in the Copper River Basin and in WRST. The Copper River drainage is the focal point of the WRST fishery, with spawning habitat for over 124 stocks of sockeye salmon (*Oncorhynchus nerka*) (Weeks 2003). Large numbers of adult salmon are harvested in commercial drift gillnet operations near the mouth of the Copper River yearly from mid-May to September (Weeks 2003). Salmon that escape into the river system contribute to subsistence, personal use, and sport fishing throughout the summer months (Weeks 2003).

Species of fish subject to subsistence harvest include sockeye salmon (*Oncorhynchus nerka*) Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus tshawytscha*), steelhead (*Oncorhynchus mykiss*), Arctic grayling (*Thymallus arcticus*), various whitefish species (*Coregonus* and *Prosopium* spp.), burbot (*Lota lota*), lake trout (*Salvelinus namaycush*), Dolly Varden (*Salvelinus malma Walbaum),* rainbow trout (*Oncorhynchus mykiss*), Pacific lamprey eel (*Entosphenus tridentatus*), and northern pike (*Esox lucius*) (in the Yukon (NE portion of park) drainage) (Simone and Kari 2002, Simeone and Kari 2005). The chief fish species harvested by subsistence users in WRST are salmon, burbot, lake trout, and Arctic grayling (NPS 2009a). Sockeye salmon account for the vast majority of fish harvested by subsistence users and sport fishers. Arctic grayling are the most harvested species in Upper Copper/Upper Susitna Management sport fishing area, which covers much of WRST, followed by Chinook salmon, rainbow trout, lake trout, burbot, Dolly Varden, whitefish species, coho salmon, landlocked sockeye salmon or kokanee, and anadromous rainbow trout or steelhead (Sommerville 2008). The previously mentioned fish species are those that are harvested upriver, however, species such as cutthroat trout (*Oncorhynchus clarkii*), eulachon (*Thaleichthys pacificus*) and other smelt, chum, and pink salmon are harvested along the coast of WRST.

Salmon management

Salmon in WRST are managed according to the sustainable salmon fisheries policy which states that ―salmon fisheries shall be managed to allow salmon escapements necessary to conserve and sustain potential salmon production and maintain normal ecosystem functioning" (NPS 2009b). Park fisheries biologists work with ADF&G, other federal agencies, tribal governments, and private non-profit organizations to manage harvest in the Copper River (NPS 2009b). The superintendent of WRST is the federal fisheries manager for the entire Copper River, having the authority to suspend harvest when necessary to ensure enough salmon survive to spawn and to meet subsistence user‗s needs (NPS 2009b). Though authority rests with the superintendent of WRST, the Federal Subsistence Board manages federal subsistence salmon harvest regulations.

State management objectives differ from NPS management objectives. The state of Alaska manages salmon for sustained yield, and according to the CAKN Vital Signs Monitoring Plan, ―This paradigm [sustained yield management] directly contradicts NPS policy to preserve fundamental biological and physical processes, as well as individual species, features, and plant and animal communities" (MacCluskie and Oakley 2005).

There are also several different specific management plans directing salmon management in and around WRST. These plans allocate fishery resources amongst users and guide managers in and adjacent to the park to maintain a sustained yield of fish stocks (Weeks 2003). These plans include the following (Weeks 2003):

> *50 Code of Federal Regulations (CFR) Part 100 Subsistence Management Regulations for Public Lands in Alaska, Subpart C and Subpart D* – Federal regulations governing subsistence harvest of fish throughout the park/preserve as well as the Copper River.
>
> *5 Alaska Administrative Code (AAC) 01.647 Copper River Subsistence Salmon Fisheries Management Plan* –This plan ensures that adequate escapement of salmon in the Copper River system occurs and that subsistence uses are accommodated. This plan pertains only to those salmon that pass ADF&G‗s sonar located at Miles Lake.
>
> *5AAC 24.360 Copper River District Salmon Management Plan* – Under this plan ADF&G currently manages the commercial fishery that establishes a sustainable escapement goal of 300,000 to 500,000 wild sockeye salmon beyond the Miles Lake sonar site and an in-river allocation of 15,000 salmon (all species) for sport fisher harvest, 61,000 to 82,500 sockeye salmon (wild stocks only) for subsistence harvest, 100,000-

150,000 (including hatchery stocks) for personal use harvest, 300,000 sockeye salmon for spawning escapement, and an amount determined annually for hatchery brood and surplus stocks (Somerville, 2008).

5AAC 77.590 Copper River Personal Use Dip Net Salmon Fishery Management Plan – This plan addresses the Chitina dip net fishery and requires a personal use permit for participation.

5AAC 75.013 Cook Inlet and Copper River Basin Rainbow/Steelhead Trout Management Plan – This plan was adopted to provide future Boards, fisheries managers, and the sport fishing public with:

- Management policies and implementation directives for area rainbow and steelhead trout fisheries
- A systematic approach to developing sport fishing regulations that includes a process for rational selection of water for special management; and
- Recommended research objectives

<u>Salmon harvest regulations</u>
Both sport and subsistence salmon harvest is permitted in the park and preserve. However, subsistence harvest requires federal or state permits in the Upper Copper River District depending on eligibility requirements. The Upper Copper River District contains two subsistence fishery subdistricts, the Glennallen and Chitina (Figure 67). Subsistence harvest of salmon under federal regulations in these subdistricts requires users to meet federal subsistence eligibility requirements and to obtain a federal permit. A small federal subsistence fishery also exists within the boundaries of the Glennallen Subdistrict near the confluence of the Copper and Slana Rivers called Batzulnetas. Subsistence under state regulations requires users to obtain a state subsistence permit in the Glennallen Subdistrict. The Chitina Subdistrict is a personal use fishery, which is different than a subsistence fishery but also requires a permit. It is important to note that a small portion of the Upper Copper River District is actually within the boundaries of WRST, and most of the salmon harvest takes place outside of WRST (Cellarius pers. comm.).

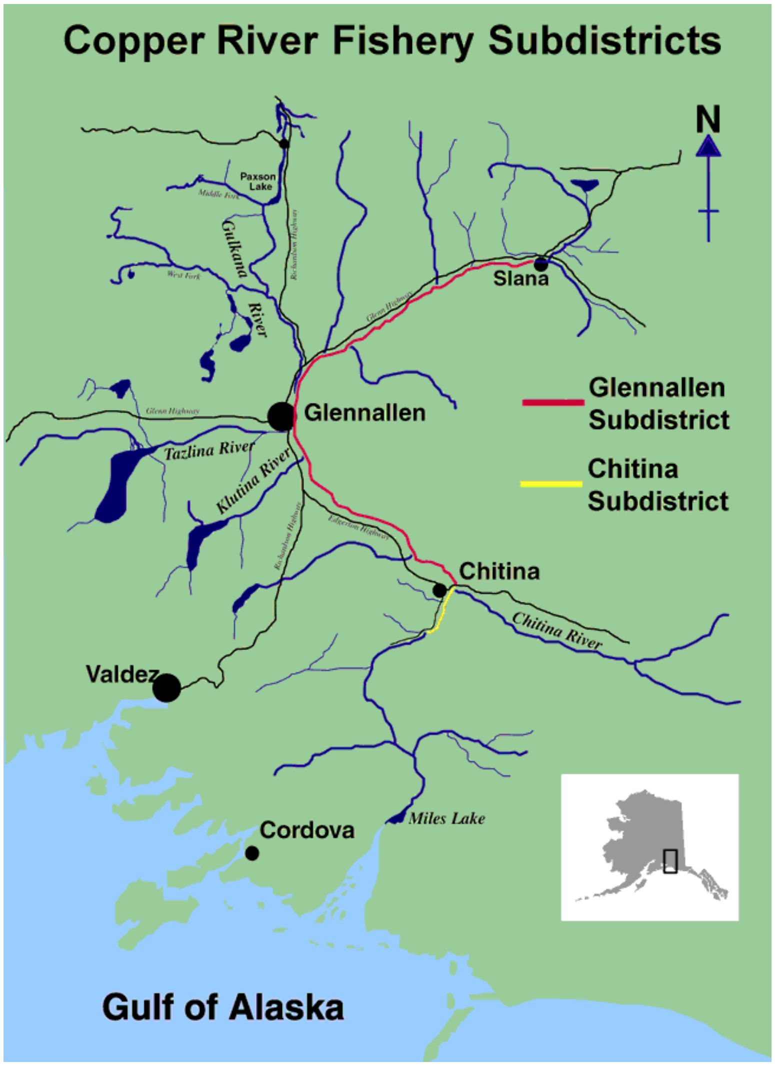


Figure 67. Personal use and subsistence fishery subdistricts in the Upper Copper River District. (ADF&G 2009b)

To harvest salmon from the Upper Copper River under federal subsistence regulations, you must be a rural Alaska resident and live in a community or area that has a positive customary and traditional use determination for the subdistrict in which you wish to fish. To harvest in the Chitina and Glennallen Subdistricts under federal permits, users must use fishwheels, dipnets or rod and reel. A household of two or more may request up to 500 salmon per year. To engage in federal subsistence harvest of salmon in the Batzulnetas fishery, users must use fishwheels, dipnets, spears, or rod and reels. The Batzulnetas fishery has no harvest limit for salmon.

A personal use fishery is similar to the state subsistence fishery in that they both use more efficient gear than rod and reel, but personal use fisheries do not meet the criteria established for customary and traditional fisheries. ADF&G define personal use fishing as, the taking, fishing, or possession of finfish, shellfish, or other fishery resource, by Alaska residents for personal use and for sale or barter, with gill or dip net, seine, fish wheel, long line, or other means defined by the Board of Fisheries (Alaska Statutes 16.05.940[24]). In the Chitina Subdistrict Personal Use Fishery the only legal gear for Chinook, sockeye, and coho salmon are dip nets.

Salmon harvest reference condition
Reference condition is defined as –natural and healthy population from historic record and traditional ecological knowledge."

Defining a specific reference condition for the harvest of salmon in WRST is difficult for several reasons. First, historic records of harvest coming from Traditional Ecological Knowledge (TEK) are often in the form of narratives and do not provide data for comparison to current numbers (Simeone and Kari 2002). Secondly, modern subsistence harvest amounts, specifically by the Ahtna, are affected by a complex process that includes factors that are political, regulatory, economic, and social in nature (Simeone and Kari 2002). These same factors also affect the levels and locations of harvest by other uses in WRST. Finally, the changes of land ownership from the time the Ahtna were principle users of resources to present have affected the access to salmon fishing sites, complicating the comparison of contemporary harvest levels and locations to historic levels and locations.

However, TEK presented here provides some indication of what a reference condition might be for the harvest of salmon in WRST. –The use of Copper River salmon has long occupied a central place in the economies and ways of life of Copper River Basin residents" (Stratton 1982). Specifically, salmon have been critical to the Ahtna, who primarily fished in the main stem of the Copper River (Simeone and Kari 2002). Simeone and Kari (2002) estimate that the Ahtna historically harvested considerably higher numbers of salmon than the Ahtna villages of today. However, Ahtna people discussed with the authors that salmon harvest is still an important part of their culture (Simeone and Kari 2002).

In 2005, Simeone and Valentine studied TEK of historical salmon populations in the Copper River Basin by holding meetings with community members representing the eight Ahtna villages in the Basin (Simeone and Valentine 2005). Participants gave their comments and the authors found five themes or issues that emerged from the meetings. The five themes were:

1) There is an overall decline in the number of salmon in the Copper River.
2) Specific stocks of salmon have declined or disappeared.
3) Residents of the Copper River are not meeting their subsistence needs.
4) Accessibility to good fishing sites and/or traditional fishing grounds is reduced because of changes in the river and/or private property restrictions.
5) Environmental change and pollution is taking place on a large-scale and is having an effect on salmon.

Note: The issues identified above represent the entire Copper River Basin which extends far beyond the boundaries of WRST.

Simeone and Valentine (2005) give responses for the five themes and summarized below are the parts that are applicable to WRST:

1) There were indications that certain wild stocks of sockeye and Chinook salmon may have declined from historic levels. However, they also assert that Ahtna oral tradition

recounts periods of starvation, which indicates that the salmon runs may have been much more variable than they are now.

2) The Ahtna recognize 12 named fisheries on the upper Copper River, above the mouth of Drop Creek recognizing different phenotypic characteristics; however, biologists only recognize fish stocks upon where they spawn. Specific stocks that are important to Ahtna people in the area that is now WRST include stocks of sockeye salmon found in Tanada Creek and Tanada Lake.
3) The Ahtna generally maintain that the upper river salmon stocks are in decline, but managers argue that up river stocks are peripheral and highly variable and are not considered a ―stock of concern," a formal process for determination (Simeone and Valentine 2005).
4) The access to good fishing sites in the Copper Basin has been reduced due to nearly all of the property on the west side of the Copper River being privately owned, whereas access to the east-side is extremely limited. Also erosion and changes in the river channel has reduced access.
5) Environmental change and pollution is taking place on a large scale and having an effect on the salmon, including small lake drying, higher and thicker brush growth, and warming temperatures.

Salmon harvest distribution

Currently, most harvest of salmon near WRST takes place in the Copper River, and focuses on sockeye salmon. While, harvest within the boundaries of the park or preserve is currently limited to a few fish wheels used by federal subsistence users near Slana and in the Batzulnetas fishery, a significant percentage of the salmon harvested originate within WRST (Cellarius pers. comm.). Tanada Lake and Long Lake support specific stocks of sockeye that are important to these subsistence harvests. Tanada Lake sockeye salmon are specifically important to subsistence salmon fisheries in the Glennallen and Batzulnetas Subdistricts. Long Lake sockeye stocks are important to subsistence harvest in the Chitina Subdistrict. Long Lake sockeye salmon are also unique, having the longest known annual spawning duration of any sockeye salmon population in North America (USFWS 2010).

Sport harvest of sockeye in the Copper River Basin primarily occurs outside of the park. Approximately 96% of the sockeye salmon sport harvest in the Upper Copper River/Susitna River management areas occurs in the Gulkana and Klutina rivers (Somerville 2008).

Based on interviews with over 200 area hunters and fishers, Stratton and Georgette (1985) created maps depicting hunting, fishing, trapping, and gathering areas by 20 communities in or near the Copper River Basin for the years 1964 to 1984. These data were entered into GIS through a cooperative agreement between NPS and ADF&G in the 1990s. The depicted spatial representations show resource use areas in and around WRST, including fishing areas. These fishing areas, identified by local residents, are shown in Plate 49. Overlap of the identified fishing areas in Plate 49, represented as polygons, indicate a relative level of importance using the assumption that the more communities that identified an area, the more important the area was to harvest as a whole.

Salmon harvest numbers and trends

Mean yearly salmon harvest in the Glennallen Subdistrict averaged 60,436 from 2004 to 2008, nearly twice as much as the five year mean for 1984 to 1988 (AD&G 2009b) (Figure 68). Sockeye, Chinook, and coho salmon accounted for 94.7%, 3%, and 2.7% of the harvested salmon, respectively, from 2004 to 2008. A mean of 1,052 state subsistence permits were issued yearly in this subdistrict over the same time span.

Yearly personal use salmon harvest in the Chitina Subdistrict has increased from 1984 to the present (ADF&G 2009b) (Figure 69). From 2004 to 2008, yearly personal use salmon harvest in this district averaged 116,673 salmon per year, compared to 44,026 from 1984 to 1988. Sockeye, Chinook, and coho salmon accounted for 95.4%, 2.6%, and 2% of the harvested salmon, respectively, between 2004 and 2008. A mean of 8,437 personal use permits were issued yearly over the same period.

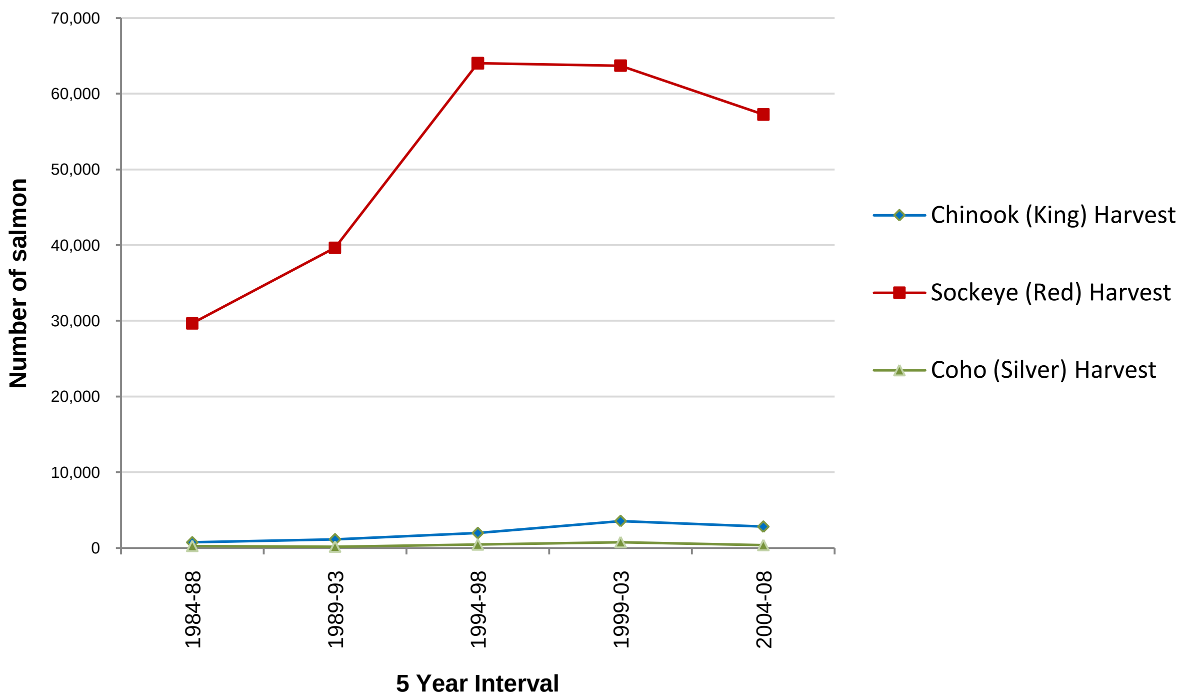


Figure 68. Mean yearly salmon harvest in the Glennallen Subdistrict under state subsistence, 5 year intervals, 1984-2008. (ADF&G 2009b)

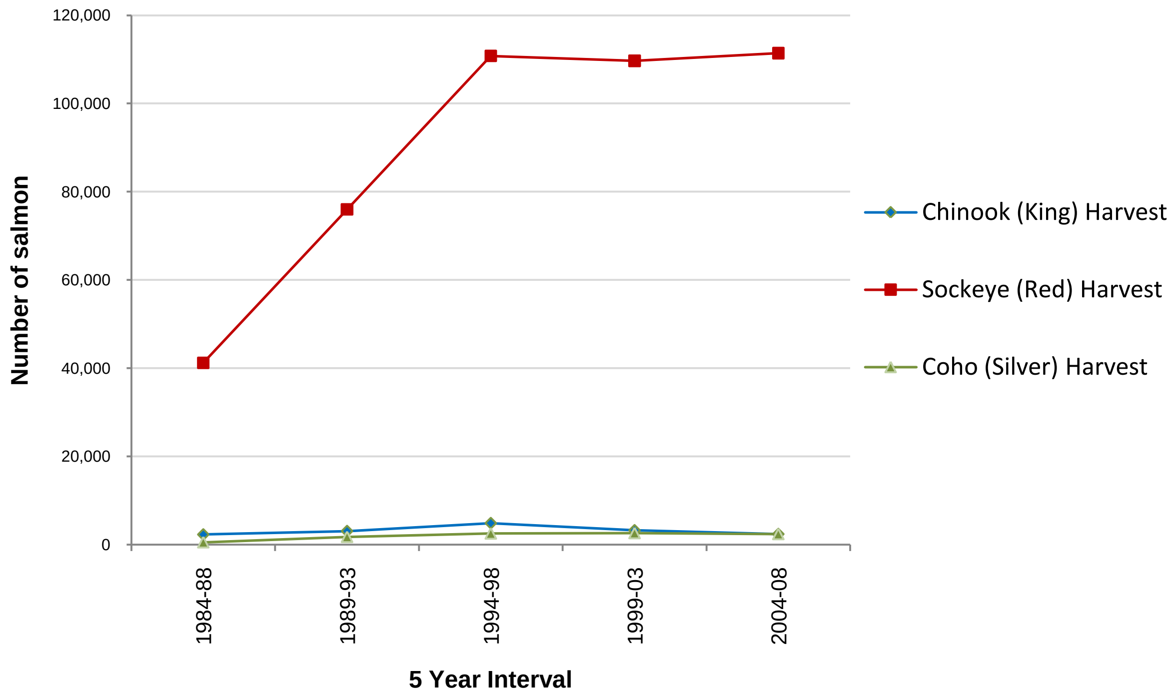


Figure 69. Mean yearly salmon harvest in the Chitina Subdistrict under state regulated personal use, 5 year intervals, 1984-2008. (ADF&G 2009b)

Since initiation in the Glennallen Subdistrict in 2002, federal subsistence harvest has fluctuated around a mean 14,454 salmon a year (McCormick 2009) (Figure 70). Sockeye salmon account for 95.3% of the harvested salmon in this Subdistrict, Chinook account for 3.7%, and coho and steelhead account for less than 1% each. Total yearly harvest has ranged from 8,657 in 2002 to 18,504 in 2004 (McCormick 2009). On average, 250 permits are issued for this fishery each year.

Also initiated in 2002, Chitina Subdistrict federal subsistence harvest has averaged 1,033 salmon per year through 2008 (McCormick 2009) (Figure 71). Sockeye, Chinook, and coho salmon account for 94.9%, 1.9%, and 3.1% of the yearly harvest, respectively. Total yearly harvest has ranged from 608 in 2002 to 1412 in 2006 (McCormick 2009). On average, 95 permits are issued for this fishery each year.

Harvest data reporting for the Batzulnetas subsistence fishery began in 1987. Yearly harvest has varied in this fishery, ranging from zero to 997. Federal regulations were established for this fishery in 2000 and there has been no participation in the state regulated Batzulnetas fishery since that time. From 2004 to 2008, only two salmon were harvested at Batzulnetas (McCormick 2009).

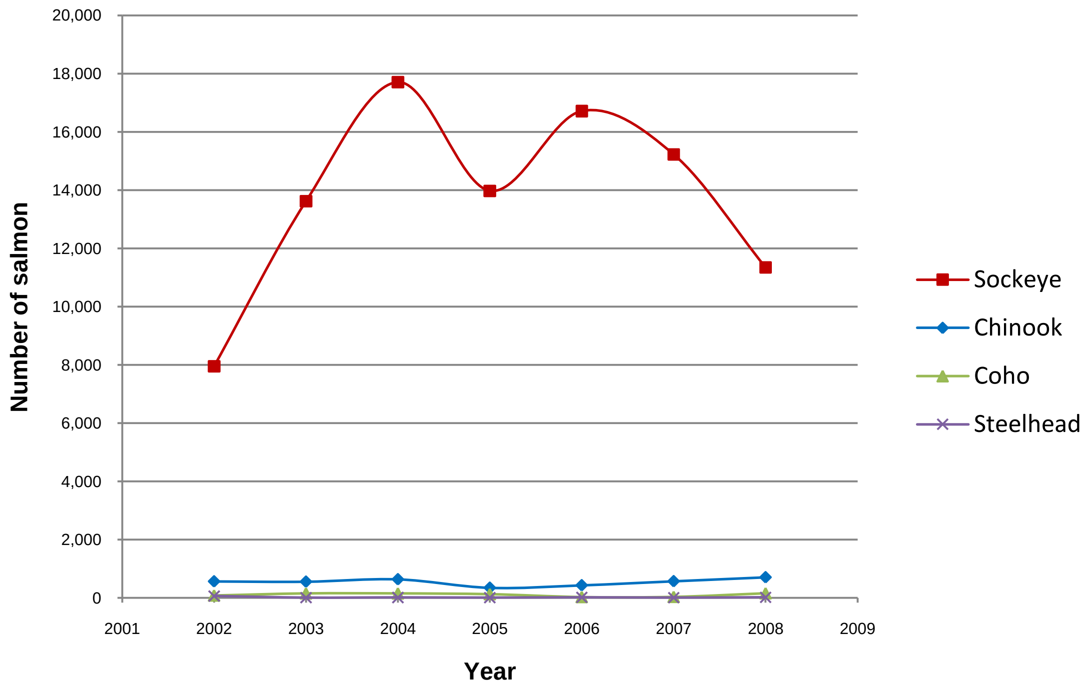


Figure 70. Yearly salmon harvest, Glennallen Subdistrict federal subsistence, 2002-2008. (McCormick, unpublished data)

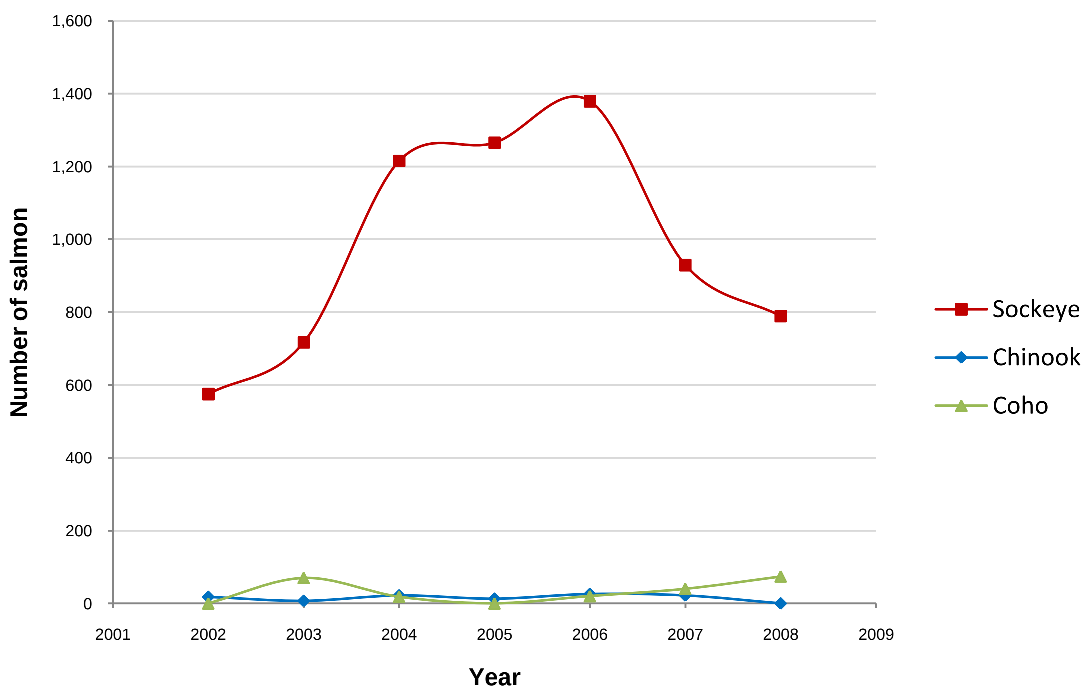
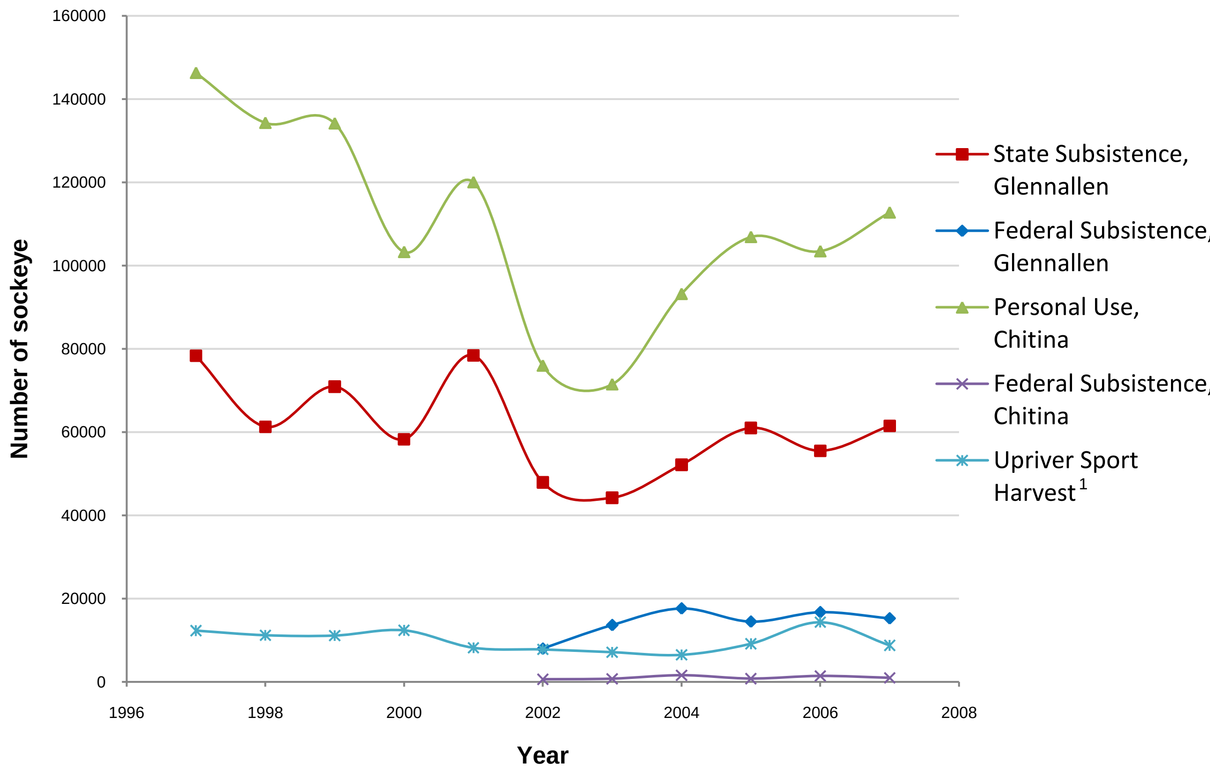


Figure 71. Yearly salmon harvest, Chitina Subdistrict federal subsistence, 2002-2008. (McCormick, unpublished data)

During the period 1997 to 2007, subsistence and personal use harvest accounted for approximately 8.5% of the yearly migrating sockeye salmon harvest upstream of the Miles Lake Sonar. Figure 72 breaks down the sockeye salmon harvest occurring in the Upper Copper River fishery. In the Upper Copper River/Susitna River Management Area, 96% of the sport harvest of sockeye occurs outside the boundaries of WRST, in the Gulkana and Klutina rivers (Somerville 2008). The federal subsistence harvests began in 2002, and this coincided with an initial drop in both state subsistence harvest in the Glennallen Subdistrict and the Personal Use Fishery in the Chitina Subdistrict.



