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Natural Resource Stewardship and Science

Lake Clark National Park and Preserve

Natural Resource Condition Assessment

Natural Resource Report NPS/LACL/NRR—2016/1250