1 - Total estimated sport harvest of sockeye upriver of the Copper River delta.

Figure 72. Yearly Sockeye salmon harvest, by fishery, Upper Copper River, 1997-2007. (Lewis et al. 2008)

Non-Salmon harvest reference condition

The character of non-salmon fish harvest has changed since the Ahtna people were the principal users of the resource, primarily the amounts harvested, species preferred, and residency of the participants (Simeone and Kari, 2005). Surveys conducted by the Division of Subsistence in 1982 and 1987, and most recently in 2001, indicate the overall harvest of non-salmon species has declined (Simeone and Kari 2005). The composition of non-salmon harvest has changed from harvests primarily composed of whitefish, Arctic grayling, and suckers to an emphasis on rod and reel and setlines for trout, burbot, and Arctic grayling (Simeone and Kari 2005). This may have been influenced by both ADF&G stocking of road accessible lakes and rivers and the substantial cultural changes that have occurred since approximately 1950, such as Ahtna moving into a wage economy (Simeone and Kari 2005).

Non-salmon – distribution of harvest

Exact distribution of harvest is not possible to assess given the available data. However, surveys identify locations of harvest and in some cases the species harvested at these locations. According to a study by Simeone and Kari (2005) respondents of a survey (2001-2002) for harvest of non-salmon fish in the Copper River Basin identified the following harvest locations on federal land within WRST: Nelson's (Sculpin) Lake, Silver Lake, Strelna Lake, and Tanada Lake. Additional locations identified in the 2002 ADF&G Department of Fish and Game, Division of Subsistemce, Household survey, included Hanagita Lakes, Jack Creek, Rufus Creek, Slana River, and Tanada Creek. Other important community non-salmon fishing locations, identified more recently, are Silver and Strelna Lakes, and the Copper River from the Nabesna Road to Haley Creek (Haley and Nemeth 2005). The Ahtna identified specific locations for harvest of non-salmon species within the Copper River Basin and the species present within each water-body; the locations common to WRST include the Copper Lake (lake trout), Jake Lake (grayling, rainbow trout), Rufus Creek (Dolly vavrden), Slana River (humpback and round whitefish), Tanada Creek (grayling and sockeye salmon), and Tanada Lake (lake trout, burbot, and grayling) (Simeone and Kari 2005).

Catch locations were identified for eight non-salmon species (burbot, Arctic char, Dolly Varden, lake trout, Arctic grayling, sucker, rainbow trout, steelhead, and whitefish) by Copper River Native Association and ADF&G household surveys in 2002 (Haley and Nemeth 2005). Nearly the entire Copper River, from the confluence of the Slana River to approximately the confluence of O'Brien Creek, is a non-salmon catch area with harvests of burbot, humpback whitefish, and steelhead occurring (Haley and Nemeth 2005). Nine of 103 identified popular locations are on federal lands within WRST (Simeone and Kari, 2005).

Haley and Nemeth (2005) identified some of the non-salmon fishing locations in WRST important for sport fisheries. These included Copper, Hanagita, Silver, Strelna, Tanada, and Van lakes and a few select streams such as Jack and Rufus Creeks. Silver Lake was the most popular stocked lake in both WRST and Upper Copper/Upper Susitna management area (Sommerville 2008). Copper and Tanada Lakes provide sport angling for lake trout, burbot, Arctic grayling, and sockeye salmon (Weeks 2003). Also, Copper Lake contains a natural kokanee population which is uncommon for most Alaskan lakes (Weeks 2003). The Hanagita lakes are important as a catch and release sport fishery for wild rainbow trout and steelhead, and Jack Lake supports a major burbot fishery (Sommerville 2008). General fishing areas (salmon and non-salmon alike) were identified by local Copper Basin communities in 1985 (Strantton & Georgette 1985, Plate 49).

Non-salmon – harvest numbers and trends

Historically, non-salmon fish such as whitefish, trout, arctic grayling, and burbot were crucial to the subsistence economy of the Copper Basin (Simeone and Kari 2005). However, records of non-salmon fisheries in the Copper Basin prior to 1960 are rare and confined to major lakes and streams (Simeone and Kari 2005). The ADF&G 1987 Copper Basin/Upper Copper River community survey and the ADF&G Division of Subsistence 2002 Copper Basin community survey indicate a continued reliance on non-salmon fish.

The most frequently reported non-salmon species harvested are (listed as most frequent to least frequent), Arctic grayling, burbot, rainbow trout, lake trout, Dolly Varden, and whitefish for the

Copper River Basin communities of Chistochina, Chitina, Copper Center/Silver Springs, Gakona, Glennallen, Gulkana, Kenny Lake, Lake Louise, McCarthy/McCarthy road, Mendeltna, Mentasta, Nelchina, Paxson, Slana, Tazlina/Copperville, Tolsona, Tonsina, and Willow Creek (Simeone and Kari 2005, Table 45). The Simeone and Kari (2005) report represents the most current information available regarding contemporary harvest of non-salmon fish by communities in or near WRST.

Table 45. Non-salmon fish harvest, Copper Basin Communities, 2001. (ADF&G 2009a)

Community	Non-salmon harvest per capita (lbs)	Mean non-salmon harvest/ household (lbs)	Total non-salmon harvest (lbs)
Chistochina	6.7	14.4	534
Chitina	2.5	6.5	241
Copper Center	5.8	18.3	3,257
Gakona	8.1	24.2	2,039
Glennallen	2.8	8.0	1,638
Gulkana	6.8	13	431
Kenny Lake	5.0	9.9	1,416
Lake Louise	31.9	66.8	2,729
McCarthy/ Mc. Road	3.2	8.0	379
Mendeltna	4.1	6.9	160
Mentasta	6.5	17.9	967
Nelchina	19.4	6.1	526
Paxson/Sourdough	6.3	11.4	240
Slana	18	35.4	2,199
Tazlina	5.8	14.6	1,757
Tolsona	2.7	5.6	84
Tonsina	4.9	10.3	352
Willow Creek	2.8	5.9	472

Salmon harvest data needs

Since the Copper River is the focal point of fisheries in WRST (Weeks 2003), the majority of available data focus on harvest of salmon from this river. Some harvest of salmon also occurs throughout the park and preserve under sport regulations, though specific harvest levels and locations generally are not reported for water bodies within WRST. In order to develop a better understanding of fish harvest numbers and locations in WRST, more location specific data should be collected on sport harvest. In addition to the Prince William Sound management area represented by the Copper River Basin, WRST also contains portions of the Upper Yukon management area in the northeast part of the park and the Yakutat management area in the southeast part of the park. Anadromous salmon fisheries are interrelated and regulations and management actions in one fishery may affect other fisheries (Weeks 2003). Therefore, data needs are complicated by the consideration of these adjacent fisheries.

Non-salmon harvest data needs

Non-salmon harvest data are relatively limited, in comparison to salmon harvest data Harvest data of non-salmon fish are limited to ADF&G sport harvest survey reports and household subsistence surveys. Updated household surveys and sport harvest reports specific to locations in WRST would help NPS develop a more thorough understanding of harvest levels and locations.

Wildlife

Important harvested wildlife species

As stated earlier, NPS (2007) lists many large mammals, including moose, caribou, Dall‘s sheep, mountain goats, ptarmigan, grouse, snowshoe hare, and a variety of furbearing animals as part of the region's main wildlife resources used for subsistence. Also, a 1987 community harvest survey found that, by pounds harvested in communities in the WRST area, moose and caribou were the most harvested mammals (ADF&G 2009a, Table 46). The 1987 community survey represents the best data for communities in this area to date. Even though many of the communities surveyed in the 1987 survey are located outside of the park, it still provides insight into important harvested species in the general area. One clear exception to this is caribou harvest. A limited number of caribou from the Nelchina herd are harvested on a sliver of land in Unit 13C of the Preserve, and a limited number are harvested outside of the WRST. It is important to note that despite limited harvest within WRST because of regulations imposed in response to herd declines, caribou remains an important subsistence resource for Basin residents (Cellarius pers. comm.).

Table 46. Reported and estimated large mammal harvest by species for the 1987 Copper Basin/Upper Tanana survey. This survey includes the following communities: Chistochina, Chitina, Copper Center, Dot Lake, Gakona, Glennallen, Gulkana, Kenny Lake, McCarthy Road, Mentasta, Northway, Slana, Tanacross, Tazlina, Tetlin, Tok, Tonsina, Yakuatat. (ADF&G 2009a). It is important to note that this information does not identify where the animals were harvested, only that a member(s) of the households surveyed harvested the animals.

Species	Reported Harvest (no. of animals)	Reported Harvest (lbs)	Estimated Harvest (no. of animals)	Estimated Harvest (lbs)
Moose	63	34,429	304	165,785
Caribou	78	10,140	577	74,866
Black Bear	13	1,238	86	6,544
Dall's Sheep	4	260	61	4,047
Deer	5	213	57	2,439
Bison	0	0	2	1,038
Goat	0	0	9	641
Brown Bear	2	0	12	443

The 1987 household harvest survey found that snowshoe hare accounted for the highest number of reported and estimated harvested animals, followed by muskrat and martin in the Copper River Basin/Upper Tanana study (ADF&G 2009a, Table 47). Today, marten are the most important furbearers for individuals trapping in GMU 11 (Schwanke and Tobey 2007) and marten, lynx, and muskrat are economically important in Unit 12, which overlaps the boundary of WRST (Hollis 2007). Though less important, beaver (*Casor Canadensis*), coyote (*Canis* *latrans*), ermine (*Mustela ermine*), mink (*Neovison vison*), red fox (*Vulpes vulpes*), land/ river otter (*Lontra canadensis*), wolf (*Canis lupis*), and wolverine (*Gulo gulo*) are all considered common in terms of relative abundance, whereas Lynx is considered scarce and red squirrel abundant (Blejwas 2006). Schwanke and Tobey (2007) suggest that, ―trapping in Southcentral Alaska has become more of a weekend/recreational activity, compared to the long-line/commercial activity seen during the 1970s and 1980s…" and that the ―…populations of furbearers in Units 11 and 13 are considered healthy with normal fluctuations".

Table 47. Reported and estimated furbearer harvest for WRST area communities in the Copper Basin/Upper Tanana 1987 survey project. Includes the following communities: Chistochina, Chitina, Copper Center, Dot Lake, Gakona, Glennallen, Gulkana, Kenny Lake, McCarthy Road, Mentasta, Northway, Slana, Tanacross, Tazlina, Tetlin, Tok, Tonsina, Yakutat (ADF&G 2009a). It is important to note that this information does not identify where the animals were harvested, only that a member(s) of the households surveyed harvested the animals.

Furbearer	Reported Harvest (no. of animals)	Estimated Harvest (no. of animals)
Hare	3,301	7,042
Muskrat	1,959	4,293
Marten	710	1,897
Fox	203	419
Mink	114	286
Weasel	46	147
Coyote	35	133
Beaver	29	87
Wolf	23	40
Lynx	22	124
Wolverine	15	35
Marmot	0	6

Harbor seals are the only marine mammal harvested according to the Yakutat marine mammal community surveys dating 1995 through 1998 and 2000 through 2006. However, the seals don‘t appear to be harvested above the mean high water mark and therefore are not harvested on land that NPS manages (Bert Adams Sr., pers. comm.).

In 2000, the communities of Chistochina, Chitina, Copper Center, Gakona, Gulkana, and Tazlina were surveyed in a project called Southcentral Birds (ADFG 2009a). The communities of Dot Lake, Healy Lake, Tanacross, Tetlin, and Tok were surveyed in a separate project called Interior Birds. The most harvested species, in terms of estimated pounds, were primarily waterfowl. Mallards were by far the most harvested species, followed by white-winged scoter (*Melanitta fusca*), bufflehead (*Bucephala albeola*), sandhill crane (*Grus Canadensis*), northern pintail (*Anas acuta*), American wigeon (*Anas Americana*), white-fronted geese (*Anser albifrons*), Canada geese (*Branta Canadensis*), lesser Canada geese, grouse, willow ptarmigan (*Lagopus lagopus*), common goldeneye (*Bucephala clangula*), canvasback (*Aythya valisineria*), green-winged teal (*Anas crecca*), lesser scaup (*Aythya affinis*), ringneck duck, greater scaup (*Aythya marila*), northern shoveler (*Anas clypeata*), Barrow goldeneye (*Bucephala islandica*), common merganser

(*Mergus merganser*), and rock ptarmigan (*Lagopus muta*). The survey data do not indicate if this harvest occurred in WRST.

Wildlife harvest regulations

In WRST, harvest of wildlife occurs under federal and state regulations. Harvest of wildlife under state sport licenses (residents and non-residents) and state subsistence permits (only state residents) can only occur in the Preserve, whereas federal subsistence harvest occurs in both the preserve and park. To hunt in the national preserve under federal subsistence regulations, hunters must be rural Alaska residents and must live in a community or area that has a positive customary and traditional use determination for the species and area (this could be a unit or subdivision thereof) where they wish to hunt. For those hunting in the national park, there is the additional requirement that they currently live in one of 23 resident zone communities, live within the national park, or live in a household that holds a 13.440 permit issued by the park superintendent.

Wildlife harvest reference condition

The following section was adapted from a study, funded by WRST, entitled, ―Some Ethnographic and Historical Information on the Use of Large Land Mammals in the Copper River Basin" (Simeone 2006).

Historically, the Ahtna people depended on caribou, Dall‘s sheep, moose, black bear, brown bear and, to some extent, mountain goat for food and for materials to make tools and clothing (Simeone 2006). However, the relative importance varied from year to year. Their relationship with these animals has changed over the last 125 years, remaining ―close and intimate, but the Ahtna no longer rely entirely on these animals for food and clothing" (Simeone 2006).

Dall‘s sheep were the most important food resource, other than salmon, to the Ahtna in the lower and upper Copper River Basin (Simeone 2006). This was because there were few moose, caribou were highly seasonal, and there was a large population of sheep, except around mining areas (i.e. Chisana, Nabesna, and Kennecott). Large numbers of animals were harvested around these communities, primarily for market hunting.

Two sub-species of caribou exist in the area of WRST, the barren ground caribou (*Rangifer tarandus granti*) and the woodland caribou (*Rangifer tarandus caribou*). The Ahtna clearly recognized and distinguished between the two sub-species, and evidence suggests they also heavily relied on these animals (Simeone 2006).

Today, moose are the preferred subsistence harvest species, representing a shift from a heavy reliance on caribou and Dall‘s sheep in the past. This is likely due to the increase in moose abundance and the relative ease of hunting them in contrast to Dall‘s sheep (Simeone 2006).

The harvest numbers reported by Traditional Ecological Knowledge (TEK) studies such as Simeone (2006) are not comparable to harvest numbers of today, because they largely consist of narratives covering a wide variety of harvest related information and generally do not contain discrete numbers.

Wildlife harvest distribution
Understanding wildlife harvest distribution in WRST is complex because of geographic boundaries used for reporting, the spatial resolution of the harvest data, and the complexity of regulations. There are two main sources of data for understanding the harvest of wildlife in WRST. The largest source, in terms of number of years of record and total records, is the ADF&G harvest database. Another data source is the community harvest survey database (ADF&G 2009a). The database contains household surveys conducted primarily in 1982, 1987, and 2004 by ADF&G for communities in or near WRST. Another source is NPS maintained data on federal subsistence permits and harvests.

The ADF&G harvest database uses a Uniform Coding Unit (UCU) system for the reporting and regulation of wildlife harvest. The system was developed in the 1980s to create a uniform location coding system for harvest related data. From the largest unit to the smallest, UCU codes are comprised of the GMU, the subunit, the Major, Minor, and Specific drainage or specific UCU. For example, in the UCU code ―11ZC051302," 11 is the GMU, Z is the subunit (in this case a Z indicates there are no subunits for GMU 11), C05 is the Major, 13 is the Minor and 01 is the Specific. Harvests in the ADF&G database are reported down to the specific UCU at various levels of consistency by year and by species. In cases where only the GMU is reported on a harvest ticket, very little spatial resolution is available. For example, various percentages of the records in the database are reported down to the specific UCU (Table 48) (Moderow 2006b). In addition, the data do not indicate if the animal was harvested in WRST or outside WRST in cases where the UCU (Uniform Coding Unit) or the GMU overlaps the park or preserve boundary. **Plate 52** shows the UCUs located in WRST and the associated GMU. Much of the harvest data are reported to the UCU. Table 48 displays the percentage of the records in which the UCU information is populated for UCUs common with WRST (within or overlapping the park or preserve boundaries). Maps indicating the relative density of harvest for moose, caribou, Dall‘s sheep, brown bear, and mountain goat are possible with this information, however, this level of data resolution is considered sensitive information and therefore is not presented here.

Table 48. ADF&G resolution of reporting for UCUs of WRST.

Species	Percentage of harvest records reported to the specific UCU
Mountain Goat	90
Dall's Sheep	87
Moose	83
Caribou	82
Brown Bear	75

GMUs 11Z, 5B, 12Z, 13C, and 6A cover the boundaries of WRST. GMUs 11 and 5B are the only units in the park that are almost completely within the park and preserve boundaries, with 97% and 94% of their area within WRST, respectively. The remaining GMUs are partially within the boundaries of WRST, with 12Z 49% within, 13C 2% within, and 6A 18% within the boundaries.

NPS (2007) state that most harvest, specifically for subsistence hunting, occurs off the Nabesna, McCarthy, and Kostina roads. Additionally, the Copper, Nabesna, Chisana and Chitina rivers serve as popular riverine access routes for subsistence users (NPS 2007). Hunting and fishing use areas, mapped by Stratton & Georgette (1985), appear to support the statement that most subsistence occurs off the Nabesna, McCarthy and Kostina Roads. Based on interviews with over 200 knowledgeable area hunters and fishers, they created maps depicting hunting, fishing, trapping, and gathering areas by 20 communities in or near the Copper River Basin, from 1964 and 1984. These data were entered into GIS through a cooperative agreement between NPS and ADF&G in the 1990s. The depicted spatial layers represent resource use areas in and around WRST. Fish, moose, and caribou topped the list of important wild resources in terms of total pounds harvested and common hunting and fishing areas ((Plate 49, Plate 50, Plate 51).

One limitation is that the survey did not take into account the settlers from the 1983 federal homestead along the Nabesna Road near Slana (Stratton & Georgette 1985). However, the areas that multiple communities identified tend to focus along the Nabesna Road despite the exclusion of this homesteaded area. The communities of Chickaloon, Chisana, Chistochina, Chitina, Copper Center, East Glennallen, Gakona, Glacier, Glennallen, Gulkana, Kenny Lake, Lake Louise, McCarthy, Mentasta Lake, Nabesna, Paxson, Slana and Tonsina were a part of the 1987 Copper Basin study area. The communities of Dot Lake, Northway, Tanacross, Tetlin, and Tok were a part of the Upper Tanana Study Area. They represent areas used from 1968 to 1988, according to the metadata associated with NPS permanent data set; however, no citation for the data is given. The Yakutat survey cited in the metadata as Mills and Firman (1985) was used in these maps, but was unavailable for this assessment.

Wildlife harvest numbers and trends

Primary data sources for understanding harvest of wildlife are the ADF&G harvest reporting database covering dates 1983 to 2007, ADF&G harvest data summarized and quality controlled by Moderow (2006a,b), and the 1987 community harvest surveys found in (ADF&G 2009a). The harvest reporting database contains thousands of records of harvest and identifies the general location of harvest, though the precision of reported location is variable. The community surveys provide information on a broad range of community features, including harvest level estimates created by an extrapolation of representative survey samples. While the community surveys do not allow for detailed understanding of harvest locations, they provide a closer approximation of overall harvest levels compared to the harvest database (Moderow 2006a). Surveys and the associated years in which they were conducted, representing local harvest of wild resources in and around WRST are displayed in (Table 49).

In addition, NPS (Cellarius pers. comm.) provided federal subsistence permit data for 2003-2008 (Appendix J).

Table 49. Resource use/harvest surveys by communities near WRST. (ADF&G 2009a)

Community Name	1982[a]	*1987[b]	2000[c]	2004[d]
Chisana		x		
Chistochina	x	x	x	
Chitina	x	x	x	
Copper Center	x	x	x	
Dot Lake		x	x	x
Gakona	x	x	x	
Glennallen	x	x		
Gulkana	x	x	x	
Healy Lake			x	
Kenny Lake		x	x	
Lower Tonsina	x			
McCarthy Road	x	x		
Mentasta	x	x		
Nabesna	not listed in ADF&G 2009a			
Northway		x		x
Slana	x	x		
Tanacross		x	x	x
Tazlina		x	x	
Tetlin		x	x	x
Tok		x	x	x
Tonsina	x	x		
Yakutat**		x	x	

[a] Copper River Project (Stratton and Georgette 1984)
[b] Copper Basin/Upper Tanana 1987
[c] Southcentral Birds 2000
[d] Marine Mammals 2004, Upper Tanana Baseline
*ADF&G considers 1987 the most representative year for many communities near WRST.
**Yakutat also includes: Southeast Timber 1984 and1985, Tongass Resource Use Cooperative Study 1987, Yakutat Household Survey 2000, and Marine Mammals 1995 through 1998 and 2000 through 2006.

Moderow (2006a) examined the harvest of beaver, bison, black bear (sealing records), brown bear (sealing records), caribou, mountain goat, lynx, moose, otter, sheep, wolf, and wolverine, comparing the harvest data of the 1987 community surveys to the ADF&G harvest database for 1987. Many of the species harvests were ―under-reported" in the ADF&G database when compared to the survey (Moderow 2006a). Moderow (2006a) derived coefficients that, when applied to the ADF&G harvest database, adjust for under-reported take to provide a better representation of actual harvest. Information derived from Moderow (2006b) in the subsequent wildlife harvest sections is accurate to the Uniform Coding Unit (UCU) level. UCUs, defined by ADF&G, are used for reporting the location of harvest. Moderow's (2006b) data incorporate all UCUs that are completely within or overlap the park boundary. Because of this, 12.4% of the area used to define harvest is located outside of the WRST boundary (Plate 52).

<u>Moose harvest</u>

From 1983 to 2007, estimated yearly harvest has remained stable (Figure 73). The average harvest over this time span was 104.3 moose per year; the largest estimated harvest was 129.5 moose and the lowest estimated harvest was 78.39 (1992). Over the same time interval; yearly number of hunters ($\bar{x}$ = 614.9, σ = 103.1) and their success rates ($\bar{x}$ = .173, σ = 0.029) were relatively constant (Figure 74). No literature exists that explains whether moose mortality from human take in WRST is additive or compensatory.

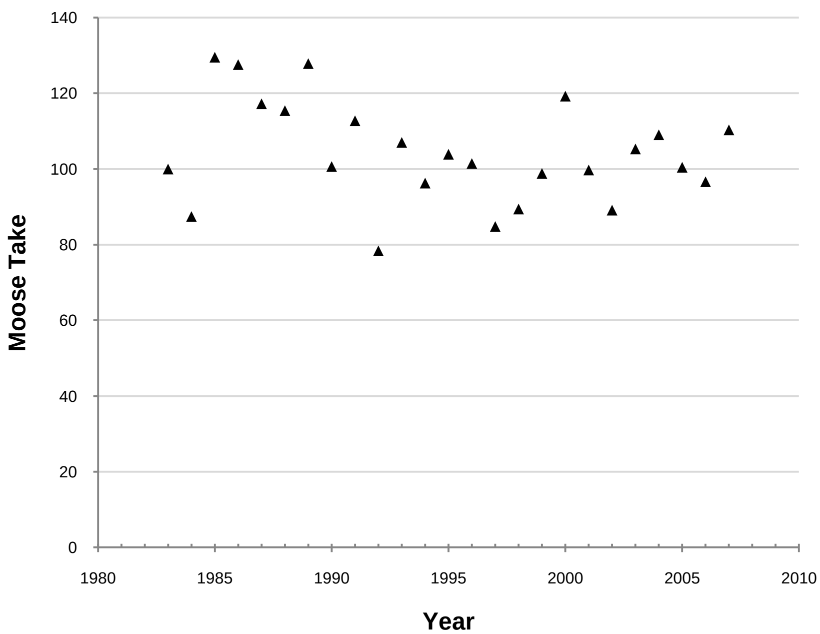


Figure 73. Estimated yearly moose harvest, WRST,1983-2006. (Moderow 2006b)

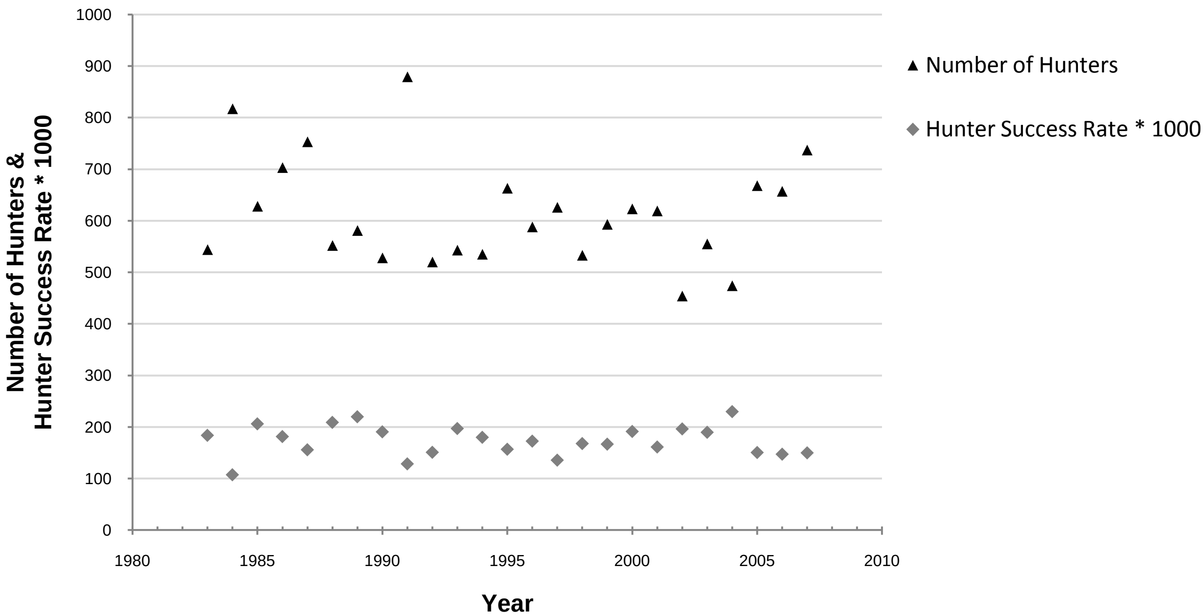


Figure 74. Number of moose hunters and hunter success rate * 1000 vs. Year, WRST, 1983-2007. (Moderow 2006b)

Caribou harvest

Caribou harvest in WRST has almost completely ceased due to population concerns and subsequent changes in harvest regulations. While no legal harvest from the Chisana caribou herd has occurred since 1994 (Gross 2008), or the Mentasta herd since 1992, some caribou continue to be harvested from the Nelchina herd in Unit 13C (Preserve lands west of Slana) and in the far northeast corner of the preserve lands in Unit 12 (Cellarius pers. comm.). Currently, no legal federal subsistence hunting of either the Mentasta or the Chisana caribou herds takes place in the United States or Canada (FSMP 2010). The data represented in Figure 75 include caribou harvest from some UCUs outside of the park. The available data do not indicate from which herd the caribou were harvested, and data for all of the specific UCUs in WRST were unavailable beyond 2003.

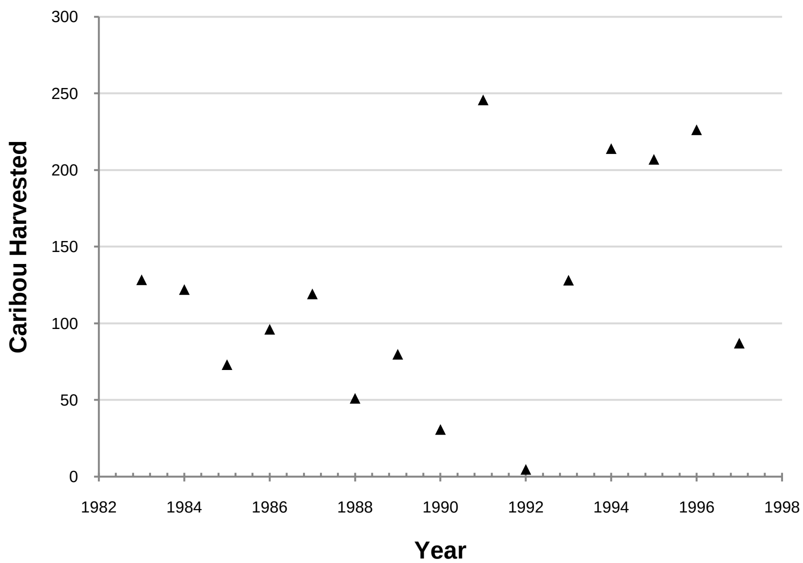


Figure 75. Estimated yearly caribou harvest in WRST, 1983-2003. (Moderow 2006b). Note: caribou records were not entered consistently in the ADF&G database from the mid '80s to the mid '90s. (Moderow 2006a)

Dall's sheep harvest

With the exception of the Elder and Junior/Senior Federal Registration Permit sheep hunts in GMU's 11 and 12, all federal (subsistence) and state sheep hunting is reported under the state harvest ticket system. Terwilliger (2005) summarized harvest data for Dall's sheep in WRST from 1983-2002. Over this time span, 6,672 total sheep were reported harvested. Seventy percent of harvested sheep over that time were rams, 3.3% were ewes, and 26.5% were of unreported sex. Terwilliger (2005) also reported that ram harvest was decreasing linearly through 2005 (r^2 = 0.93), but specific rates were not disclosed in the report.

ADF&G reported that harvest levels for game management unit (GMU) 11, which falls almost completely within the WRST boundary, have decreased consistently from 1999 to 2007, with record lows in 2006 and 2007 (Figure 76). In GMU 12, of which roughly half is located in the northwestern portion of the park, they also reported declines from 2005-2007 (Figure 77). The number of registered hunters and their success rates have also been declining in GMU 11, with record lows in 2007 (Figure 78, Figure 79). In GMU 12, the number of registered hunters has been decreasing, but success rates have remained relatively constant (Figure 80, Figure 81). On a whole, Dall's sheep harvest throughout all UCUs, within or overlapping the WRST boundary, appears to have declined slightly from 1983 to 2005 with a record low occurring in 2005 (Figure 82).

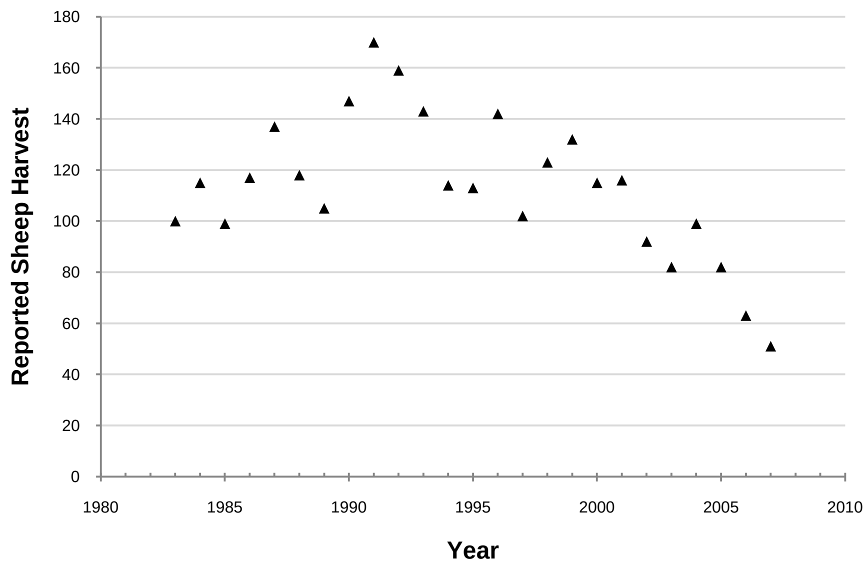


Figure 76. Dall's Sheep harvest in GMU 11, 1983-2007. (Moderow 2006b)

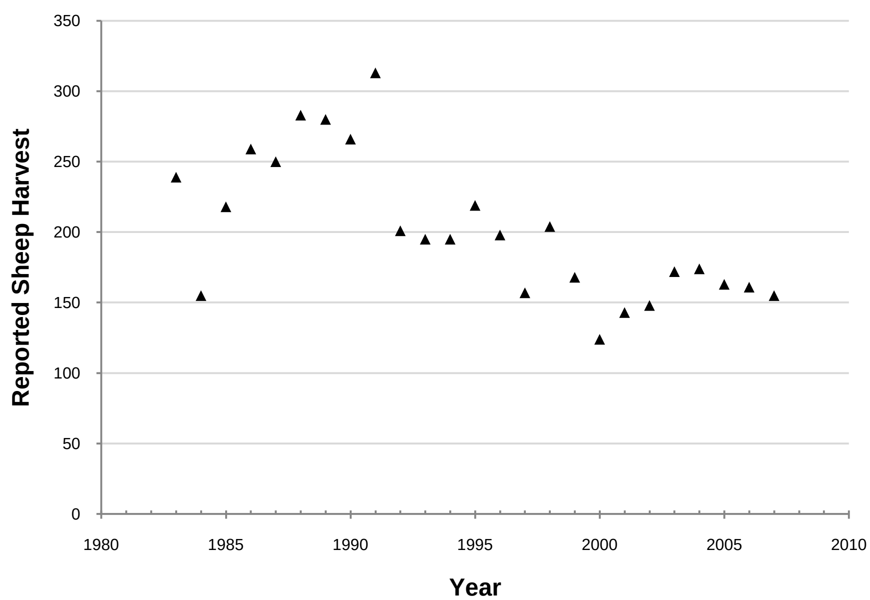


Figure 77. Dall's Sheep harvest in GMU 12, 1983-2007. (Moderow 2006b)

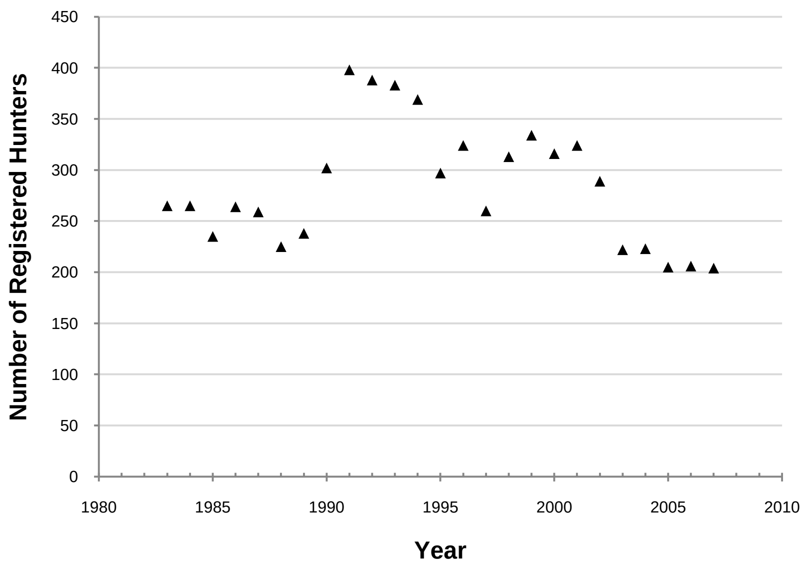


Figure 78. Registered Dall's sheep hunters in GMU 11, 1983-2007. (Moderow 2006b)

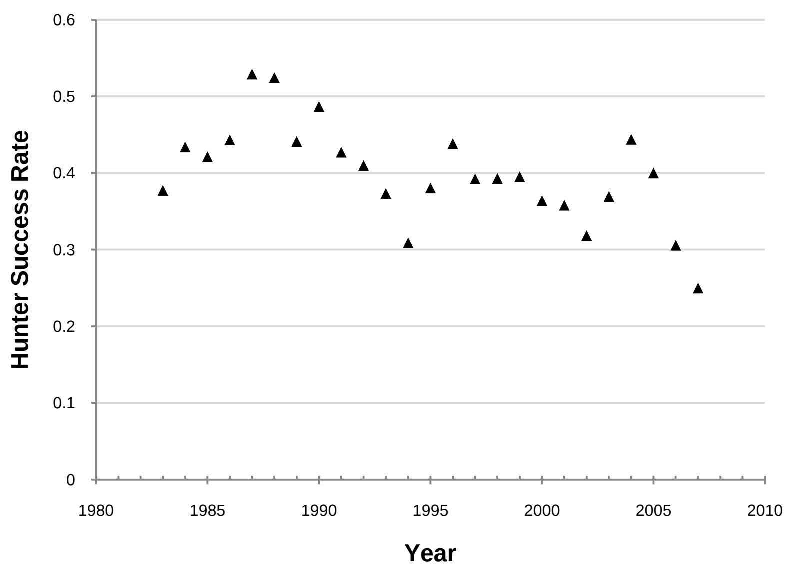


Figure 79. Dall's sheep hunter success rate in GMU 11, 1983-2007. (Moderow 2006b)

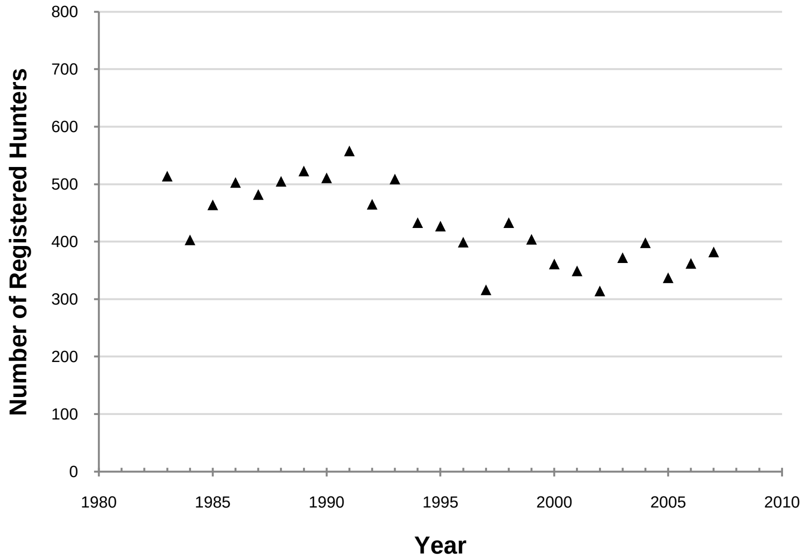


Figure 80. Registered Dall's sheep hunters in GMU 12, 1983-2007. (Moderow 2006b)

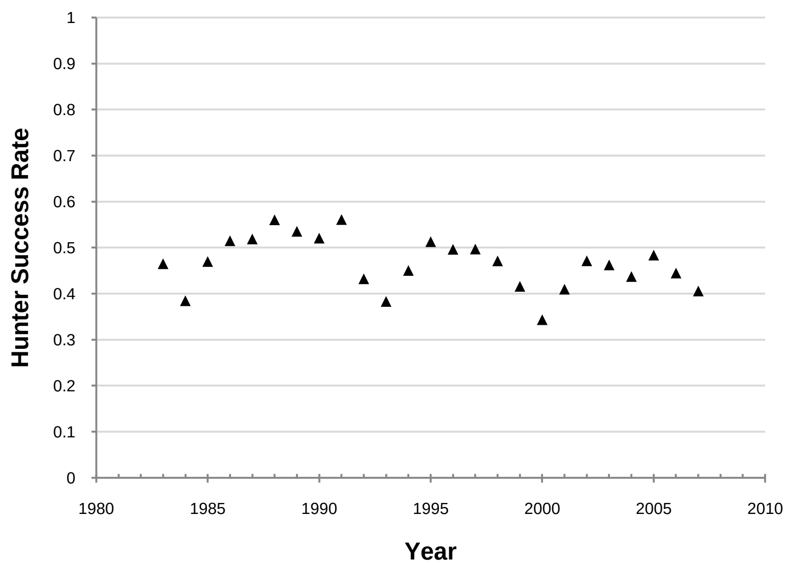


Figure 81. Dall's sheep hunter success rate in GMU 12, 1983-2007. (Moderow 2006b)

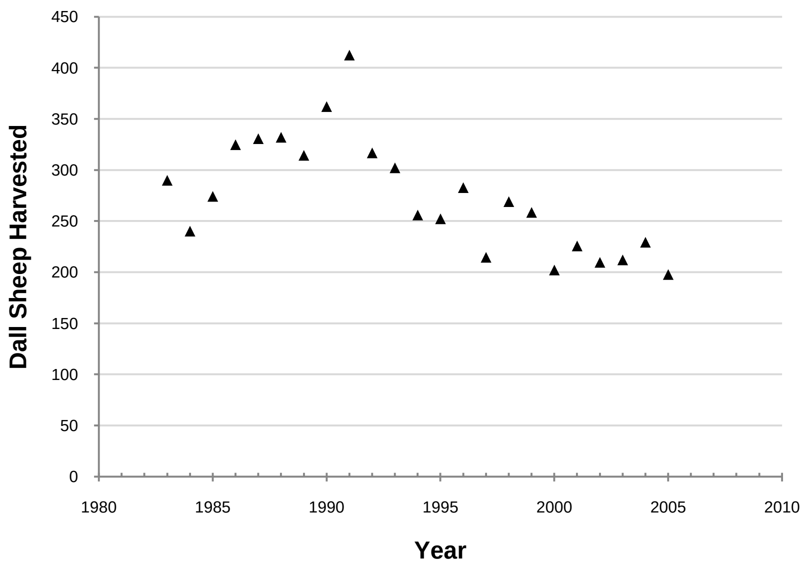


Figure 82. Estimated yearly Dall's sheep harvest, WRST, 1983-2005. (Moderow 2006b) Data summarized for the entire park were only availabe through 2005.

Mountain goat harvest

Mountain goat harvest appears to be decreasing throughout the UCUs in and overlapping WRST (Figure 83). Harvest has ranged from a high of 46 (1986) to a low of nine (2002). Goat harvest decreased every year from 1998 to 2002. The last years of available data, 2002 and 2003, were the lowest goat harvests on record for the UCUs in and overlapping WRST.

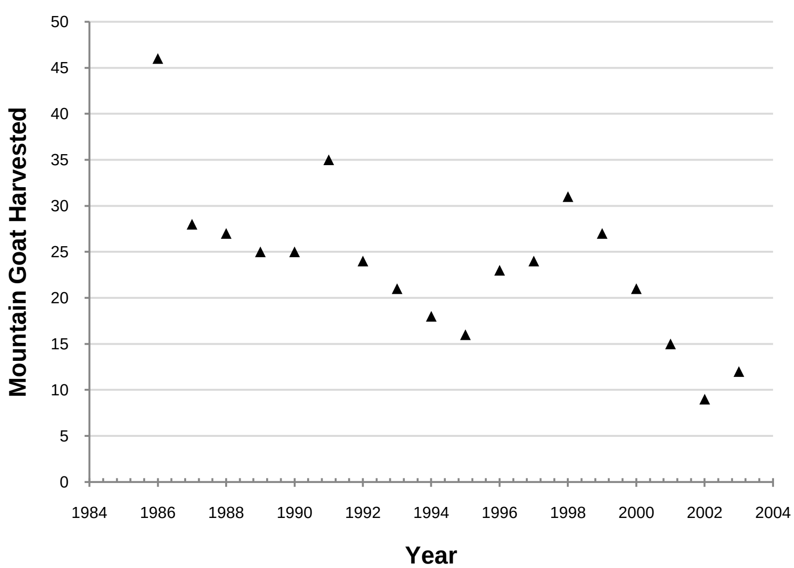


Figure 83. Estimated yearly mountain goat harvest, WRST, 1986-2003. (Moderow 2006b)

Brown bear harvest

Reported brown bear (*Ursus arctos*) harvest of all UCUs within or overlapping WRST, from 1960 to 2005, has averaged 27.3 bears per year. Harvest has ranged from four in 1960 to 50 in 2000. Currently, brown bear harvest seems to be increasing (Figure 84).

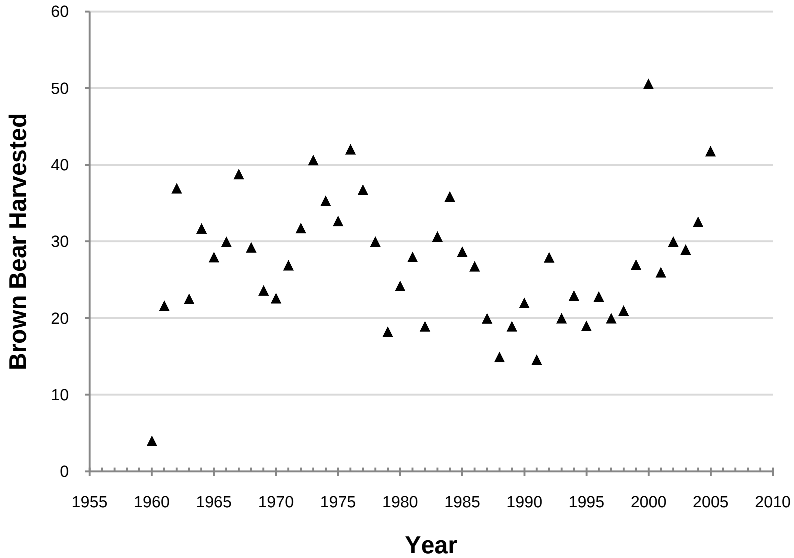


Figure 84. Estimated yearly brown bear harvest, WRST, 1960-2005. (Moderow 2006b)

Black Bear harvest

Black bear (*Ursus americanus*) harvest is minimal in WRST. From 1975 to 1998, it is estimated that only 19 black bear were harvested (Moderow 2006b).

Furbearer harvest

An important factor that affects the harvest levels of lynx are the fluctuations in their populations due to fluctuations in hare populations. Lynx harvests are often low after a snowshoe hare population crash. Trapping efforts fluctuate based on a variety of extraneous factors, but primarily due to fur price (Schwanke and Tobey 2007). For instance, lynx harvest dropped off significantly during the mid 1990s when fur prices were low (Figure 85). Trends established for trapping are species specific. The actual harvest of some animals was high in some years and low in others.

Furbearer populations, including beaver, otter, lynx, marten, wolf, wolverine, fox, coyote, muskrat, mink, and weasels, are considered healthy in GMU 11 (Schwanke and Tobey 2007), which represents a large portion of WRST. For GMU 12, furbearer harvest is difficult to report since nearly half of the unit is outside the boundaries of WRST. Hollis (2007) notes that marten and lynx are the most economically important furbearers, while muskrats are economically and culturally important in GMU 12. Trapping in GMU 5 occurs primarily in Unit 5A (Barten 2007), which is almost completely outside of WRST. Finally the portion of GMU 6A that is within WRST consists of largely mountainous areas covered by snow and ice, and therefore, it is likely that little or no furbearer harvest occurs within this unit of the park. Though wolves are furbearing animals, they are discussed in Chapter 4.7 of this report. Lynx and river otter are the only furbearers with long-term data available in WRST (Figure 85, Figure 86).

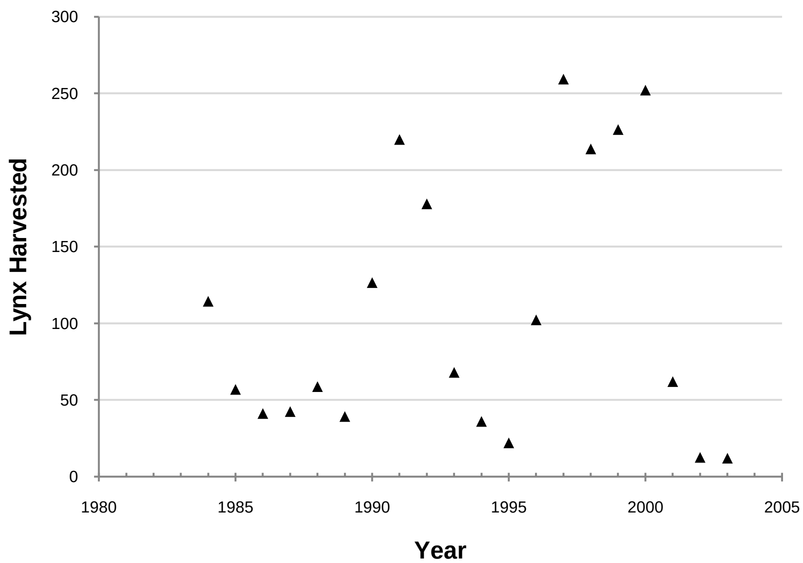


Figure 85. Estimated yearly lynx harvest, WRST, 1984-2003. (Moderow 2006b)

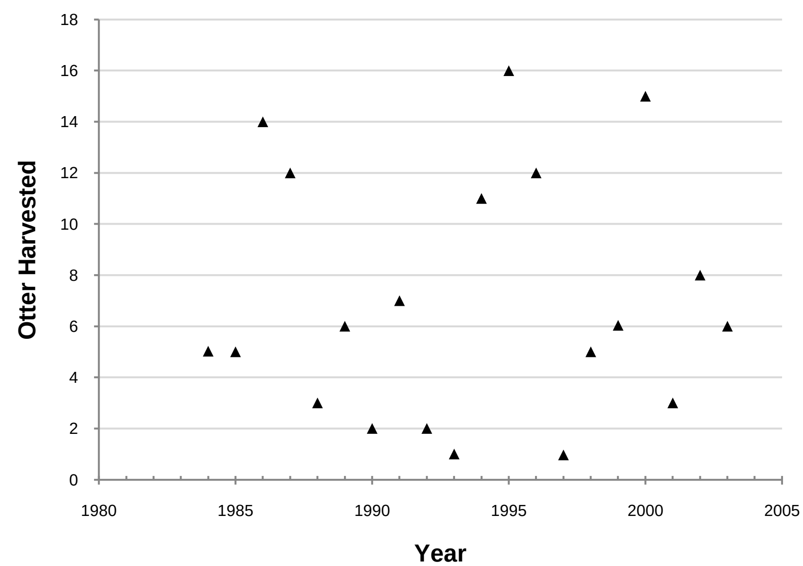


Figure 86. Estimated yearly river otter harvest, WRST, 1984-2003. (Moderow 2006b)

Wildlife harvest condition

The harvest of moose, mountain goat, Dall's sheep, and brown bear under federal regulations requires a registration permit in some units. The federal subsistence harvest only represents a small portion of the total harvest in the administrative boundaries of WRST. However, this represents the most recent information of harvest of large land mammals in WRST. Harvest data beyond 2005 and sometimes beyond 2003 were unavailable at the time of this report for large land mammals in WRST.

Caribou harvest in WRST has almost completely ceased due to population concerns and subsequent changes in harvest regulations. No legal harvest from the Chisana caribou herd has occurred since 1994 (Gross 2008), or from the Mentasta herd since 1992. According to the

Moderow (2006b) harvest database, developed from the ADF&G harvest database, Dall‘s sheep and mountain goat harvests appear to be declining in WRST. Dall‘s sheep harvest peaked in 1991 and declined in WRST throughout 2005. Mountain goat harvest has fluctuated from 1986 to 2003, but generally shows a decline. Moose harvest throughout the park seems to be relatively stable to slightly declining. Brown bear and black bear remain highly variable.

Other wildlife species are harvested at much lower levels, based on total pounds, than the large land mammals listed above. Other species harvested include harbor seals, furbearing animals, and birds. Qualified subsistence users in Yakutat, a community whose residents qualify for subsistence in the coastal regions of the park, harvest harbor seals. However, the seals are not harvested within the administrative boundaries of the park. Furbearing animals are considered healthy and within natural fluctuations in Unit 11 (Schwanke and Tobey 2007). According to community surveys in 2000, local residents harvest upland game birds and migratory birds. However, no trend or population information is available for bird harvests.

A decline in harvest of a given species does not necessarily indicate a condition of concern for that species. Various factors may contribute to a decrease in harvests and identifying the causes for decreases requires more research. However, multiple species harvest‘s (Dall‘s sheep, mountain goat, and moose) may be declining.

The location of harvest is variable by species, likely due to many factors including, but not limited to, differing habitat needs, availability and type of access to hunting areas, and the harvest regulations of a given species.

Wildlife harvest data needs

The National Parks Conservation Association (NPCA) states, ―Wrangell St. Elias has the most urgent population data needs among national park units in Alaska" (NPCA 2006). When looking at the two sources for harvest data, the ADF&G harvest database and the community survey data (ADF&G 2009a), residents in the community surveys reported a much higher portion of their harvest activities than many other local park communities in Alaska. NPCA (2006) suggests that repeating the 1987 all-community-survey (which is over 20 years old) could provide an updated understanding of park harvest. However, efforts to obtain funding for community harvest assessments have been ongoing and pre-date the NPCA report. Currently, NPS, in conjunction with the ADF&G Subsistence Division, are conducting community harvest surveys in four Copper Basin communities and have funding proposals in place for similar surveys in Yakutat and the Upper Tanana region (Cellarius pers. comm.). A cyclical reoccurrence of these surveys would help to further inform the topic of consumptive use, identifying potential trends or resource use patterns.

The ADF&G harvest ticket database contains which Game Management Unit (GMU) an animal was harvested in, and for the majority of individual records in the database, it also indicates what uniform coding unit (UCU) (a smaller geographic unit within each GMU) an animal was harvested in. However, some hunters fail to record the specific UCU when they turn in their harvest ticket. Subsequently, these data represent a coarser scale harvest location, usually only the GMU (Unit and subunit). The ADFG summarizes harvests by species to the public by GMUs. The boundaries of the GMUs do not line-up with the boundaries of the park or preserve in most cases. GMU 11 is the only unit in the Park that is nearly completely (approximately

97%) within the park/preserve boundaries, with a relatively small amount of USFS land in the southwest corner of the unit. Unit 5B is mostly (over 90%) within the park and preserve boundary. Unit 12Z is approximately 50% within the boundary, and unit 6A is partially (less than 15%) within the boundary. Several individual UCUs overlap park boundaries (i.e. portions of UCUs lie within and outside of park boundaries), complicating the understanding of where harvests occur within the park and preserve.

Flora

The consumptive use/harvest of flora in WRST is largely a data gap. Harvest of flora includes firewood harvest, birch bark, berries, and mushrooms. According to the community subsistence information system (ADFG 2009a), community harvest questionnaires identify berries, bull kelp and red seaweed (communities along the coast), and uncategorized vegetation (non commercial harvest). Households in communities examined in the Copper Basin/Upper Tanana 1987 survey harvested an average of 15 lbs of berries and 3 lbs of plants/greens/mushrooms. Examining other surveys with communities with potential to use resources in WRST (Copper River/Upper Tanana 1987, Yakutat Household 2000) the average lbs per household of vegetation (non-commercial) was 11 lbs. This however is the extent of information regarding the harvest of flora in WRST available for this assessment.

<u>Flora data needs</u>

While the harvest of berries, mushrooms, and other plants are important to subsistence use, WRST resource staff are particularily concerned about the lack of data on firewood harvest in WRST. In the context of increasing prices for fuel oil in recent years, subsistence harvest of firewood may be increasing.

Stressors and emerging threats – fish and wildlife harvest

WRST NPS resource staff identified the following stressors on or potential threats to consumptive use of fish and wildlife resources in WRST:

1. Influx of new residents in resident zone communities results in additional pressures on limited subsistence resources;
2. Competition with sport hunters, commercial fishing, and other state-regulated fishing affects subsistence harvest opportunities;
3. Climate change causing a change in consumptive uses;
4. Possible influx of exotic species such as northern pike, Atlantic salmon, and sweetclover (*Melilotus* spp.) may affect subsistence species populations and distribution;
5. Conflicts between state and federal mandates, management, and regulations.
    - Concurrent jurisdiction between NPS and state of Alaska over fish and wildlife populations exists in the Preserve and may affect the subsistence opportunities of federally qualified users and the populations of fish and wildlife that they rely upon.
    - State and federal subsistence policies differ and at times conflict.
    - The complexity of the existing regulations is confusing to both subsistence users and managers, which could provide a threat to continued opportunities for subsistence use.

- State mandates entering into federal regulations present a challenge in managing subsistence opportunities because it can interfere with managing for natural and healthy populations

6. There is a potential for development by the State of Alaska to occur in response to navigability determinations.

Influx of new residents in resident zone communities results in additional pressures on limited subsistence resources.

McCormick (2003) suggested that the growing population of the area puts more demand on subsistence resources in WRST, particularly fisheries. NPS estimated that approximately 6,000 individuals were eligible to engage in subsistence activities in WRST as of 2000 (NPS 2007). While population growth within resident zone communities may present a potential issue by causing increases in subsistence resource pressures, recent resident zone community populations totals have decreased slightly overall (Figure 87). However, census data show that population has increased occurred from 2000 to 2009 in the Municipality of Anchorage (+ 30,305) and the Matanuska-Susitna Borough (+24,992) (AKDOLWD 2010). Population increases in these areas may lead to increased pressure on subsistence resources due to increases in participants of state regulated hunting in the Preserve.

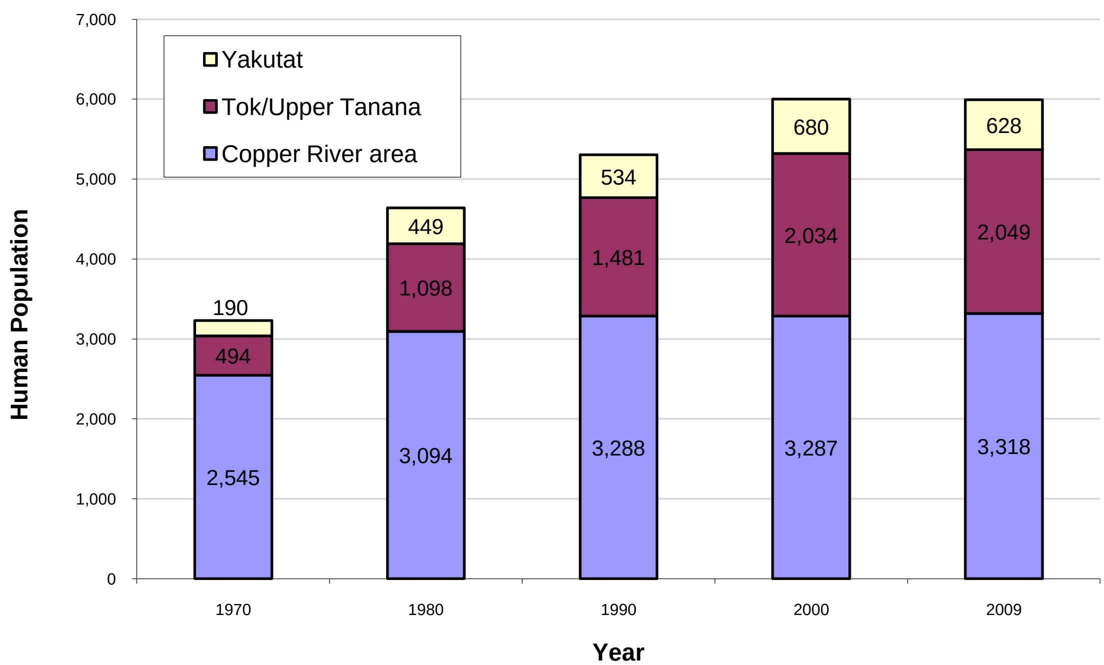


Figure 87. Resident Zone community population. (Alaska Dept. of Community and Econ. Development 2009, Alaska Department of Labor and Workforce Development 2009)

Competition with sport hunters, commercial fishing, and other state-regulated fishing affects subsistence harvest opportunities.

"The ongoing challenge of the subsistence laws is how to apply them in ways that allow for localized traditions to be sustainable" (Wolf 2004). The number of subsistence and personal use salmon harvest permits increased from 1960 through 2000 (Figure 88), but overall harvest from these fisheries has remained stable (Figure 89). As a result, during this period, it is likely the competition of resources increased substantially during this 40 year period. However, permit numbers have shown some relative stability for approximately the last decade and local population growth has generally remained stable from 2000 to 2009. Therefore, these data do not suggest that competition between user groups has increased over the last decade.

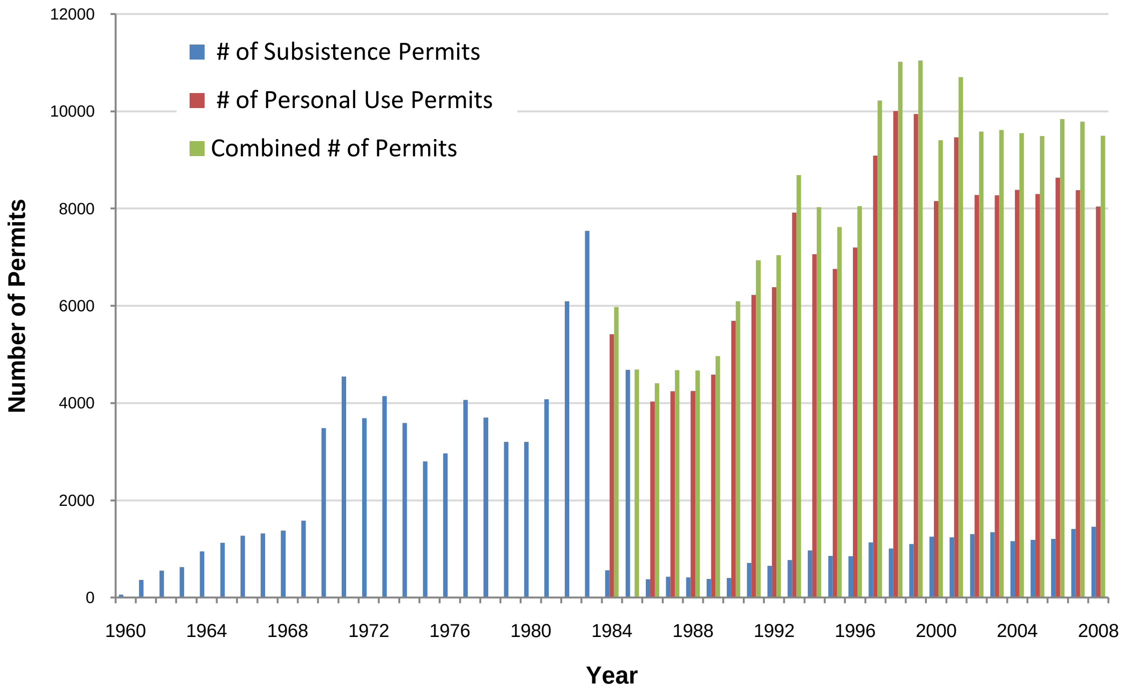


Figure 88. Combined federal and state subsistence and personal use fishery permits issued in the Copper River Basin, 1960-2008. Data 1960-2001 were reported in McCormick (2003), the remaining years (2002-2008) were a combination of ADF&G (2009b) data and NPS unpublished data). McCormick 2003, ADF&G 2009b, NPS unpublished data). From 1960 to 1983 both the Glennallen and Chitina subdistricts. were considered subsistence fisheries and in 1984 the Chitina subdistrict became a personal use fishery with different harvest limits and different regulations. In 2001 the Batzulnetas Federal Fishery began issuing permits, and in 2002 the Federal Fisheries in the Chitina subdistrict began.

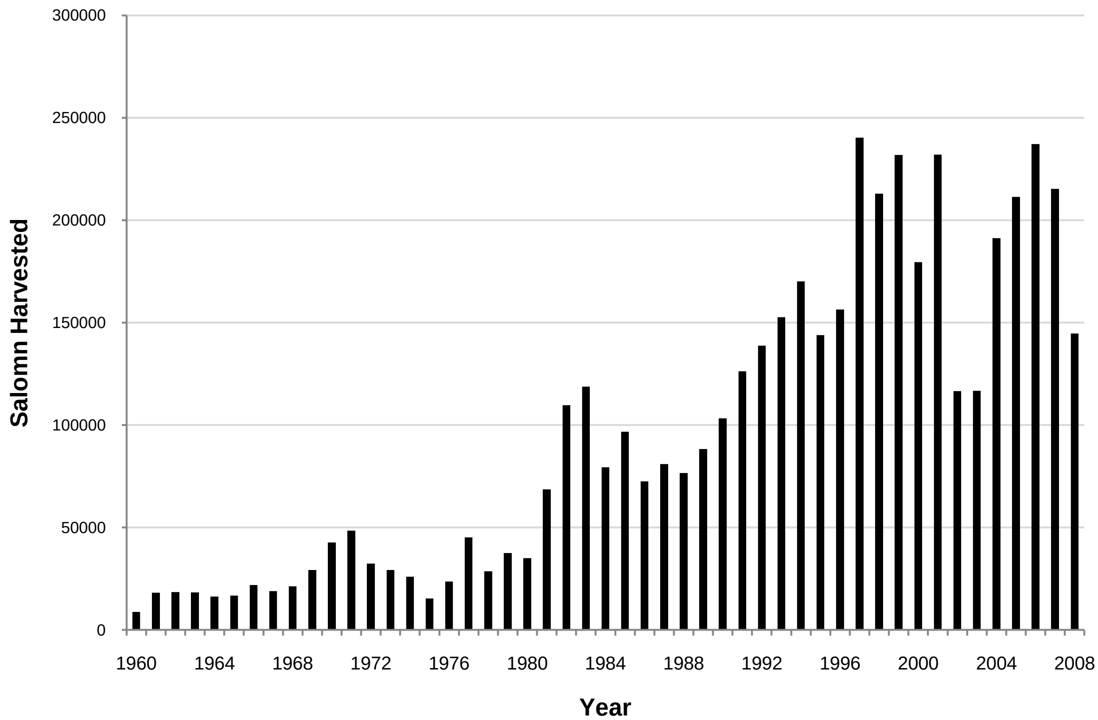


Figure 89. Total estimated salmon harvest in the Copper River Fishery. Data 1960-2001 were reported in McCormick (2003), the remaining years (2002-2008) were a combination of ADF&G (2009b) data and NPS unpublished data). These data include all sockeye, chinook, and coho salmon harvested and recorded in the subsistence fishery. From 1960 to 1983 both the Glennallen and Chitina subdistricts were considered subsistence fisheries and in 1984 the Chitina subdistrict became a personal use fishery with different harvest limits and different regulations. In 2001 the Batzulnetas Federal Fishery began issuing permits and in 2002 the Federal Fisheries on the Chitina Subdistrict in the Upper Copper River District began.

Climate change causing a change in consumptive uses.

Discussion of impacts on specific natural resources are discussed elsewhere in this report. Climate change may also impact the timing and extent of some tradition uses and harvests.

Possible influx of exotic species such as Atlantic salmon and sweetclover (Melilotus spp.) may affect subsistence species populations and distribution.

The influx of non-native species could have significant effects on subsistence species and their populations. This topic is discussed separately in Chapter 4.13 of this report.

Conflicts between state and federal mandates, management, and regulations.

- Concurrent jurisdiction between NPS and state of Alaska over fish and wildlife populations exists in the Preserve and may affect the subsistence opportunities of federally qualified users and the populations of fish and wildlife that they rely upon.

  No information is available that documents this stressor and therefore this represents a potential data need.

- *State and Federal Management objectives differ and at times conflict.*

  The State management of fish and wildlife objectives is focused on maximum sustained yield, whereas federal management of fish and wildlife focuses on maintaining opportunities for subsistence hunting and fishing by local rural residents, and sustaining natural and healthy populations of fish and wildlife. With regard to salmon management, Steve Moffit from ADF&G said ―Our metric is the management plan. That has allocations – supposedly – for all the different user groups. That‗s how we measure our success at the end of the season – has the escapement been met and have the harvests of the different groups been addressed?" (EcoTrust 2005).

- *The complexity of the existing regulations is confusing to both subsistence users and managers, which could provide a threat to continued opportunities for subsistence use.*

  There currently is no information available to quantify any potential effects of complex regulations on the harvest of fish and wildlife resources in WRST.

- *State mandates entering into federal regulation presents a challenge in managing subsistence opportunities because it interferes with managing for natural and healthy populations.*

  An example of this is the potential for predator control on lands adjacent to affected populations within the park or preserve. Management objectives differ between NPS and ADF&G. Depending on the GMU and the species, wildlife populations have different management directions established by ADF&G. Below is an example of the ADF&G management direction for moose in Unit 11 in Tobey (2008). Population objectives include, 1) allow the population to fluctuate as dictated by available habitat and predation rates; and 2) maintain a population with a post-hunt minimum of 30 bulls: 100 cows, with 10-15 adult bull:100 cows. The human use objective is to allow human harvest of bulls when it does not conflict with management goals for the unit or population objectives for the herd. However in Unit 12, which is approximately 50% within and 50% outside the park and preserve, management direction for moose is more complex. Below is the ADF&G management goals, objectives, and intensive management objective for moose in GMU 12 from Gross (2008).

  The management goals include;
  - Protect, maintain, and enhance the moose population in concert with other components of the ecosystem.
  - Continue sustained opportunities for subsistence use of moose.
  - Maximize sustained opportunities to participate in hunting moose.
  - Maximize opportunities for the non-consumptive use of moose.

  Management Objective
  - Maintain a minimum post-hunting sex ratio of 40 bulls:100 cows east of the Nabesna River and a minimum ratio of 20 bulls:100 cows in the remainder of the unit.

  Intensive Management Objectives
  - Population: 4000-6000 moose.

- Harvest: 240-450 moose annually.

There is a potential for development by the State of Alaska to occur in response to navigability determinations.

This is a potential emerging threat, but no information was found on possible new developments or any potential stress they might create.

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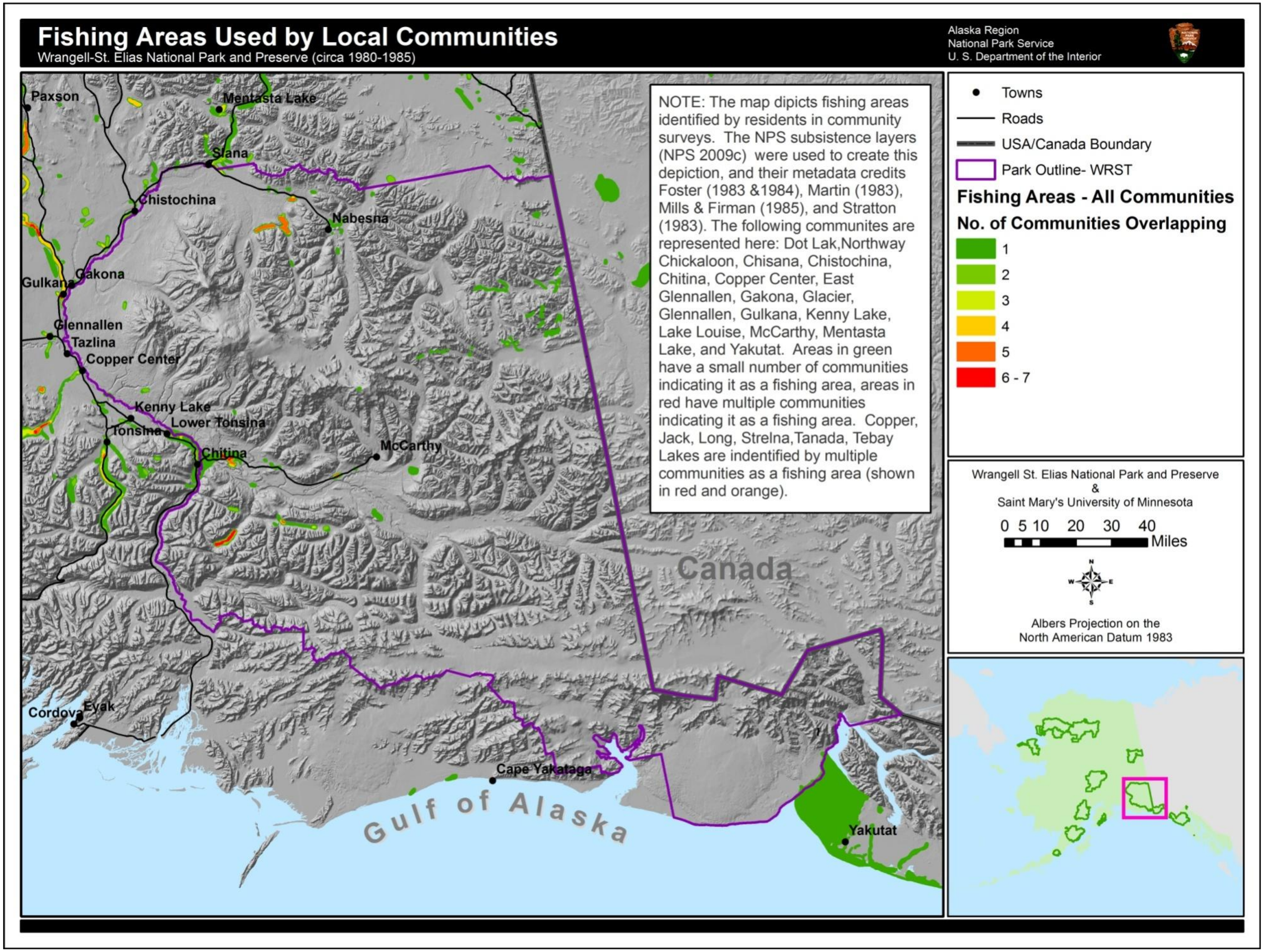


Plate 49. Fishing areas used by local communities from a community harvest survey. (NPS PDS 2009a)

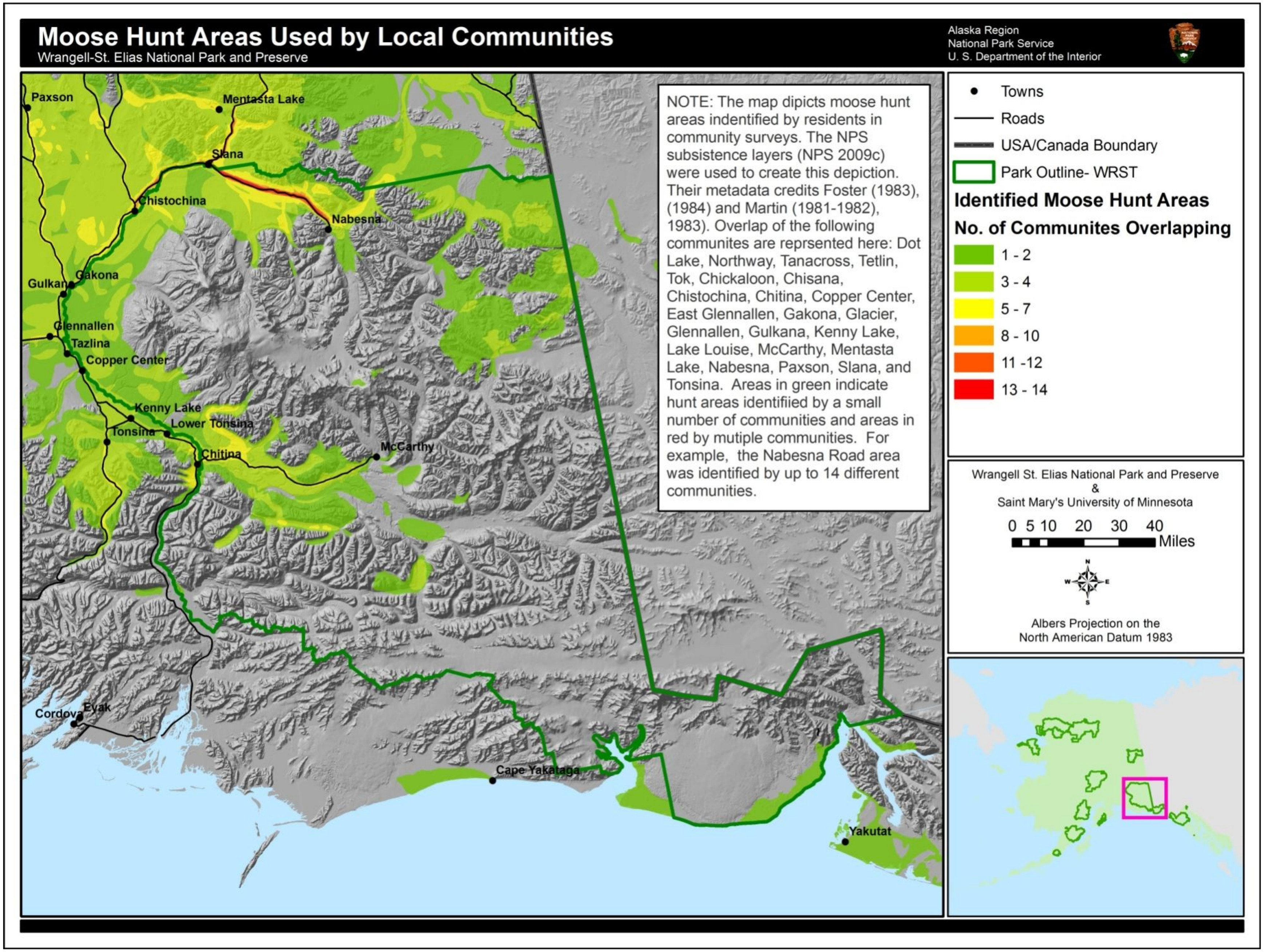


Plate 50. Moose hunt areas used by local communities. (NPS PDS 2009a)

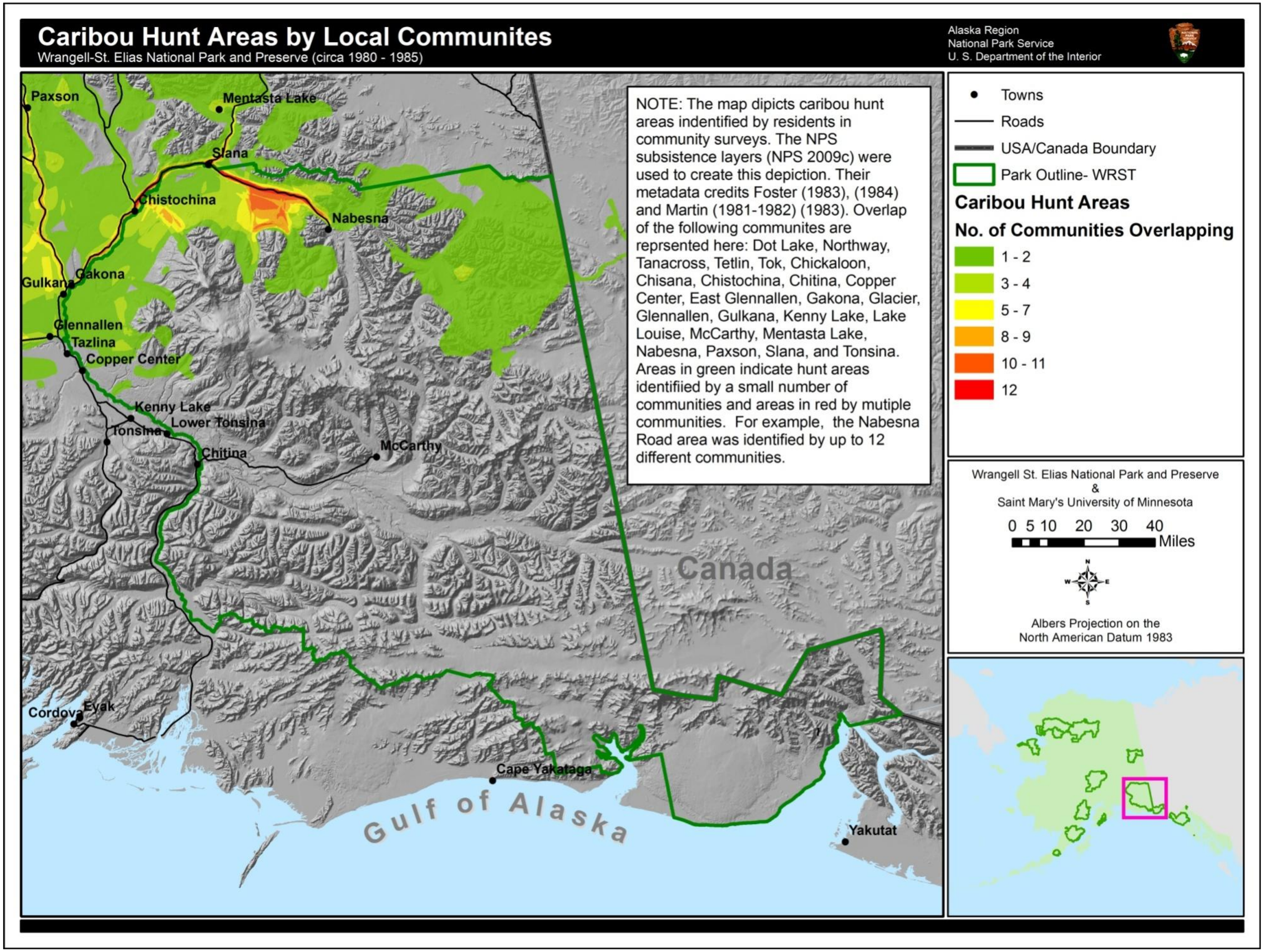


Plate 51. Caribou hunt areas by local communities. (NPS PDS 2009a)

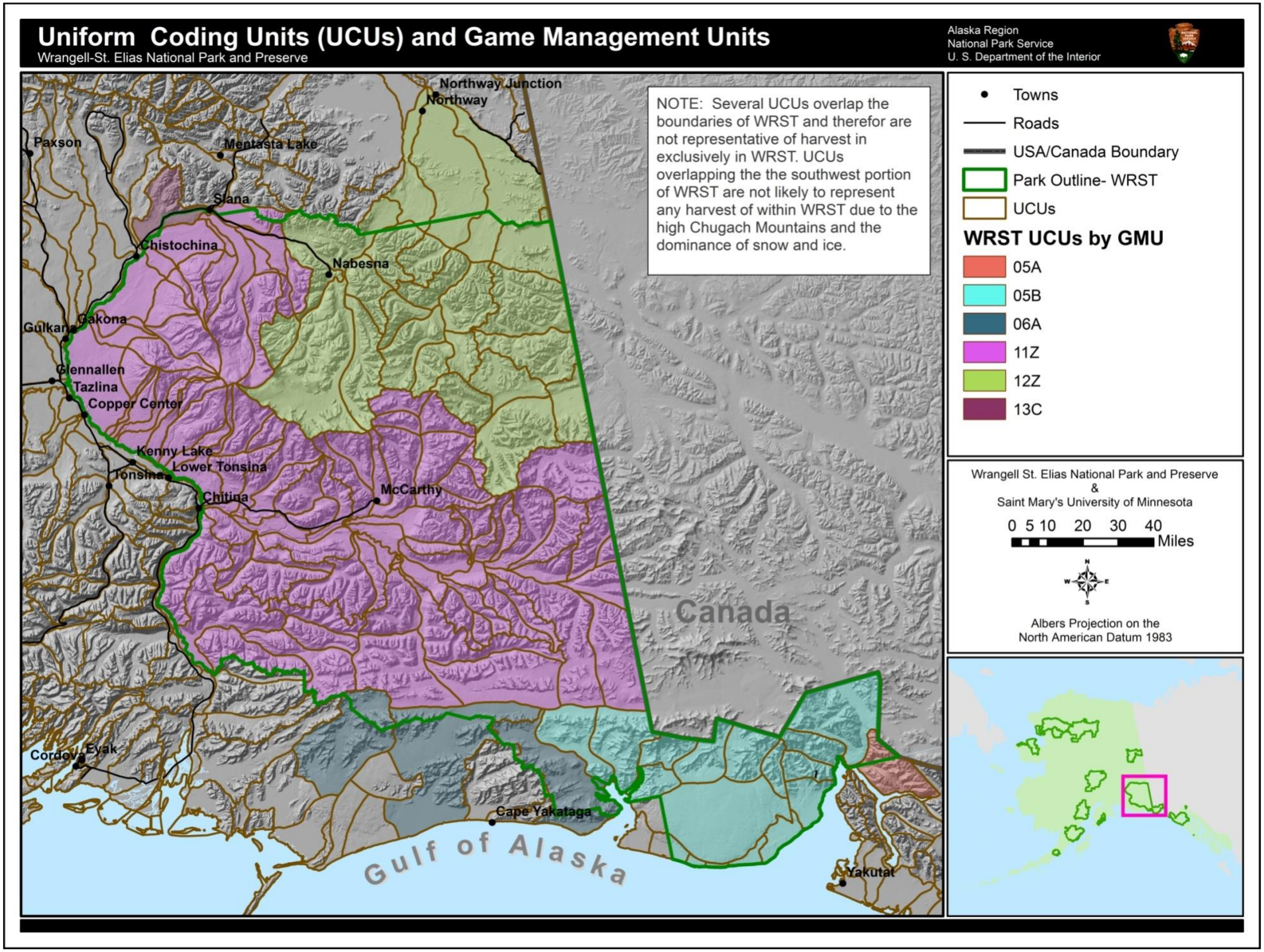
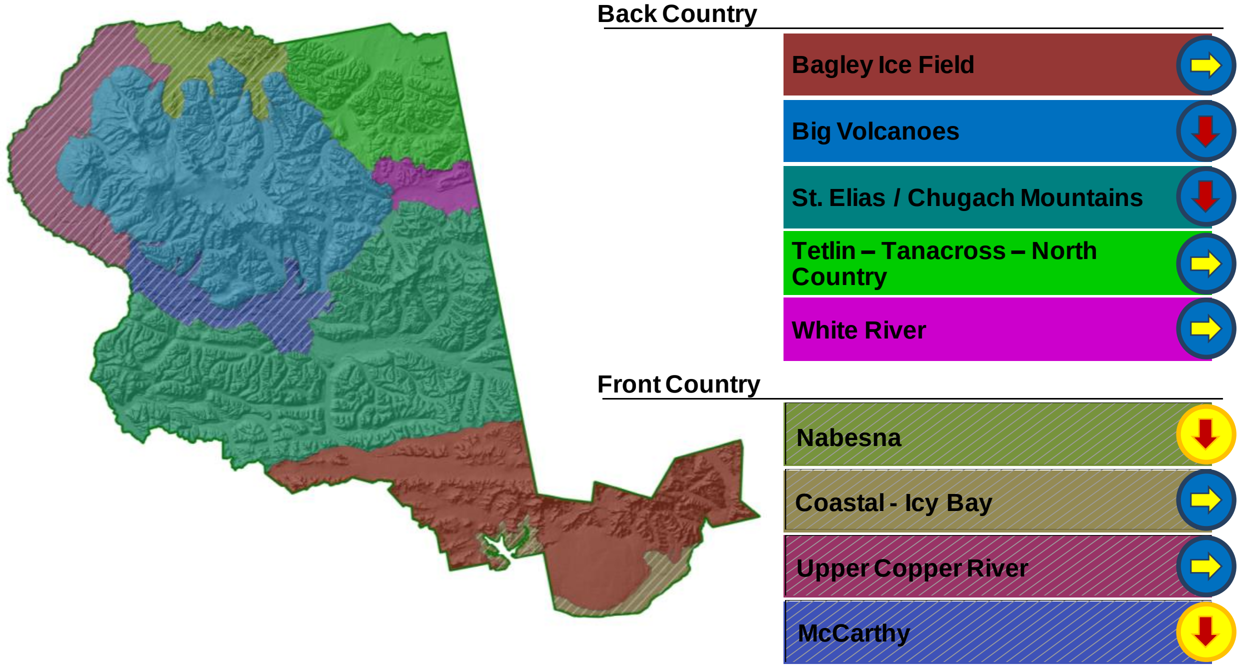


Plate 52. UCUs and GMUs in WRST. (NPS PDS 2009b)

4.25 Human Presence

Indicators and Measures

Visitor Use Intensity and Spatial Distribution



Condition

Human presence has impacts on the natural environment. In WRST human presence and activity is focused along the Nabesna and McCarthy roads and in the area around McCarthy and Kennecott Mines National Historic Landmark (NHL). As a whole, given the size of the park and the relatively limited visitor use, the condition in the McCarthy and Nabesna RZs are of moderate concern with a declining trend and all other zones are in good condition. In the St. Elias/Chugach Mountains and the Big Volcanoes RZs, resource managers suspect certain locales may be receiving increasing human use, therefore the condition is designated as good with a decreasing trend. The trend of condition appears to be stable for all of the RZs in WRST.

Visitor use in WRST is quite low when compared to other Alaska NPS units such as Glacier Bay National Park and Preserve, Denali National Park and Preserve, and Sitka National Historic Park. The distribution of visitors in WRST is generally concentrated in the McCarthy/Kennecott area. Visitors primarily use the Nabesna and McCarthy roads to access points of interest in the park. Visitor use is heaviest in natural and cultural sites in the McCarthy/Kennecott area (Littlejohn 1996, Scott 2009a). In the McCarthy/Kennecott area scenic driving, wildlife viewing, walking around/ touring, and day hiking are the most common activities (Littlejohn 1996). The Nabesna road corridor and OHV trails see high visitor use in the fall during hunting season. Preliminary data, mainly from Commercial Use Authorization (CUA) reports, suggest that remote locations appear to have relatively low use in comparison to road accessible sites. However, visitor use data, collected through a variety of methods are difficult to analyze (Scott 2009a).

Human presence background

Visitor use is important because it is one of the primary agents of change in protected natural areas (Lawson 2006). The NPS Central Alaska Network (CAKN) identifies human presence/ use as a vital sign, with the objective of monitoring long-term trends in the spatial distribution of human presence in CAKN parks by season, level and type of activity (MacCluskie and Oakley 2005). CAKN also identifies trails as a vital sign. For the purpose of this assessment, human presence is a function of visitor use numbers, visitor use distribution, and trail and airstrip use.

Accessibility is a crucial factor that drives the human presence in National Park units. The primary access to WRST is via the 42 mile Nabesna and the 59 mile McCarthy roads. Though the Park Visitor Center is often a first stop for visitors, the facility is located outside WRST, nearly 74 miles from the nearest park land along the McCarthy road and approximately 83 miles from the nearest park land along the Nabesna road (Scott 2009a). These two roads provide the only drivable access into the park and represent the most common method of access for visitors pursuing recreational activities. Littlejohn (1996) indicates private vehicles, rental cars, and recreational vehicles (RV‘s) account for the vast majority of reported forms of transportation in WRST. However, other major of forms of access include flights to airstrips and floatplane lakes, OHV use on designated trails, and hiking on trails and overland routes, most of which start from the Nabesna or McCarthy roads or from backcountry landing strips.

Understanding visitors use patterns, such as density of use, locations of use, and types of use, within WRST is challenging, but data collection protocols are under development. The main data sources used for this assessment include a visitor use survey conducted in 1995 (Littlejohn 1996), reported visitor use statistics from the NPS Public Use Statistics Office (NPS 2009a), spatial layers from the Alaska NPS Permanent Data set, and a recent examination of visitor use location and density using Geographic Information Systems technology (GIS) (Scott 2009a).

Reference condition

The human presence reference condition is low intensity within a wilderness setting interspersed with a few widely distributed, small communities and individual homesteads. Though this reference condition is somewhat generalized, it is important to recognize that visitor use can quantifiably affect sensitive animals and ecosystems in a primarily natural landscape such as WRST. The CAKN Vital Signs Monitoring Plan considers human activities as stressors to park ecosystems (MacCluskie and Oakley 2005). Understanding the trends in visitor use can aid management in minimizing these effects (Fay and Colt 2007). Visitor use numbers, the spatial distribution of visitation and, the intensity of trail, campsites, and landing strip use in the park are all important indicators of human presence in WRST. Particularly of interest are OHV effects on vegetation, wetlands, and soils. These quantifiable effects result in changes to the wilderness character of the park.

Visitor use numbers

When compared with other Alaska National Park units, WRST has a relatively low number of reported recreational visitors per year and very low density of visitors by total land area. The following are data from the National Public Use Statistics Office of the NPS. In 2009, WRST is sixth in the number of reported recreational visitors for Alaska NPS units, behind Klondike Gold Rush, Glacier Bay, Denali, Sitka, and Kenai Fjords, respectively. When comparing the number of recreational visitors by NPS unit land area, WRST is eighth behind Sitka, Klondike Gold Rush, Kenai Fjords, Glacier Bay, Denali, Gates of the Arctic and Katmai park units (Table 50).

Table 50. Recreational visitor numbers and density in Alaska NPS units. (Visitor information from NPS 2009a, and land area from NPS PDS 2009a)

NPS unit	2009* visitors	total land area (mi^2)	visitors per (mi^2)
Klondike Gold Rush	880,512	20.3	43,374.98
Glacier Bay	438,361	5,130.8	85.44
Denali	358,041	9,416.9	38.02
Sitka	246,866	0.2	1,234,330.00
Kenai Fjords	218,358	1,042.8	209.40
Wrangell-St. Elias	59,966	20,589	2.91
Katmai	43035	6,405.8	6.72
Gates of the Arctic	9,975	1,323.8	7.54
Lake Clark	9,711	6,304	1.54
Yukon-Charley Rivers	6,432	3,940.3	1.63
Noatak	2,474	10,280.9	0.24
Kobuk Valley	1,879	2,737.2	0.69
Cape Krusenstern	1,810	1,031.2	1.76
Bering Land Bridge	1,054	4,351.2	0.24
Aniakchak	14	942.9	0.01

Note: The number of visitors reported here follow the counting and reporting instructions according to the NPS Office of Public Use Statistics. For WRST this includes the number of visitors to the visitor center, Slana, Chitina, and Yakutat ranger station, and adds an estimation to account for the number of visitors entering the park but not going to the visitor center or a ranger station. This estimation is calculated using forty-eight percent of the sum of the visitor center and ranger station. These data do not include tour ships.

Since there are no entrance stations in WRST, visitors are counted at the following locations: the Copper Center and Kennecott visitor centers, the Slana, Chitina, and Yakutat ranger stations (NPS 1998). WRST has also attempted to quantify visitor numbers through reports from vendors operating under a concession or commercial use authorization in the park. These include air taxis, wilderness guides, hunting and fishing guides, and rafting guides (Scott 2009a). While this provides a partial understanding of visitor use it is by no means a complete one.

The total number of recorded visitors steadily increased from 1982 to 1995 (NPS 2009a). In 1996, it appears that there was a large dip in park visitation, which is likely due to a change in visitor reporting methods (Scott 2009b). Numbers of visitors to WRST have been increasing since this change (Figure 90). Like most Alaska NPS units, WRST recreational use is highest in the summer months (Figure 91).

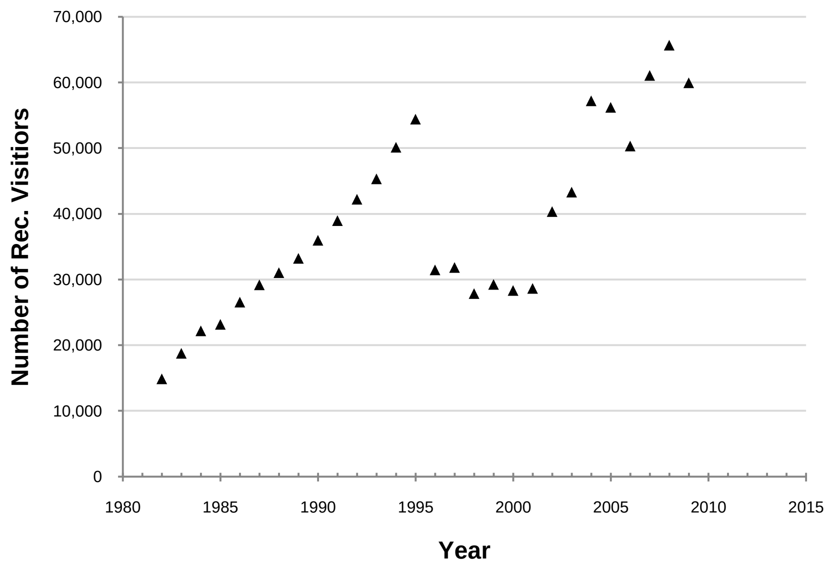


Figure 90. Total recorded visitors, WRST, 1982-2009. (NPS 2009a). Note: The number of visitors shown here were calcualted using the counting and reporting instructions according to the NPS Office of Public Use Statistics. For WRST this includes the number of visitors to the visitor center, Slana, Chitina, and Yakutat ranger station, and adds an estimation to account for the number of visitors entering the park but not going to the visitor center or a ranger station. This estimation is calculated using forty-eight percent of the sum of the visitor center and ranger station.These data do not include individuals on tour ships.

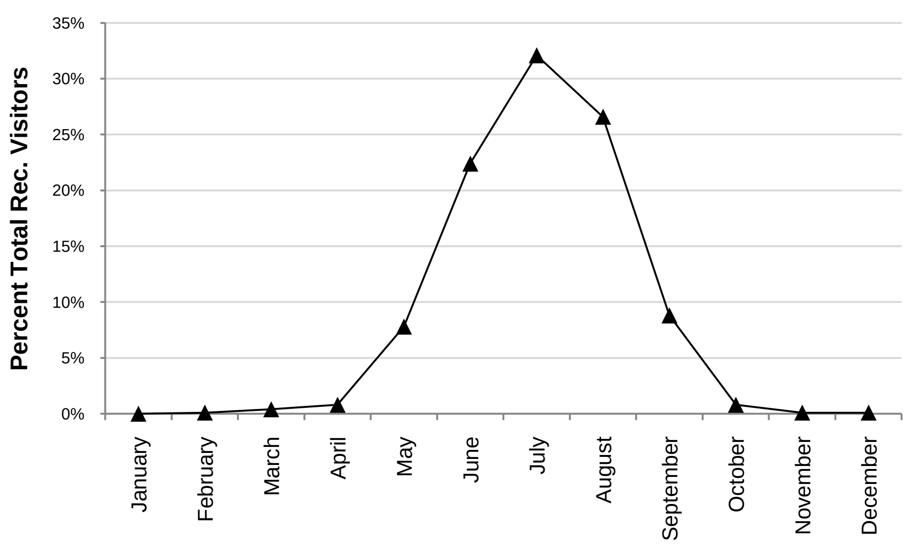


Figure 91. Percent of recreation visitation by month in WRST during 2009. (NPS 2009a)

Visitor use distribution

When asked in a 1996 visitor questionnaire, respondents commonly visited just a few main sites in WRST: McCarthy (58% of visitors), Kennecott mine/Kennicott (53% of visitors), the park visitor center (52% of visitors), and the Kuskulana bridge (39% of visitors) (Littlejohn 1996). When asked to name the first site visited, the Greater Copper Valley Chamber of Commerce Visitor Information Center and the Chitina Ranger Station were the most common sites noted by respondents (Littlejohn 1996). The Littlejohn (1996) report was done before the establishment of the Kennecott National Historic Landmark and before the construction of the new Copper Center visitor center. A more recent examination of visitor use from 2002 to 2007 found that the new Park visitor center receives the largest number of visitors (23,363) over the three year period of analysis by Scott (2009a). Finally, when asked where visitors day hike, 26% (n=298) reported the Kennecott mine/Kennicott, 14.7% indicated the Root Glacier, 12.8% indicated McCarthy, 10% indicated an unspecified glacier, and 7.4% indicated the Bonanza mine (Littlejohn 1996).

The most recent visitor use study (Scott 2009a) utilized data from 2000 to 2007 and included several different sources: ADF&G hunt reports, state of Alaska highway data, NPS bear-resistant food container loans (BRFC), NPS backcountry report forms, NPS Commercial Use Authorization report forms (CUA), NPS backcountry observation forms, and state of Alaska transporter activity reports. Data from these sources were combined and then related to point locations, showing concentrations of visitor use across various locations in WRST (Scott 2009a).

Table 51. Reported visitation by location in WRST, 2000-2007. (Scott 2009b)

Place	Reported Visitors	% of Total Visitors*	Visitor Days	% of Visitor Days**
Root Glacier	9,588	39.4	519,484	66.9
Kennicott Glacier	4,260	17.5	153,421	19.8
Landing Strip, Skolai	1,055	4.3	7,687	1.0
McCarthy Creek	732	3.0	19,728	2.5
Iceberg Lake	598	2.5	3,642	0.5
Kennicott River Launch	566	2.3	3,811	0.5
McCarthy Town	401	1.6	3,139	0.4
Nizina Glacier	369	1.5	1,494	0.2
Landing Strip, Glacier Creek	290	1.2	1,496	0.2
Landing Strip, Huberts	281	1.2	844	0.1
Bonanza Mine	242	1.0	898	0.1

*These do not sum to 100% as trails accounting for less than one percent were not included in this table. There were 181 other locations in the database with less than 0.1 % of the total people visiting.
**Calculated as number of visitors by number of days reported (length of stay)
Note: the data in this table do not include cruise ship visits to the Russell Fjord area.

It is important to note that it is likely that authorized users of the Native corporation lands come and go without any record by NPS (Scott 2009a). The majority of the data used by Scott (2009b) came from CUA reports and some ADF&G hunt records. Scott (2009a) also notes that there is no legal obligation to report flights from state or private lands to private lands in WRST. The NPS issues CUAs to persons (referring to individuals, corporations or other entities) to provide commercial services to park visitors (NPS 2006). In WRST, many different commercial visitor services are approved including air taxi, guided backpacking, guided boating, guided dog sled rides, guided hiking, guided horse packing, guided horse rides, big game transport, incidental big game transport, guided kayaking, guided mountaineering, guided photography, guided sport-fishing, commercial vehicle tours, guided winter back country trips skiing, sledding, snowshoeing, and guided wagon rides (NPS 2006). The reports contain beginning and end locations and route information with GPS coordinates. It is unknown if the CUA reports are representative of visitors to WRST. However, the Root and Kennicott Glaciers are clearly the most visited locations in WRST. Appendix K displays all locations reported visited and the frequency of visits.

Trail & River Route Use

Several types of trail use occur in WRST including (but not limited to) walking, hiking, mountaineering, horseback riding, OHV use, dog sledding, and snowmobile use. However, a majority of the data focuses on OHV trails because of their effect on soils, vegetation, wetlands, and wildlife; and, potentially, to values such as visitor experience, scenic quality, cultural resources and subsistence opportunities. Trail use information is recorded from a variety of sources, including recreational OHV permits, backcountry reports, bear resistant food container (BRFC) forms, and CUAs. When combined, these sources provide an indication of trail use by total number of visitors (Table 52). The McCarthy Creek/ Nizina River route accounts for 48% of total trail visitors. Several other trails in the vicinity of the Kennecott/McCarthy area also show a high number of reported visitors.

Table 52. Common trails and river routes used in WRST, 2002 to 2007. (Scott 2009b)

Trail or Route	# of Visitors	% of Total**
McCarthy Creek, Nizina River	2,891	48.18
Kennecott, Donoho	445	7.42
Root Glacier trail	430	7.17
Kennecott, Kennicott Glacier	338	5.63
Kennicott, Chitina River	211	3.52
Bonanza Trail*	156	2.60
Kennicott River, Copper River	153	2.55
Goat Trail	146	2.43
Dixie Pass	142	2.37
Lost Creek Trail*	104	1.73
Bremner, Iceberg Lake	101	1.68
Kennicott River, Cordova	86	1.43
Trail Creek Trail*	67	1.12
Kennicott, Nizina	58	0.97

*Off-highway-vehicle permitted trail.
**This does not sum to 100% as trails accounting for less than one percent were not included in this table.

Off-highway-vehicle trail area

OHV trails traversing wetlands, permafrost soils, and steep slopes are of particular concern along the Nabesna Road (Weeks 2003). Trail use occurs by both subsistence and recreational OHV users. Subsistence users are encouraged to obtain a permit and to use established trails and dry river beds; however, no designation of specific subsistence OHV routes or trails is in effect. Recreational OHV users are required to obtain a permit, and are currently only allowed on the following trails along Nabesna Road: Caribou Creek, Trail Creek, Lost Creek, Soda Creek, and Reeve‘s Field as well as Nugget Creek and Kotsina trails off the McCarthy Road. Copper Lake (beyond the Boomerang trail), Suslota Lake, and Tanada Lake trails are currently closed to recreation ORV use. The Boomerang trail, accessed via the Copper Lake trail is open to use.

An EIS is being developed to assess a range of alternatives for managing recreational off-road use on the nine Nabesna road area trails. This statement addresses impacts to soils, vegetation, wetlands, wildlife, visitor experience, scenic quality, cultural resources, and subsistence opportunities (NPS 2008). ―Mud bogs" along trails can cause trail braiding (expansion of existing trail footprints) and can impact wetlands, soils, and vegetation (NPS 2008).

Trail width or braiding associated with OHV use is detected using visible wetland and vegetation signatures on IKONOS near-infrared satellite imagery. Using GPS-defined locations of OHV trails for orientation, visible vegetation scars are interpreted from background imagery and digitized in GIS to represent the true affected area of OHV use. The exact time period or history of use represented by visible changes to vegetation and wetland patterns on the imagery is unknown. However, points measured on Suslota, Tanada and Copper Lake OHV trails in the 1985 and again in 2008 indicate that the average trail width for Suslota grew slightly and, for Tanada, it almost doubled (NPS, Blaine Anderson Biologist, pers. comm.) In the photo-interpretation process, braided trail sections are included in one polygon only when there is less than 30 meters between parallel braided trail sections. For distances greater than 30 meters, braids are digitized separately, creating an island of non-trail area between braids. Plate 54 shows trail braiding on IKONOS imagery (GeoEye) and digitized OHV trail width by image interpretation.

The standard footprint for OHV trails is a two meter width (NPS, Anderson & Meyers, pers. comm.). Comparing a two meter wide footprint to the photo-interpreted footprint of actual trail use creates an indication of the amount of expansion for each trail. This trail expansion acts as a qualitative indication of damage to wetlands, soils, and vegetation beyond the trail centerline. In this analysis, the Suslota, Tanada, Copper Lake, and Reeve's Field trails show the highest percent of damaged area respectively (Table 53).

Table 53. OHV trail area interpreted by vegetation signature on 2004-2006 IKONOS imagery.

Trail Name	2 Meter Width Area (acres)[a]	Total Trail Area (acres)[b]	Trail Braiding (acres)[c]	% Braided Area (acres)[d]
Suslota Trai*l	5.8	138.5	132.7	96
Tanada Lake Trail*	14.3	261.7	247.4	95
Copper Lake Trai*l	29.3	229.6	200.4	87
Reeve's Field Trail*	4.0	29.4	25.4	86
Soda Creek Trail*	9.6	15.1	5.6	37
Batzulnetas Trail	4.1	6.4	2.3	36
Boomerang Lake Trail*	13.5	19.5	5.9	31
Kotsina River Trail	22.0	27.8	5.9	21
Jacksina Trail	1.0	1.3	0.2	18
Caribou Creek Trail*	2.9	3.5	0.6	17
Nugget Creek	14.8	15.1	0.3	2
Trail Creek Trai*l	4.8	4.8	0	0
Lost Creek Trail*	5.7	5.7	0	0

[a] calculated by multiplying the length of all segments (meters) by 2, then converting to acres.
[b] This includes photo-interpreted trail braiding area.
[c] Braiding is the area of trail beyond the normal 2 meter wide ORV trail footprint.
[d] This represents the relative level of braiding and an indication of relative historic damage by trail.
*These trails are included in an Environmental Impact Statement (EIS)
Note: Trail Creek and Lost Creek Trails follow creeks and the primary surface character is gravel or mixed fines and gravel, therefore vegetation was not interpreted for these trails and no additional trail area was determined to be

Trails by Reporting Zone

Trails in WRST are concentrated along the Nabesna and McCarthy roads, in comparison to the more remote areas of the park. The highest density of both hiking and OHV trails occurs in the Nabesna RZ. This zone contains 30 hiking trails, 10 hiking routes and 21 OHV trails (Table 54, Table 55). While, none of the OHV densities are really high, the highest density is 1.6 mi/mi^2 in the (Nabesna RZ).

Table 54. Hiking trails and routes by reporting zone. (Scott 2009b)

Reporting Zone	Reporting Zone Area (mi^2)*	# of Hiking Trails	# of Hiking Routes	Length (mi.)	Density of Trails**
St. Elias/ Chugach Mountains	6,326	5	7	216.1	0.034
Nabesna	715	30	10	192.0	0.269
Tetlin-Tanacross-North Country	1,895	14	2	179.6	0.095
McCarthy	845	29	1	105.6	0.125
Big Volcanoes	5,056	20	4	34.1	0.007
White River	397	1	1	22.9	0.058
Upper Copper River	129	0	1	2.1	0.016
Bagley Icefield - Malaspina	3,660	0	0	0	0
Coastal-Icy Bay	388	0	0	0	0
Total	19,411	99	26	752.3	

*total reporting zone land area regardless of land status

**calculated by miles of trail per square mile of reporting zone land area.

Table 55. OHV trails by reporting zones. (Scott 2009b)

Reporting Zone	Reporting Zone Area (mi^2)*	# of Trails	Length (mi)	Trail Density**
Nabesna	715	21	140.6	1.60
McCarthy	845	2	45.9	0.4
St. Elias/ Chugach Mountains	6,326	0	34.1	0[a]
Big Volcanoes	5,056	1	7.9	0[a]
Bagley Icefield - Malaspina	3,660	0	0.0	0
Coastal-Icy Bay	388	0	0.0	0
Upper Copper River	129	0	0.0	0
Tetlin-Tanacross -North Country	1,895	9	0.0	0
White River	397	0	0.0	0
Total	19,411	33	228.5	

*total reporting zone land area regardless of land status

**calculated by miles of trail per square mile of reporting zone land area.

[a] less than 0.1 mi/mi^2

Airstrip use

Landing strip use in WRST is not well understood. The data presented here only represent flights that require a CUA permit and report. These data do not include trips such as flights to private landing strips and administrative flights. As a result, the available information likely does not represent a complete summary of actual landing/air strip use in WRST. Unimproved airstrips, gravel bars, tundra ridges, glaciers, and lakes, exist in most backcountry regions of WRST, and fixed-wing aircraft are permitted to land and operate on lands and waters in the park and preserve (Weeks 2003). WRST provides maintenance on approximately 20 airstrips, the state of Alaska maintains four airstrips, and private owners maintain several others (NPS, Miranda Terwilliger WRST Ecologist, pers. comm.).

In the visitor locations database there are 454 records listed as an airport, air strip, landing strip, or float lake in WRST (Scott 2009b). Only 30 of these locations report visitors. Sources of visitor reports include CUA reports, BRFC, backcountry reports, and backcountry observations from 2002 to 2007 (Scott 2009b). The landing strip with the heaviest visitor use is Skolai, followed by Glacier Creek and Huberts landing strips, Horsfeld, Moose Valley West Fork, Wolverine, Jake‘s Bar, Chelle, and Ali‘s Valley landing strips.

Stressors and Issues

NPS staff noted several issues or stressors to general visitor use, trail use, and airstrip use in WRST (see below).

Visitor use stressors/issues

- Increased use of trails and campsites can cause damage to the natural environment such as trampling, loss of ground cover and erosion, and an increase in human waste and associated issues.
- High visitor density can degrade the wilderness experience of other users.
- Expansion of use areas

Trail stressors/issues:

- Demand for more and developed trails and road and facility improvements and possible overuse of existing trails. This is under examination for the Nabesna OHV EIS.
- Use during wet periods or during freeze thaw cycles.
- Location of trails in sensitive ecological zones, where damage is likely to occur.
- Management of easements

Airstrip stressors/issues:

- Flooding can washout airstrips
- Vegetation growth requires maintenance on airstrips.
- Low funding for adequate maintenance and to address any safety issues

Data needs

The NPS Southwest Alaska Network (SWAN) indentifies the data needs for monitoring long-term visitor impacts, which could also be applied to WRST. They include the following:

- Number of visitors and guides by location
- Number of visitor/guide days by location
- Number of visitor/guide nights by location
- Visitor activities by location

- Party or group size
- Length of stay by location guided or unguided
- Method of travel to and within the park
- Method of transportation access
- Spatial and temporal travel patterns – timing of visits, trip itineraries of multiple day trips.

Data needs for understanding visitor use levels and spatial distribution in WRST are summarized as the need to answer fundamental questions such as when, where, and how many people enter an area or location and where they go once in the park.

- Stream-lined visitor use data collection sources (CUA, BRFC, back-country reports, etc.) which create standardized data that are comparable year to year.
- Relational database of CUA reports in order to analyze these as an individual data source.

Data needs for understanding OHV use and trail degradation include:

- Ongoing monitoring of use levels and trail responses as well as weather

Data needs for understanding non-OHV trail use:

- Completion of a GIS trail database, including standardized data fields and documentation using thorough metadata.
- Information on the temporal and spatial pattern of hiking, horseback riding, and snowmobile use of trails

Data needs for understanding landing strip and airstrip use:

- Completion of a GIS airstrips database, including standardized data fields and documentation using thorough metadata
- Relational database of CUA reports in order to analyze these as an individual data source.
- Stream-lined visitor use data collection sources (CUA, BRFC, back-country reports, etc.) in order to create standardized data that are comparable year to year.
- Documentation of administrative and private flight airstrip use. Private use could be ascertained through questionnaires, whereas administrative flights could be through direct reporting.

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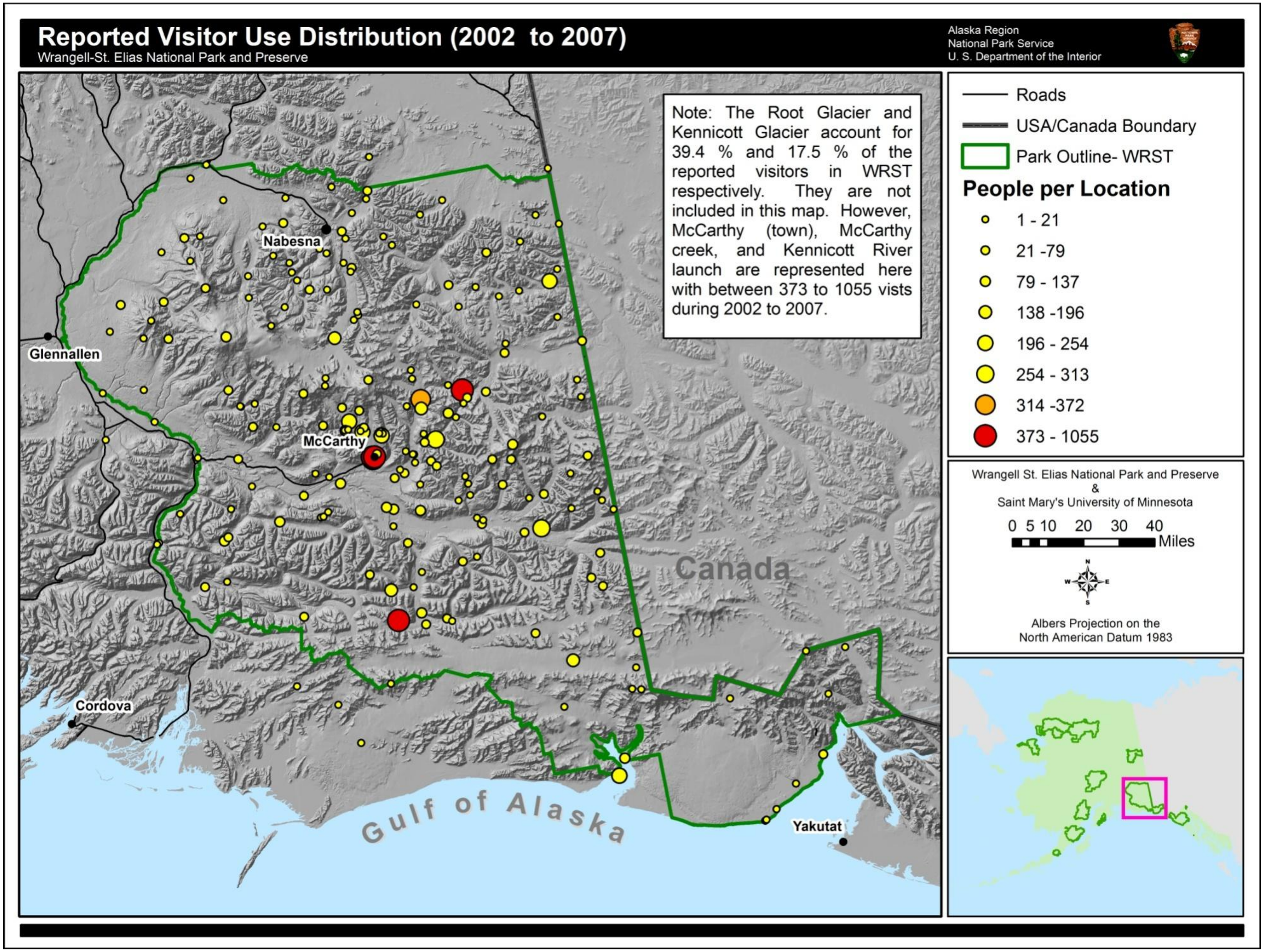


Plate 53. Reported visitor use distribution, WRST, 2002-2007. (Scott 2009b)

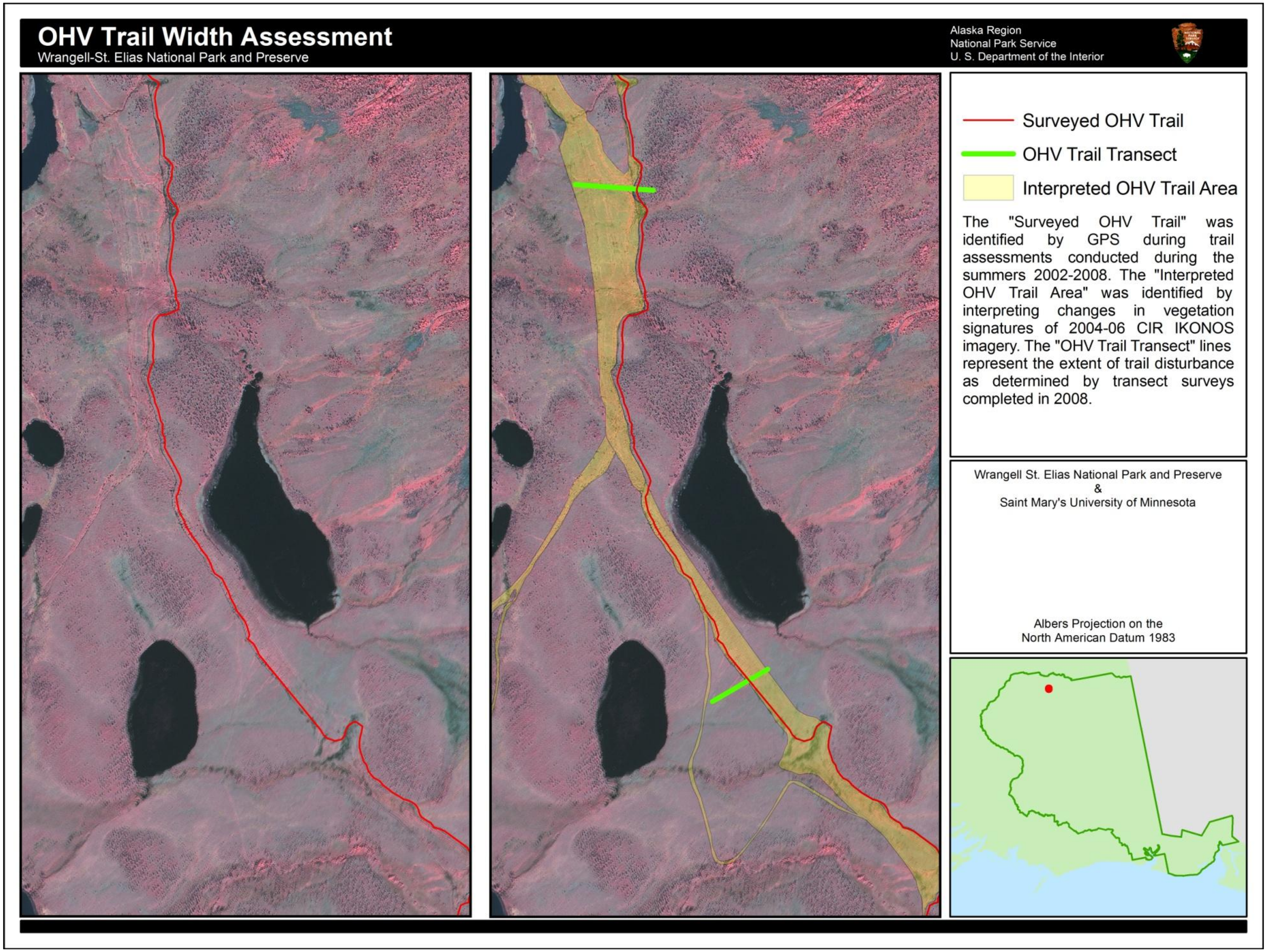
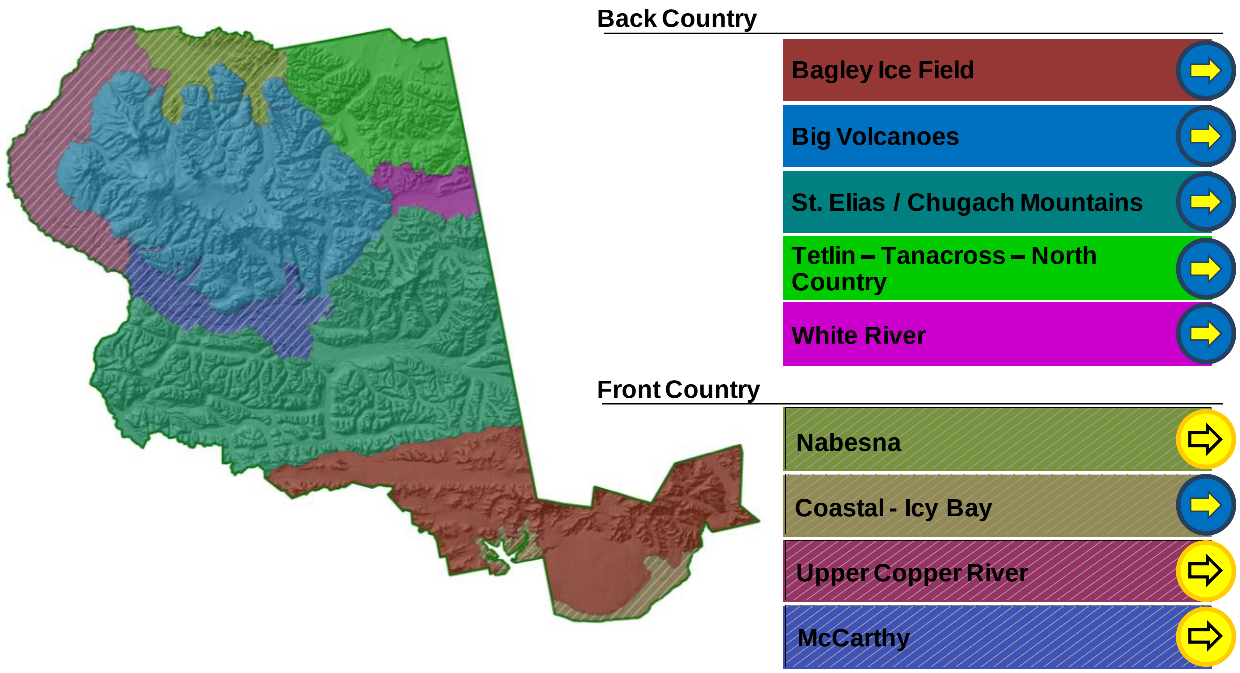


Plate 54. OHV trail width assessment, Nabesna Area. (NPS PDS 2009b, NPS PDS 2009c)

4.26 Viewshed

Indicators and Measures
Natural Undeveloped Viewsheds



Condition
The viewsheds in WRST are in good condition, except for the Nabesna Upper Copper River, and McCarthy RZs which are of moderate concern due to human presence. On a whole, logging, mining, oil and gas exploration, airborne pollution, and other stressors that would affect WRST viewsheds are not prevalent.

Background

A viewshed is the area that can be "seen" from a particular target location. The National Park Service Organic Act (16 U.S.C. l) implies the need to protect the viewsheds of National Parks, Monuments, and Reservations. In addition, the WRST Foundation Statement establishes "Superlative Scenic Beauty" as a significant resource in the Park and Preserve (NPS 2007). Three elements describe this resource in WRST: expansive vistas, ecological resources, and scenic wildlands. The scenic wildlands element is defined as natural and undeveloped viewsheds, including water bodies and landforms that dominate the viewscape (NPS 2007).

Reference Condition

The reference condition for viewsheds in WRST, as described in the framework of this NRCA, is an –unimpaired wilderness park experience."

Stressors

Stressors to viewsheds in WRST include logging activities, mineral development, oil and gas exploration, industrial expansion (e.g. power generation), restoration activities in the National Historic Landmark (Kennecott Mines), communication towers, seismic lines, wildland fires, airborne pollutants, snowmachine tracks, and OHV access trails. All of these stressors are present in WRST at some level.

Data Needs

WRST viewsheds are currently undefined. Areas of highest concern are those with the highest visitor use, such as the WRST Visitor Center, Nabesna and McCarthy road corridors, Kennecott Mines National Historic Landmark, Russell Fjord, and the Richardson Highway viewpoints. In addition, investigation into the effects of non-point stressors such as long range transportation of industrial pollution could be beneficial.

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Chapter 5: Discussion

Park Wide Condition

Assessing the condition of WRST natural resources at a park-wide or landscape level is challenging. First, WRST is not a single, homogenous landscape. At 13.2 million acres, WRST encompasses three mountain ranges, numerous watersheds and subwatersheds, and a suite of unique ecological systems. In fact the largest reporting zone (St. Elias/Chugach Mountains) is nearly twice the size of Yellowstone National Park and nearly three times larger than Glacier National Park. Second, defining a sole condition for the whole park implies that the interrelationships between all of the components comprising this vast and diverse area are simple and easy to understand.

However, it can be stated confidently that WRST represents a premier North American wilderness area, based on the limited human impacts, and the presence and quality of the natural resources across the large and diverse landscape. While human presence is evident in some areas of front country RZs, the back country RZs may be considered pristine in comparison to much of North America. In addition, it can be confidently stated that the fish, wildlife, and plant communities in WRST are functioning in a healthy manner.

Component Condition Summaries

Definition of reference condition proved to be the biggest challenge in defining the condition of components in this NRCA. While ANILCA mandates that NPS manage WRST Park lands (vs. Preserve lands) for ―natural and healthy populations" of fish and wildlife, this might not be the best or most realistic reference condition. Nothing defines what value of a given measure (e.g. population size, fire return interval, age and sex ratio) constitutes a ―natural and healthy" resource. A "natural and healthy" reference condition actually refers to a component‘s measurable values at a vague moment in time that is unknown, making comparison to the present condition virtually impossible. Additionally, ANILCA recognizes subsistence use as part of the ―natural and healthy" condition of WRST; this complicates the assessment of harvested species.

For these reasons, this NRCA relies on the best professional judgment of WRST resource specialists to create condition statements for components where data and information are particularly lacking. This makes it difficult to estimate assessment confidence. However, in the absence of quantified metrics, we believe this was the best method available. We also believe that the synthesis of literature and data presented in this document would aid the process of reformulating component reference conditions for similar documents in the future. In conclusion, "natural and healthy" is an appropriate management direction, but is problematic as a reference condition for NRCAs.

Data Needs

There are significant data gaps for most resource categories in WRST. For biological components, accurate, park-wide population estimates and population parameter data are lacking for many key species, such as fresh water fish, many plant species, moose, and Dall‘s sheep. Additionally, population estimates are completely absent for carnivores in the park.

Significant knowledge gaps also exist regarding the chemical and physical characteristics of WRST. While data are available regarding air and water quality, thorough analyses have not been completed. Additionally, resource vulnerability due to climate change is currently unknown.

WRST provides the public with many park values that are not well documented or easily quantified. Viewsheds, soundscapes, wilderness, air and water quality, and quality of visitor experience are some examples. While there is data regarding use by visitors who use commercial services, data for those who do not is limited. As a result, these topics are difficult to assess.

While the size and difficulty of accessing WRST help to preserve its wilderness character, these qualities also represent significant challenges for efficient and cost effective data collection. The intent of this condition assessment is to present a comprehensive summary of data needs.

NRCA Lessons Learned

We learned many lessons during development of this NRCA that will hopefully benefit future projects. NPS staff engagement and interaction is a key factor in conducting an NRCA. We also believe that quality of information, with respect to defining resource condition, is more important than the quantity acquired; the best way to determine high quality information is through engagement with NPS resource staff. Specifically, independent data and literature searches do not result in information that is as relevant to defining resource condition as data and literature recommended or provided by NPS resource specialists. In addition, the lack of analog data and literature represents a potential information resource that is outside the realistic reach of projects implemented at this scale.

We found that the initial immaturity of the NRCA program created project inefficiencies. However, as the program has evolved, new guidance provided significant focus to the WRST NRCA. Because of this, we believe this project and report represent the most comprehensive summary of available information specific to describing Wrangell-St. Elias natural resource conditions.

Appendices

Page

Appendix A. WRST Peaks and Summits Analysis

Introduction

As part of the development of the Wrangell-St. Elias National Park and Preserve - Natural Resource Condition Assessment (WRST NRCA), GeoSpatial Services (GSS) conducted a geomorphologic analysis of the mountains of Wrangell-St. Elias National Park and Preserve (WRST). LandSerf ™, a free GIS application, is used for this analysis. The outputs of the analysis include peaks, defined as areas of topographic prominence, and summits, defined as the highest points on a peak.

Methods

A thirty meter digital elevation model is used in this analysis in the form of a grid entitled wrstef.grd. This data set is a subset of the National Elevation Data set (NED) for Alaska and is the result of a set individual tiles from the NED, which were mosaiced for an area of interest surrounding the park, and then projected to Alaska Albers and converted to an integer grid. A one mile buffer of the Park and Preserve is used as a mask to extract the area of interest and to reduce the file size and analysis time. The resulting grid is then converted to a file type usable in LandSerf ™ called ‗.bil‘.

Minimum drops of one thousand feet (304.8 m), two thousand feet (609.6 m), and three thousand feet (914.4 m) surrounding peaks, provide a three different parameters for this analysis. All three analyses use a minimum height of peak of two thousand feet (609.6 m). This creates both a GIS point file indicating the summits and a grid representing the peaks (peak areas) for each of three minimum drops analyses.

Results

The following tables offer summaries of the number of summits identified by RZ in the WRST Natural Resource Condition Assessment and by the analysis parameter of minimum drop surrounding peaks (Table 1, Table 2, Table 3). The following tables include summits within 200 meters of the WRST boundary. This allows for inclusion of important peaks of mountains such as St. Elias, Hubbard, Alverstone, and TomWhite that may lack locational accuracy because of the relative coarseness of the DEM used in the analysis. In addition to the tables below, the summits (points) and the peak areas (grids) are contained in a geodatabase called ‗PeakFeatures.mdb‘. Figure 1 illustrates a sample area showing peaks and summits based on the three parameters (one, two, and three thousand foot relative drops) chosen for the analysis.

Table 1. Summits Identified by: 1,000 ft. Relative Drop & 2,000 ft. Min. Elevation.

Reporting Zone*	# of Summits	Minimum Drop		Maximum Drop		Minimum Elevation		Maximum Elevation	
		(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)
BIM	82	1000	304.8	18061*	5505.0	2969	905.0	18061*	5504.9
BVL	105	1002	305.4	11527	3513.4	5064	1543.5	16323	4975.2
CIB	1	1011	308.2	1011	308.2	3632	1107.0	3632	1107.0
LRC	0	-	-	-	-	-	-	-	-
MCC	3	1087	331.3	1537	468.5	2775	845.8	6884	2098.2
NAB	14	1041	317.3	5155	1571.2	4524	1378.9	8274	2521.9
SEM	267	1000	304.8	12002	3658.2	2423	738.5	16430	5007.9
TTN	46	1000	304.8	4244	1293.6	4011	1222.5	9339	2846.5
WHR	3	1054	321.3	1482	451.7	5255	1601.7	5590	1703.8
Total	521								

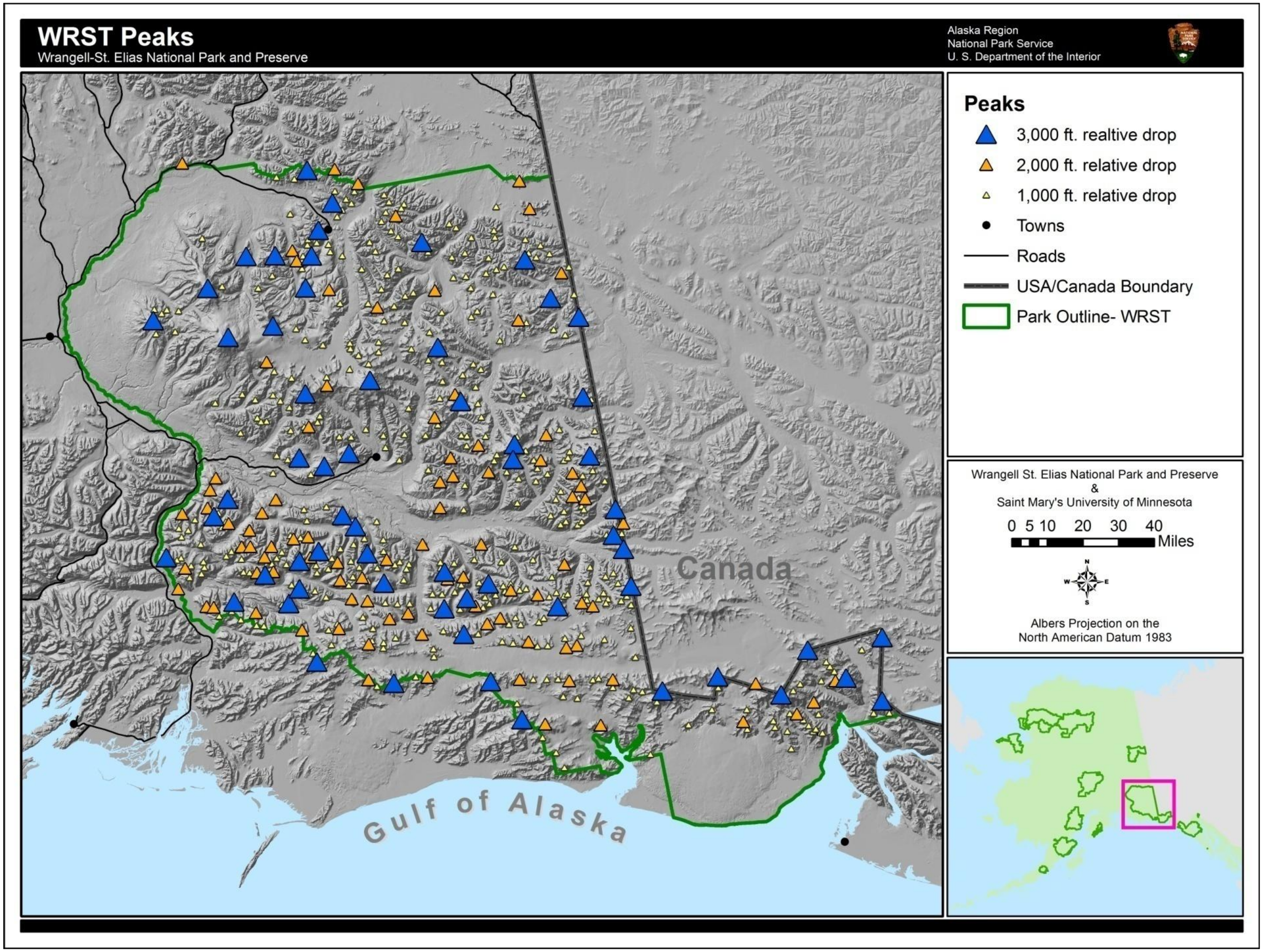
Table 2. Summits Identified by: 1,000 ft. Relative Drop & 2,000 ft. Min. Elevation.

Reporting Zone*	# of Summits	Minimum Drop		Maximum Drop		Minimum Elevation		Maximum Elevation	
		(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)
BIM	24	2031	619.0	18061	5505.0	5582	1701.4	18061	5505.0
BVL	24	2011	612.9	11527	3513.4	6450	1966.0	16323	4975.3
CIB	0	-	-	-	-	-	-	-	-
LRC	0	-	-	-	-	-	-	-	-
MCC	0	-	-	-	-	-	-	-	-
NAB	4	2590	789.4	5155	1571.2	6503	1982.1	8274	2521.9
SEM	85	2011	612.9	12002	3658.2	2423	738.5	16430	5007.9
TTN	10	2052	625.4	4244	1293.6	4960	1511.8	9339	2846.5
WHR	0	-	-	-	-	-	-	-	-
Total	147								

Table 3. Summits Identified by: 1,000 ft. Relative Drop & 2,000 ft. Min. Elevation.

Reporting Zone*	# of Summits	Minimum Drop		Maximum Drop		Minimum Elevation		Maximum Elevation	
		(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)
BIM	10	4552	1387.4	18061	5505.0	9575	2918.5	18061	5505.0
BVL	15	3084	940.0	11527	3513.4	6450	1966.0	16323	4975.3
CIB	0	-	-	-	-	-	-	-	-
LRC	0	-	-	-	-	-	-	-	-
MCC	0	-	-	-	-	-	-	-	-
NAB	3	3104	946.1	5155	1571.2	6503	1982.1	8274	2521.9
SEM	28	3017	919.6	12002	3658.2	5935	1809.0	16430	5007.9
TTN	4	3091	942.1	4244	1293.6	6751	2057.7	9339	2846.5
WHR	0	-	-	-	-	-	-	-	-
Total	60								

Figure 1. Peaks in WRST - GSS Peak Analysis.



Appendix B. Dall's sheep sex ratio statistics from all surveys, separated into SRRs, developed from data received from Judy Putera, Feb 8, 2010.

	Number of Surveys	Average (Range) Rams: 100 Ewes	Average (Range) Lambs: 100 Ewes
Big Volcanoes North	12	35.0 (9.6 – 61.0)	24.7 (4.2 – 36.2)
Big Volcanoes Southeast	14	27.2 (5.2 – 56.8)	26.9 (11.4 – 39.4)
Big Volcanoes Southwest	52	34.1 (4.9 – 79.0)	26.8 (9.2 – 55.1)
Nabesna	4	39.3 (24.1 – 55.0)	27.8 (14.1 – 47.2)
St. Elias/ Chugach Mountains East	48	36.1 (10.0 – 90.2)	27.4 (11.2 – 54.8)
St. Elias/ Chugach Mountains South	2	41.3 (26.7 – 55.8)	32.5 (31.7 – 33.3)
St. Elias/ Chugach Mountains West	3	52.1 (32.0 – 89.5)	19.1 (7.9 – 32.0)
Tetlin-Tanacross	22	49.4 (20.5 – 86.8)	28.1 (4.8 – 43.3)

Appendix C. Dall's sheep Lamb: Ewe: Ram Ratios from the most recent surveys for all WRST SSUs, subdivided by geographic group. Data received from Judy Putera, Feb 8, 2010.

Big Volcanoes North

SSU	Year	Rams per 100 Ewe	Lambs per 100 Ewe	Sample Size
02	2002	60.9	36.2	207
03	2009	27.0	23.8	718
04E	2006	47.6	38.4	121
04W	2006	42.5	43.1	585

Big Volcanoes Southeast

SSU	Year	Rams per 100 Ewe	Lambs per 100 Ewe	Sample Size
15	1999	24.2	26.2	149
16	1992	22.1	34.0	303
17	1983	24.1	26.7	282
18	1983	56.8	19.1	257

Big Volcanoes Southwest

SSU	Year	Rams per 100 Ewe	Lambs per 100 Ewe	Sample Size
10	1990	9.9	22.5	147
11	2009	13.1	17.5	149
12	2009	79.0	24.7	165
13	1992	19.6	14.1	123
14	2006	47.7	38.5	121

Nabesna

SSU	Year	Rams per 100 Ewe	Lambs per 100 Ewe	Sample Size
01	2002	54.9	21.4	1014

St. Elias East

SSU	Year	Rams per 100 Ewe	Lambs per 100 Ewe	Sample Size
19	1983	51.6	54.8	128
20	2002	50.5	30.8	194
21	2002	38.0	34.7	209
22	2002	39.4	31.7	243
24	1983	33.9	41.1	98
23E and 23W	2002	90.2	40.6	307

St. Elias South

SSU	Year	Rams per 100 Ewe	Lambs per 100 Ewe	Sample Size
29	1983	Nodata	Nodata	0
30/31	1984	55.8	31.7	95
31	1991	Nodata	Nodata	27

Appendix C. Dall's sheep Lamb: Ewe: Ram Ratios from the most recent surveys for all WRST SSUs, subdivided by geographic group. Data received from Judy Putera, Feb 8, 2010. (continued)

St. Elias West

SSU	Year	Rams per 100 Ewe	Lambs per 100 Ewe	Sample Size
25	1983	32.0	32.0	41
26	2002	Nodata	Nodata	0
27	1983	34.6	17.3	114
28	1983	Nodata	Nodata	0

Tetlin - Tanacross - North Country

SSU	Year	Rams per 100 Ewe	Lambs per 100 Ewe	Sample Size
05E	2001	66.2	12.8	376
05W	2001	46.7	20.8	484
07E	2002	57.1	29.5	709
07W	2005	48.5	24.2	449
09	2005	49.1	24.5	757

Appendix D. Birds of Wrangell-St. Elias documented in NPSpecies database and presence on NABBS Routes (refer to http://www.pwrc.usgs.gov/bbs/ for raw data regarding NABBS).

Species Common Name	Scientific Name	NPSpecies Park Status	McCarthy Road	Kuskulana	Kenny Lake	Chisto-china	Nabesna Road	Nabesna
Alder Flycatcher	*Empidonax alnorum*	Present in Park	X	X	X	X	X	
Aleutian Tern	*Onychoprion aleuticus*	Present in Park						
American Cliff Swallow, Cliff Swallow	*Petrochelidon pyrrhonota*	Present in Park						
American Coot	*Fulica americana*	Present in Park						
American Dipper	*Cinclus mexicanus*	Present in Park					X	
American Kestrel	*Falco sparverius*	Present in Park					X	
American Pipit, Buff-bellied Pipit	*Anthus rubescens*	Present in Park						
American Robin	*Turdus migratorius*	Present in Park	X	X	X	X	X	X
American Three-toed Woodpecker	*Picoides dorsalis*	Present in Park			X	X	X	
American Tree Sparrow	*Spizella arborea*	Present in Park				X	X	X
American Wigeon	*Anas americana*	Present in Park	X		X	X	X	
American Yellow Warbler, Yellow Warber	*Dendroica petechia*	Present in Park						
Ancient Murrelet	*Synthliboramphus antiquus*	Present in Park						
Arctic Redpoll, Hoary Redpoll	*Carduelis hornemanni*	Present in Park						
Arctic Tern	*Sterna paradisaea*	Present in Park	X	X	X	X	X	
Arctic Warbler	*Phylloscopus borealis*	Present in Park						
Baird's Sandpiper	*Calidris bairdii*	Present in Park						
Bald Eagle	*Haliaeetus leucocephalus*	Present in Park	X	X	X	X		
Bank Swallow, Sand Martin	*Riparia riparia*	Present in Park						
Barn Swallow	*Hirundo rustica*	Present in Park						
Barrow's Goldeneye	*Bucephala islandica*	Present in Park	X	X	X		X	
Belted Kingfisher	*Megaceryle alcyon*	Present in Park	X	X	X	X	X	

Appendix D. Birds of Wrangell-St. Elias documented in NPSpecies database and presence on NABBS Routes (refer to http://www.pwrc.usgs.gov/bbs/ for raw data regarding NABBS). (continued)

Species Common Name	Scientific Name	NPSpecies Park Status	McCarthy Road	Kuskulana	Kenny Lake	Chisto-china	Nabesna Road	Nabesna
Black Oystercatcher	*Haematopus bachmani*	Present in Park						
Black Scoter	*Melanitta nigra*	Present in Park						
Black Turnstone	*Arenaria melanocephala*	Present in Park						
Black-backed Woodpecker	*Picoides arcticus*	Present in Park						
Black-billed Magpie	*Pica hudsonia*	Present in Park	X	X	X	X	X	
Black-capped Chickadee	*Poecile atricapillus*	Present in Park	X	X	X	X	X	
Black-legged Kittiwake	*Rissa tridactyla*	Present in Park						
Blackpoll Warbler	*Dendroica striata*	Present in Park	X	X	X	X	X	
Blue-winged Teal	*Anas discors*	Present in Park			X			
Bohemian Waxwing	*Bombycilla garrulus*	Present in Park	X	X	X	X	X	X
Bonaparte's Gull	*Larus philadelphia*	Present in Park	X	X		X	X	
Boreal Chickadee	*Poecile hudsonica*	Present in Park	X	X	X	X	X	X
Boreal Owl	*Aegolius funereus*	Present in Park			X			
Brant, Brent Goose, Brant Goose	*Branta bernicla*	Present in Park						
Brewer's Sparrow	*Spizella breweri*	Present in Park						
Brown Creeper	*Certhia americana*	Present in Park						
Bufflehead	*Bucephala albeola*	Present in Park	X		X	X	X	
Canada Goose	*Branta canadensis*	Present in Park				X	X	
Canvasback	*Aythya valisineria*	Present in Park						
Caspian Tern	*Hydroprogne caspia*	Present in Park						
Cassin's Auklet	*Ptychoramphus aleuticus*	Present in Park						
Chestnut-backed Chickadee	*Poecile rufescens*	Present in Park						
Chipping Sparrow	*Spizella passerina*	Present in Park			X	X		
Common Goldeneye	*Bucephala clangula*	Present in Park	X		X	X		

Appendix D. Birds of Wrangell-St. Elias documented in NPSpecies database and presence on NABBS Routes (refer to http://www.pwrc.usgs.gov/bbs/ for raw data regarding NABBS). (continued)

Species Common Name	Scientific Name	NPSpecies Park Status	McCarthy Road	Kuskulana	Kenny Lake	Chisto-china	Nabesna Road	Nebesna
Common Loon	*Gavia immer*	Present in Park	X	X		X	X	
Common Merganser	*Mergus merganser*	Present in Park			X	X		
Common Murre	*Uria aalge*	Present in Park						
Common Redpoll	*Carduelis flammea*	Present in Park	X	X	X	X	X	
Common Snipe	*Gallinago gallinago*	Present in Park						
Dark-eyed Junco	*Junco hyemalis*	Present in Park	X	X	X		X	
Double-crested Cormorat	*Phalacrocorax auritus*	Present in Park						
Downy Woodpecker	*Picoides pubescens*	Present in Park	X	X	X	X	X	
Dunlin	*Calidris alpina*	Present in Park						
Eurasian Teal, Green-winged Teal	*Anas crecca*	Present in Park						
Eurasian Wigeon	*Anas penelope*	Present in Park						
Fox Sparrow	*Passerella iliaca*	Present in Park	X	X	X	X	X	
Gadwall	*Anas strepera*	Present in Park						
Glaucous Gull	*Larus hyperboreus*	Present in Park						
Glaucous-winged Gull	*Larus glaucescens*	Present in Park		X				
Golden Eagle	*Aquila chrysaetos*	Present in Park					X	
Golden-crowned Kinglet	*Regulus satrapa*	Present in Park		X	X			
Golden-crowned Sparrow	*Zonotrichia atricapilla*	Present in Park	X					
Gray-cheeked Thrush, Grey-cheeked Thrush	*Catharus minimus*	Present in Park						
Gray-crowned Rosy-Finch, Grey-crowned Rosy Finch	*Leucosticte tephrocotis*	Present in Park						
Gray-headed Chickadee	*Poecile cinctus*	Present in Park						
Great Blue Heron	*Ardea herodias*	Present in Park						
Great Gray Owl	*Strix nebulosa*	Present in Park		X				
Great Horned Owl	*Bubo virginianus*	Present in Park	X	X	X	X	X	

Appendix D. Birds of Wrangell-St. Elias documented in NPSpecies database and presence on NABBS Routes (refer to http://www.pwrc.usgs.gov/bbs/ for raw data regarding NABBS). (continued)

Species Common Name	Scientific Name	NPSpecies Park Status	McCarthy Road	Kuskulana	Kenny Lake	Chisto-china	Nabesna Road	Nabesna
Greater Scaup	*Aythya marila*	Present in Park	X	X	X	X	X	
Greater White-fronted Goose	*Anser albifrons*	Present in Park			X			
Gray Jay	*Perisoreus canadensis*	Present in Park	X	X	X	X	X	X
Grey Plover, Black-bellied Plover	*Pluvialis squatarola*	Present in Park						
Gyrfalcon	*Falco rusticolus*	Present in Park					X	
Hairy Woodpecker	*Picoides villosus*	Present in Park	X	X	X	X	X	
Harlequin Duck	*Histrionicus histrionicus*	Present in Park						
Hermit Thrush	*Catharus guttatus*	Present in Park	X	X	X	X	X	X
Herring Gull	*Larus argentatus*	Present in Park		X	X	X	X	
Horned Grebe	*Podiceps auritus*	Present in Park	X		X	X	X	X
Horned Lark	*Eremophila alpestris*	Present in Park						
Hudsonian Godwit	*Limosa haemastica*	Present in Park						
Killdeer	*Charadrius vociferus*	Present in Park						
Kittlitz's Murrelet	*Brachyramphus brevirostris*	Present in Park						
Lapland Longspur	*Calcarius lapponicus*	Present in Park						
Least Sandpiper	*Calidris minutilla*	Present in Park						
American Golden-Plover	*Pluvialis dominica*	Present in Park				X	X	
Lesser Scaup	*Aythya affinis*	Present in Park	X	X	X	X	X	
Lesser Yellowlegs	*Tringa flavipes*	Present in Park	X	X	X	X	X	X
Lincoln's Sparrow	*Melospiza lincolnii*	Present in Park	X	X	X	X	X	X
Long-billed Dowitcher	*Limnodromus scolopaceus*	Present in Park						
Long-tailed Duck, Oldsquaw	*Clangula hyemalis*	Present in Park						

Appendix D. Birds of Wrangell-St. Elias documented in NPSpecies database and presence on NABBS Routes (refer to http://www.pwrc.usgs.gov/bbs/ for raw data regarding NABBS). (continued)

Species Common Name	Scientific Name	NPSpecies Park Status	McCarthy Road	Kuskulana	Kenny Lake	Chisto-china	Nabesna Road	Nabesna
Long-tailed Jaeger	*Stercorarius longicaudus*	Present in Park						
Mallard	*Anas platyrhynchos*	Present in Park	X	X	X	X	X	X
Marbled Murrelet	*Brachyramphus marmoratus*	Present in Park						
Merlin	*Falco columbarius*	Present in Park			X	X	X	
Mew Gull	*Larus canus*	Present in Park	X	X	X	X	X	
Mountain Bluebird	*Sialia currucoides*	Present in Park						
Northern Flicker	*Colaptes auratus*	Present in Park						
Northern Goshawk	*Accipiter gentilis*	Present in Park	X		X			
Northern Harrier	*Circus cyaneus*	Present in Park			X			
Northern Hawk Owl	*Surnia ulula*	Present in Park			X		X	
Northern Pintail	*Anas acuta*	Present in Park			X		X	X
Common Raven	*Corvus corax*	Present in Park	X	X	X	X	X	
Northern Shoveler	*Anas clypeata*	Present in Park	X		X		X	X
Northern Shrike, Great Grey Shrike	*Lanius excubitor*	Present in Park						
Northern Waterthrush	*Seiurus noveboracensis*	Present in Park	X	X	X	X	X	
Northern Wheatear	*Oenanthe oenanthe*	Present in Park						
Northwestern Crow	*Corvus caurinus*	Present in Park						
Olive-sided Flycatcher	*Contopus cooperi*	Present in Park	X	X	X	X	X	
Orange-crowned Warbler	*Vermivora celata*	Present in Park	X	X	X	X	X	
Osprey	*Pandion haliaetus*	Present in Park						
Pacific Loon	*Gavia pacifica*	Present in Park	X	X			X	
Parasitic Jaeger	*Stercorarius parasiticus*	Present in Park						
Pectoral Sandpiper	*Calidris melanotos*	Present in Park						

Appendix D. Birds of Wrangell-St. Elias documented in NPSpecies database and presence on NABBS Routes (refer to http://www.pwrc.usgs.gov/bbs/ for raw data regarding NABBS). (continued)

Species Common Name	Scientific Name	NPSpecies Park Status	McCarthy Road	Kuskulana	Kenny Lake	Chisto-china	Nabesna Road	Nabesna
Pelagic Cormorant	*Phalacrocorax pelagicus*	Present in Park						
Peregrine Falcon	*Falco peregrinus*	Present in Park						
Pigeon Guillemot	*Cepphus columba*	Present in Park						
Pine Grosbeak	*Pinicola enucleator*	Present in Park	X	X	X	X	X	
Pine Siskin	*Carduelis pinus*	Present in Park	X	X	X		X	X
Pomarine Jaeger, Pomarine Skua	*Stercorarius pomarinus*	Present in Park						
Red Crossbill	*Loxia curvirostra*	Present in Park						
Red Knot	*Calidris canutus*	Present in Park						
Red Phalarope	*Phalaropus fulicarius*	Present in Park						
Red-breasted Merganser	*Mergus serrator*	Present in Park			X			
Red-breasted Nuthatch	*Sitta canadensis*	Present in Park		X			X	
Red-breasted Sapsucker	*Sphyrapicus ruber*	Present in Park						
Redhead	*Aythya americana*	Present in Park						
Red-necked Grebe	*Podiceps grisegena*	Present in Park	X	X	X			
Red-necked Phalarope	*Phalaropus lobatus*	Present in Park	X		X	X		
Red-tailed Hawk	*Buteo jamaicensis*	Present in Park		X	X	X	X	
Red-throated Loon	*Gavia stellata*	Present in Park	X				X	
Red-winged Blackbird	*Agelaius phoeniceus*	Present in Park			X	X		
Ring-necked Duck	*Aythya collaris*	Present in Park		X	X		X	
Rock Ptarmigan	*Lagopus muta*	Present in Park						
Rock Sandpiper	*Calidris ptilocnemis*	Present in Park						
Roughleg, Rough-legged Hawk	*Buteo lagopus*	Present in Park						
Ruby-crowned Kinglet	*Regulus calendula*	Present in Park	X	X	X	X	X	
Ruffed Grouse	*Bonasa umbellus*	Present in Park						

Appendix D. Birds of Wrangell-St. Elias documented in NPSpecies database and presence on NABBS Routes (refer to http://www.pwrc.usgs.gov/bbs/ for raw data regarding NABBS). (continued)

Species Common Name	Scientific Name	NPSpecies Park Status	McCarthy Road	Kuskulana	Kenny Lake	Chisto-china	Nabesna Road	Nabesna
Rufous Hummingbird	*Selasphorus rufus*	Present in Park			X			
Rusty Blackbird	*Euphagus carolinus*	Present in Park	X	X	X	X	X	
Sanderling	*Calidris alba*	Present in Park						
Sandhill Crane	*Grus canadensis*	Present in Park			X			
Savannah Sparrow	*Passerculus sandwichensis*	Present in Park	X	X	X	X	X	
Say's Phoebe	*Sayornis saya*	Present in Park	X	X		X		
Semipalmated Plover	*Charadrius semipalmatus*	Present in Park			X	X		
Semipalmated Sandpiper	*Calidris pusilla*	Present in Park						
Sharp-shinned Hawk	*Accipiter striatus*	Present in Park			X	X		
Sharp-tailed Grouse	*Tympanuchus phasianellus*	Present in Park						
Short-billed Dowitcher	*Limnodromus griseus*	Present in Park						
Short-eared Owl	*Asio flammeus*	Present in Park					X	
Smith's Longspur	*Calcarius pictus*	Present in Park					X	
Snow Bunting	*Plectrophenax nivalis*	Present in Park						
Snow Goose, Blue Goose	*Chen caerulescens*	Present in Park						
Solitary Sandpiper	*Tringa solitaria*	Present in Park		X	X	X		X
Song Sparrow	*Melospiza melodia*	Present in Park	X			X	X	
Spotted Sandpiper	*Actitis macularius*	Present in Park	X		X	X	X	
Spruce Grouse	*Falcipennis canadensis*	Present in Park						
Steller's Jay	*Cyanocitta stelleri*	Present in Park						
Surf Scoter	*Melanitta perspicillata*	Present in Park						
Surfbird	*Aphriza virgata*	Present in Park						
Swainson's Hawk	*Buteo swainsoni*	Present in Park						

Appendix D. Birds of Wrangell-St. Elias documented in NPSpecies database and presence on NABBS Routes (refer to http://www.pwrc.usgs.gov/bbs/ for raw data regarding NABBS). (continued)

Species Common Name	Scientific Name	NPSpecies Park Status	McCarthy Road	Kuskulana	Kenny Lake	Chisto-china	Nabesna Road	Nabesna
Swainson's Thrush	*Catharus ustulatus*	Present in Park	X	X	X	X	X	X
Townsend's Solitaire	*Myadestes townsendi*	Present in Park	X		X	X		
Townsend's Warbler	*Dendroica townsendi*	Present in Park	X		X	X	X	
Tree Swallow	*Tachycineta bicolor*	Present in Park	X	X	X	X	X	
Trumpeter Swan	*Cygnus buccinator*	Present in Park	X	X		X	X	
Tundra Swan	*Cygnus columbianus*	Present in Park						
Upland Sandpiper	*Bartramia longicauda*	Present in Park					X	
Varied Thrush	*Ixoreus naevius*	Present in Park	X	X	X	X	X	X
White-winged Scoter	*Melanitta fusca*	Present in Park	X		X			
Violet-green Swallow	*Tachycineta thalassina*	Present in Park	X	X	X	X	X	
Wandering Tattler	*Heteroscelus incanus*	Present in Park	X					
Western Sandpiper	*Calidris mauri*	Present in Park						
Western Screech-Owl, Western Screech Owl	*Megascops kennicottii*	Present in Park						
Western Wood-Pewee	*Contopus sordidulus*	Present in Park	X	X	X	X	X	
Whimbrel	*Numenius phaeopus*	Present in Park						
White-crowned Sparrow	*Zonotrichia leucophrys*	Present in Park	X	X	X	X	X	X
White-tailed Ptarmigan	*Lagopus leucura*	Present in Park						
White-winged Crossbill	*Loxia leucoptera*	Present in Park		X	X	X	X	
Willow Ptarmigan	*Lagopus lagopus*	Present in Park	X				X	
Wilson's Snipe	*Gallinago delicata*	Present in Park	X	X	X	X	X	X
Wilson's Warbler	*Wilsonia pusilla*	Present in Park	X	X	X	X	X	X

Appendix D. Birds of Wrangell-St. Elias documented in NPSpecies database and presence on NABBS Routes (refer to http://www.pwrc.usgs.gov/bbs/ for raw data regarding NABBS). (continued)

Species Common Name	Scientific Name	NPSpecies Park Status	McCarthy Road	Kuskulana	Kenny Lake	Chisto-china	Nabesna Road	Nabesna
Winter Wren	*Troglodytes troglodytes*	Present in Park	X					
Yellow-billed Loon	*Gavia adamsii*	Present in Park						
Yellow-rumped Warbler	*Dendroica coronata*	Present in Park						
American Redstart	*Setophaga ruticilla*	Probably Present						
Rosy Finch, Asian Rosy Finch	*Leucosticte arctoa*	Probably Present						
Warbling Vireo	*Vireo gilvus*	Probably Present						
Yellow-bellied Flycatcher	*Empidonax flaviventris*	Probably Present						
Yellow-bellied Sapsucker	*Sphyrapicus varius*	Probably Present				X		

Appendix E. WRST species of birds by Order and Family.

Order (Species in WRST)	Families (Species in WRST)
Anseriformes (29)	Anatidae (29)
Apodiformes (1)	Trochilidae (1)
Ciconiiformes (71)	Accipitridae (9)
	Alcidae (6)
	Ardeidae (1)
	Charadriidae (5)
	Falconidae (4)
	Gaviidae (4)
	Laridae (9)
	Phalacrocoracidae (2)
	Podicipedidae (2)
	Scolopacidae (26)
	Stercorariidae (3)
Coraciiformes (1)	Alcedinidae (1)
Galliformes (7)	Phasianidae (7)
Gruiformes (2)	Gruidae (1)
	Rallidae (1)
Piciformes (7)	Picidae (7)
Strigiformes (6)	Strigidae (6)

Appendix E. WRST species of birds by Order and Family. (continued)

Order (Species in WRST)	Families (Species in WRST)
Passeriformes (70)	Alaudidae (1)
	Bombycillidae (1)
	Certhiidae (1)
	Cinclidae (1)
	Corvidae (5)
	Emberizidae (13)
	Fringillidae (8)
	Hirundinidae (5)
	Icteridae (2)
	Laniidae (1)
	Motacillidae (1)
	Muscicapidae (1)
	Paridae (4)
	Parulidae (8)
	Regulidae (2)
	Sittidae (1)
	Sylviidae (1)
	Troglodytidae (1)
	Turdidae (7)
	Tyrannidae (5)
	Vireonidae (1)

Appendix F. Total birds by species and day from the 1992 Coastal Wildlife Survey (reproduced from Kozie 1993).

Bird Group/Common Name	Scientific Name	# Observed:	7/15/1992	7/16/1992	7/17/1992	Total
Loons						
Pacific Loon	*Gavia pacifica*		0	0	1	1
Common Loon	*Gavia immer*		0	5	0	5
Unidentified Loon			0	0	1	1
Waterfowl						
Canada Goose	*Branta canadensis*		70	0	0	70
Mallard	*Anas platyrhynchos*		15	3	0	18
Northern Shoveler	*Anas clypeata*		2	6	0	8
Barrows Goldeneye	*Bucephala islandica*		0	1	0	1
White-winged Scoter*			25	3	13	41
Surf Scoter	*Melanitta perspicillata*		282	93	188	563
Unidentified Scoter			0	133	125	258
Harlequin Duck	*Histrionicus histrionicus*		5	4	58	67
Common Merganser	*Mergus merganser*		77	2	31	110
Shorebirds						
Black Oystercatcher	*Haematopus bachmani*		16	0	0	16
Semipalmated Plover	*Charadrius semipalmatus*		5	10	0	15
Whimbrel	*Numenius phaeopus*		0	16	0	16
Red-necked Phalarope*			6	0	0	6
Unidentified Phalarope			3	1	8	12
Short-billed Dowitcher	*Limnodromus griseus*		0	10	0	10
Ruddy Turnstone*			205	80	0	285
Black Turnstone	*Arenaria melanocephala*		65	20	0	85
Western Sandpiper	*Calidris mauri*		0	30	0	30
Least Sandpiper	*Calidris minutilla*		0	170	0	170

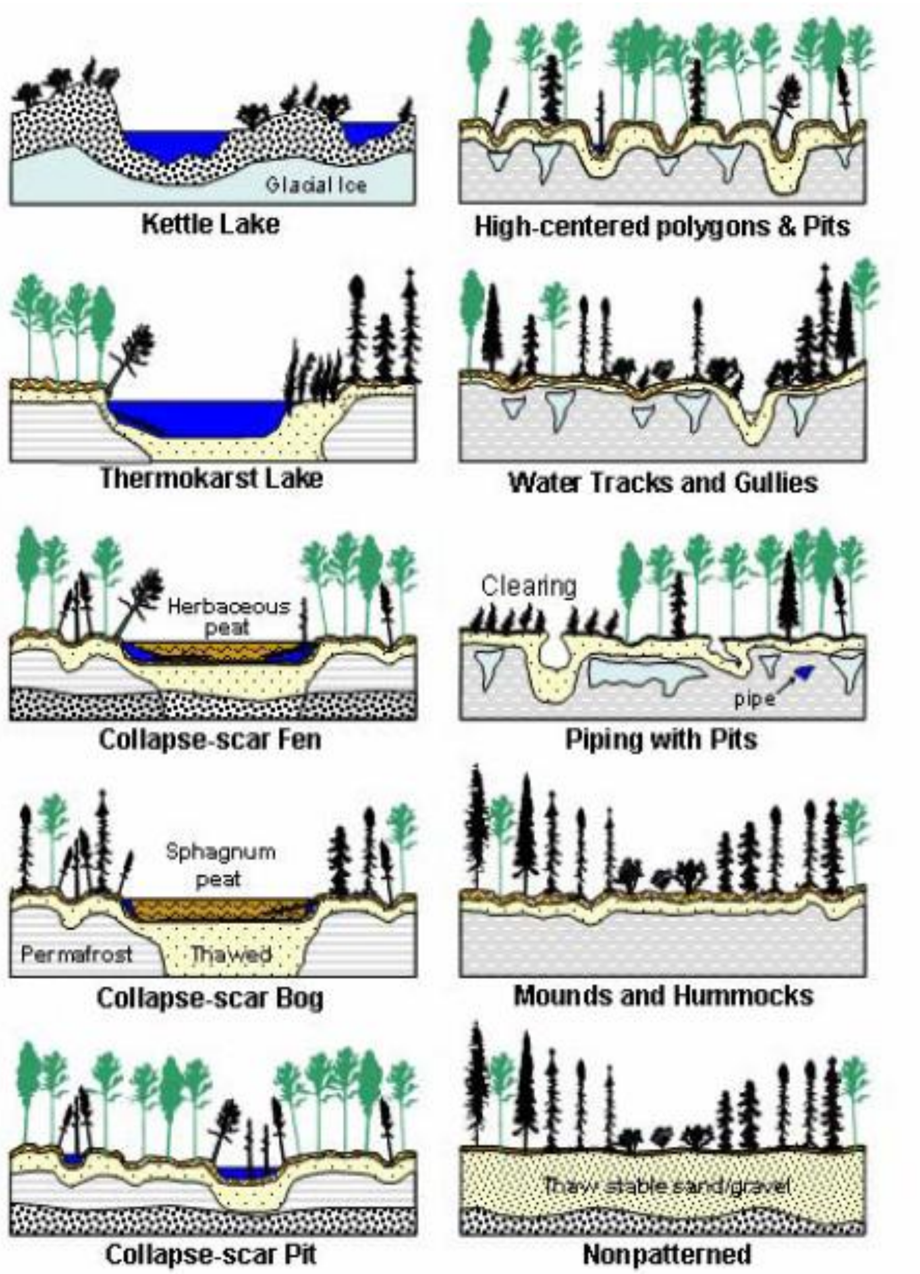
Appendix F. Total birds by species and day from the 1992 Coastal Wildlife Survey (reproduced from Kozie 1993). (continued)

Bird Group/Common Name	Scientific Name	# Observed:	7/15/1992	7/16/1992	7/17/1992	Total
Gulls & Terns						
Parasitic Jaeger	*Stercorarius parasiticus*		8	0	0	8
Herring Gull	*Larus argentatus*		1	0	0	1
Mew Gull	*Larus canus*		7	14	0	21
Bonaparte's Gull	*Larus philadelphia*		0	2	0	2
Glacous-winged Gull	*Larus glaucescens*		4	2	0	6
Black-legged Kittiwake	*Rissa tridactyla*		0	0	50	50
Arctic Tern	*Sterna paradisaea*		0	1	0	1
Alcids						
Pigeon Guillemont	*Cepphus columba*		19	7	0	26
Marbled Murrelet	*Brachyramphus marmoratus*		3	6	22	31
Kittlitz's Murrelet	*Brachyramphus brevirostris*		13	5	6	24
Unidentified Brachyramphus			5	6	5	16
Other Birds						
Bald Eagle	*Haliaeetus leucocephalus*		1	1	1	3
Refous Hummingbird	*Selasphorus rufus*		0	1	0	1
Savannah Sparrow	*Passerculus sandwichensis*		0	1	0	1
White-crowned Sparrow	*Zonotrichia leucophrys*		0	1	0	1
Black-billed Magpie	*Pica hudsonia*		1	0	0	1

Appendix G. Species documented in Christmas Bird Counts, 1991-2009.

Kenny Lake	Gakona
American Three-toed Woodpecker	Black-billed Magpie
American Tree Sparrow	Black-capped Chickadee
Bald Eagle	Boreal Chickadee
Black-backed Woodpecker	Common Raven
Black-billed Magpie	Common Redpoll
Black-capped Chickadee	Dark-eyed Junco
Bohemian Waxwing	Downy Woodpecker
Boreal Chickadee	Gray Jay
Boreal Owl	Great Horned Owl
chickadee sp.	Hairy Woodpecker
Common Raven	Pine Grosbeak
Common Redpoll	Pine Siskin
Dark-eyed (Slate-colored) Junco	Red-breasted Nuthatch
Downy Woodpecker	Ruffed Grouse
Gray Jay	Ruffed Grouse
Great Gray Owl	Spruce Grouse
Great Horned Owl	White-winged Crossbill
Hairy Woodpecker	
hawk sp.	
Hoary Redpoll	
Merlin	
Northern Goshawk	
Northern Hawk Owl	
Northern Shrike	
owl sp.	
Pine Grosbeak	
Pine Siskin	
Red-breasted Nuthatch	
Red-breasted Sapsucker	
redpoll sp.	
Ruffed Grouse	
Rusty Blackbird	
Snow Bunting	
Spruce Grouse	
Three-toed Woodpecker	
White-winged Crossbill	
Willow Ptarmigan	
woodpecker sp.	

Appendix H. Typical modes of thermokarst and permafrost degradation for central Alaska (from Karle and Jorgenson 2004).



Appendix I. Modes of permafrost degradation and their associated terrain characteristics in central Alaska. From (Karle and Jorgenson 2004)

Degradation Mode	Landscape Position	Hydrologic Regime	Soil Texture	Excess Ice Content (%)	Dominant Ice Morphology	Maximum Feature Size	Thaw Settlement (m)	Lateral Degradation Rates
Kettle Lake	Kame and kettle	Flooded by precipitation	Dia-micton	>90%	Massive glacial ice	10s of ha	5–20	Highly variable
Thermokarst Lake	Flat to gentle Slopes	Flooded by precipitation, groundwater, surface flow	Silt to fine sand	60–90%	Thick layered ice, massive ice	100s ha	2–10	
Collapse-scar fens	Flat to gentle Slopes	Groundwater	Silt	40–60%	Thick layered ice	10s of ha	1–3	0.5–1
Collapse-scar bogs	Flat to gentle slope	Water below surface, precipitation	Silt	40–60%	Thick layered ice	1s of ha	1–3	0.1–0.5
Collapse-scar pits	Flat to gentle Slopes	Flooded, precipitation	Silt	40–60%	Thick layered ice	10s of m^2	1–2	0.1–0.5
Mixed Pits and Polygons	Flat to gentle Slopes	Partially flooded, precipitation	Silt to med. Sand	30–50%	Ice wedges	10s of m^2	0.5–2	0.1–0.3
High-centered polygons	Flat to gentle Slopes	Partially flooded, precipitation	Silt to med. sand	30–50%	Ice wedges	10s of m^2	0.5–2	0.1–0.3
Water tracks and Gullies	Gentle to mod. slopes	Surface flow	Silt	Uncertain	Uncertain	100s of m^2	0.2–1	0.1–1
Piping with Pits	Toe slopes	Groundwater	Silt	Uncertain	Ice wedges, tunnel (cave) ice	10s of m^2 at surface	Pits 2–5	Little after collapse
Mounds and Hummocks	Flat to steep slopes	Drained, precipitation	Silt to fine sand	10–20%	Lenticular, Reticulate, Ataxitic	1s of m^2	0.2–1	NA
Nonpatterned	Flat to steep slopes	Drained, precipitation	Sand and gravel	0–10%	Lenticular, Pore	NA	<0.2	NA

Appendix J. Federal subsistence registration permits in WRST, 2003-2008. (Received from Barbara Cellarius, WRST Subsistence Specialist on 2-17-2009)

GMU/Species	2003	2004	2005	2006	2007	2008	Mean
Unit 11 Moose							
Permits Issued	245	263	231	254	283	280	259
Harvest Report Rate (%)	82	84	88	95	96	91	89
Individuals Hunting	156	153	147	169	185	173	164
Animals Harvested	15	26	24	18	24	28	23
Unit 11 Goat							
Permits Issued	50	39	41	37	52	67	48
Harvest Report Rate (%)	74	92	93	95	89	79	87
Individuals Hunting	16	15	16	16	18	18	17
Animals Harvested	5	3	3	2	2	4	3
Unit 11 Elder Sheep							
Permits Issued	13	20	13	16	11	18	15
Harvest Report Rate (%)	85	95	92	100	100	94	94
Individuals Hunting	6	3	5	7	6	4	5
Animals Harvested	0	0	0	2	0	0	0
Unit 11 Elder/Junior Sheep							
Permits Issued			2	0	0	1	1
Harvest Report Rate (%)			50			100	75
Individuals Hunting			0			0	0
Animals Harvested			0			0	0
Unit 12 Elder Sheep							
Permits Issued		10	8	8	6	7	8
Harvest Report Rate (%)		100	100	100	100	100	100
Individuals Hunting		4	5	3	3	2	3
Animals Harvested		0	0	0	0	0	0
Unit 12 Elder/Junior Sheep							
Permits Issued				0	0	0	0
Harvest Report Rate (%)							
Individuals Hunting							
Animals Harvested							
Unit 5B Goat							
Permits Issued	0	4	0	0	1	3	1
Harvest Report Rate (%)		0			100	100	67
Individuals Hunting					0	3	2
Animals Harvested					0	3	2

Appendix J. Federal subsistence registration permits in WRST, 2003-2008 (Received from Barbara Cellarius, WRST Subsistence Specialist on 2-17-2009). (continued)

GMU/Species	2003	2004	2005	2006	2007	2008	Mean
Unit 5 Brown Bear **(**all of Unit 5**)**							
Permits Issued	0	6	6	6	3	0	4
Harvest Report Rate (%)		67	83	33	100		71
Individuals Hunting		2	2	1	3		2
Animals Harvested		0	1	0	0		0

Appendix K. Reported visitors at WRST locations, 2002 to 2007. Adapted from Scott 2009b.

Place	Reported Visitors	% of Total Visitors	Visitor Days	% of Visitor Days
Root Glacier	9,588	39.356	519,484	66.917
Kennicott Glacier	4,260	17.485	153,421	19.763
Landing Strip, Skolai	1,055	4.331	7,687	0.990
McCarthy Creek	732	3.005	19,728	2.541
Iceberg Lake	598	2.455	3,642	0.469
Kennicott River Launch	566	2.323	3,811	0.491
McCarthy Town	401	1.646	3,139	0.404
Nizina Glacier	369	1.515	1,494	0.192
Landing Strip, Glacier Creek	290	1.190	1,496	0.193
Landing Strip, Huberts	281	1.153	844	0.109
Bonanza Mine	242	0.993	898	0.116
The Fosse	217	0.891	1,395	0.180
Horsfeld Airport	216	0.887	657	0.085
Icy Bay	213	0.874	888	0.114
Donoho Lakes	206	0.846	12,439	1.602
Doubtful Creek	169	0.694	844	0.109
Bagley Ice Valley	166	0.681	1,292	0.166
Nabesna Glacier	150	0.616	2,828	0.364
Moose Valley West Fork	139	0.571	295	0.038
Bona, Mount	135	0.554	1,015	0.131
Hanagita Lake	132	0.542	530	0.068
Kageet Point	121	0.497	459	0.059
Landing Strip, Wolverine	120	0.493	815	0.105
Tana River	116	0.476	267	0.034
Tebay Lakes	112	0.460	315	0.041
Granite Creek, Tana Glacier	105	0.431	322	0.041
Jakes Bar Airport	97	0.398	97	0.012
Wrangell, Mount	91	0.374	188	0.024
MacColl Ridge	88	0.361	822	0.106
Hidden Creek	87	0.357	424	0.055
Nizina River	80	0.328	315	0.041
Goat Creek, Chitina River	76	0.312	106	0.014
Tana Dune	74	0.304	74	0.010
Sanford, Mount	74	0.304	1,953	0.252
Hawkins Glacier	72	0.296	177	0.023
Landing Strip, Chelle	68	0.279	281	0.036
Quintino Sella Glacier	65	0.267	911	0.117
Esker Stream	65	0.267	87	0.011
Peavine Bar	64	0.263	132	0.017

Appendix K. Reported visitors at WRST locations, 2002 to 2007. Adapted from Scott 2009b. (continued)

Place	Reported Visitors	% of Total Visitors	Visitor Days	% of Visitor Days
Alis Valley	63	0.259	246	0.032
White River, Canada	60	0.246	564	0.073
Bonanza Ridge	56	0.230	600	0.077
Tana Glacier	55	0.226	111	0.014
May Creek	53	0.218	513	0.066
Chitistone Pass	51	0.209	2,152	0.277
Russell Glacier	51	0.209	1,276	0.164
Landing Strip, Sanford 2, W Side of River	50	0.205	181	0.023
Long Glacier	49	0.201	137	0.018
Blackburn	46	0.189	859	0.111
Strelna	45	0.185	585	0.075
Blackburn, Mount	43	0.177	575	0.074
Lakina Glacier	42	0.172	458	0.059
Chisana	42	0.172	472	0.061
University Peak	42	0.172	374	0.048
Fraser Glacier	42	0.172	486	0.063
Solo Creek	41	0.168	79	0.010
Landing Strip, Dadina	39	0.160	233	0.030
Tanada Lake	38	0.156	248	0.032
Nikolai Butte	37	0.152	424	0.055
Lakina River	37	0.152	2,543	0.328
Logan Glacier	36	0.148	732	0.094
Barnard Glacier	35	0.144	92	0.012
Nabesna	35	0.144	743	0.096
Nutzotin Mountains	35	0.144	363	0.047
Jefferies Glacier	34	0.140	238	0.031
Steamboat Lake	33	0.135	121	0.016
Jacksina Creek	32	0.131	98	0.013
Martin Creek	32	0.131	60	0.008
Bear, Mount	32	0.131	218	0.028
Landing Strip, Ross Green	32	0.131	119	0.015
Granite Creek, Chitina River	30	0.123	496	0.064
Regal Mountain	30	0.123	1,082	0.139
Packsaddle Island	29	0.119	290	0.037
Hancock Pass	29	0.119	671	0.086
Orange Hill	28	0.115	173	0.022
Donoho Peak	27	0.111	121	0.016
Boulder High	27	0.111	150	0.019
Baldwin Glacier	26	0.107	26	0.003

Appendix K. Reported visitors at WRST locations, 2002 to 2007. Adapted from Scott 2009b. (continued)

Place	Reported Visitors	% of Total Visitors	Visitor Days	% of Visitor Days
Twaharpies, The	26	0.107	26	0.003
Nabesna River	24	0.099	122	0.016
Verde, Mount	24	0.098	24	0.003
Gates Glacier	24	0.099	2,952	0.380
Dixie Pass	24	0.099	134	0.017
Fan Glacier	24	0.099	552	0.071
Lower Tebay Lake	24	0.099	99	0.013
Mesa Lake	22	0.090	208	0.027
Baultoff Lakes	22	0.090	147	0.019
Long Lake Landing Strip	19	0.078	41	0.005
Cooper Pass	19	0.078	145	0.019
Granite Creek, Kotsina River	18	0.074	115	0.015
Gunnar Naslund, Mount	18	0.074	198	0.026
Grizzly Lake	18	0.074	168	0.022
Jarvis, Mount	18	0.074	18	0.002
Steamboat Mesa	17	0.070	59	0.008
Jaeger Mesa	16	0.066	59	0.008
Drum, Mount	16	0.066	470	0.061
Kotsina River	15	0.062	450	0.058
Bernard Creek	15	0.062	175	0.023
Chimney Mountain	15	0.062	61	0.008
Stuver Creek	14	0.057	105	0.014
Landing Strip, Canyon Creek	14	0.057	86	0.011
Osar Stream	14	0.057	20	0.003
Copper Lake	13	0.053	213	0.027
Oldhams	13	0.053	105	0.014
Manby Point	13	0.053	25	0.003
Huxley, Mount	13	0.053	13	0.002
Nikolai Pass	13	0.053	25	0.003
Dadina Lake	13	0.053	98	0.013
Chetaslina River	12	0.049	133	0.017
Braye Lakes	12	0.049	74	0.010
Nizina Mountain	12	0.049	31	0.004
Tumble Creek	12	0.049	152	0.020
Nikonda Creek	12	0.049	105	0.014
KO Bar	12	0.049	84	0.011
Yahtse Glacier	12	0.049	12	0.002
Bering Glacier	11	0.045	11	0.001
Hump, The	11	0.045	11	0.001
Tebay River	11	0.045	11	0.001

Appendix K. Reported visitors at WRST locations, 2002 to 2007. Adapted from Scott 2009b. (continued)

Place	Reported Visitors	% of Total Visitors	Visitor Days	% of Visitor Days
Canyon Creek Glacier	11	0.045	11	0.001
Landing Strip, Lakina River	11	0.045	12	0.002
Dan Creek	11	0.045	28	0.004
Rohn Glacier	11	0.045	53	0.007
Gibraltar Hill	11	0.045	11	0.001
Green Hills	11	0.045	11	0.001
Landing Strip, Windy Ridge	11	0.045	45	0.006
Sudden Stream, Malaspina Lake	10	0.041	20	0.003
Atna Peaks	10	0.041	110	0.014
Erickson Creek	10	0.041	16	0.002
Ophir Creek	10	0.041	10	0.001
Blue Lake	9	0.037	78	0.010
Sheep Lake	9	0.037	79	0.010
Dewey Creek	9	0.037	81	0.010
Bond Creek	9	0.037	80	0.010
Soda Lake	9	0.037	45	0.006
The Goat Trail	8	0.033	8	0.001
Beaver Creek	8	0.033	52	0.007
Nugget Creek	8	0.033	14	0.002
Steller, Mount	8	0.033	88	0.011
Chisana Glacier	8	0.033	88	0.011
Seward Glacier	7	0.029	89	0.011
Mother Lode Mine	7	0.029	7	0.001
Snag Creek	7	0.029	80	0.010
Carden Lake	7	0.029	76	0.010
Ptarmigan Lake	7	0.029	7	0.001
Anderson Glacier	6	0.025	6	0.001
Copper Glacier	6	0.025	6	0.001
Crystalline Hills	6	0.025	414	0.053
Mountaineers Pass	6	0.025	6	0.001
Solo Lake	6	0.025	48	0.006
Upper Barnard	6	0.025	6	0.001
Stone Creek	6	0.025	61	0.008
Tittmann Glacier	6	0.025	6	0.001
Salmon Creek	6	0.025	6	0.001
Landing Strip, Geohenda Creek	5	0.021	40	0.005
Hidden Valley	5	0.021	379	0.049
Tana Strip	5	0.021	5	0.001
Tanada Peak	5	0.021	5	0.001

Appendix K. Reported visitors at WRST locations, 2002 to 2007. Adapted from Scott 2009b. (continued)

Place	Reported Visitors	% of Total Visitors	Visitor Days	% of Visitor Days
Chitistone Mountain	5	0.021	553	0.071
Guerin Glacier	5	0.021	5	0.001
Chitistone Gorge	5	0.021	20	0.003
Nadina Glacier	5	0.021	13	0.002
Tana Canyon	4	0.016	4	0.001
Martin River Glacier	4	0.016	12	0.002
Kiagna Glacier	4	0.016	492	0.063
Chititu Camp	4	0.016	8	0.001
Summit Lake, Tebay River	4	0.016	44	0.006
Boomerang Lake	4	0.016	34	0.004
Wait Creek	4	0.016	20	0.003
Hubbard Glacier	4	0.016	4	0.001
Manby Stream	4	0.016	4	0.001
Gordon, Mount	4	0.016	20	0.003
Sheep Glacier	4	0.016	17	0.002
Landing Strip, Kotsina	4	0.016	34	0.004
Vancouver, Mount	4	0.016	68	0.009
Natazhat, Mount	4	0.016	164	0.021
Hidden Creek Lake	3	0.012	15	0.002
Landing Strip, Wilson Camp	3	0.012	14	0.002
Valerie Glacier	3	0.012	3	0.000
Ross Green Lake	3	0.012	12	0.002
George, Mount	3	0.012	93	0.012
Jumbo Mine	3	0.012	93	0.012
Nadina River	3	0.012	18	0.002
Young Creek, Nizina River	3	0.012	9	0.001
Bryson Bar	3	0.012	3	0.000
Spirit Mountain	3	0.012	87	0.011
Spruce Point	3	0.012	3	0.000
Steller Glacier	3	0.012	3	0.000
Cheslina Lake	2	0.008	24	0.003
Frederika Creek	2	0.008	8	0.001
Drop Creek	2	0.008	12	0.002
Landing Strip, Ellis-Jack Lake	2	0.008	6	0.001
Upper Klutlan	2	0.008	2	0.000
Arson Lake	2	0.008	18	0.002
Columbus Glacier	2	0.008	22	0.003
Beaver Lake	2	0.008	22	0.003
Peninsula Strip Kotsina	2	0.008	2	0.000
Crescent Creek	2	0.008	20	0.003

Appendix K. Reported visitors at WRST locations, 2002 to 2007. Adapted from Scott 2009b. (continued)

Place	Reported Visitors	% of Total Visitors	Visitor Days	% of Visitor Days
Ram Glacier	2	0.008	10	0.001
Monte Cristo Creek	2	0.008	10	0.001
Jacksina Glacier	2	0.008	16	0.002
Antler Creek	2	0.008	16	0.002
Capital Mountain	2	0.008	12	0.002
Camp Creek	2	0.008	16	0.002
West Fork Tana River	2	0.008	3	0.000
Mud Lake, Copper River	1	0.004	6	0.001
Slana	1	0.004	1	0.000
Big Bend Lakes	1	0.004	9	0.001
Chitistone River	1	0.004	1	0.000
Donoho Lake Airstrip	1	0.004	2	0.000
Tiekel River	1	0.004	1	0.000

NPS 190/107958, June 2011

National Park Service
U.S. Department of the Interior

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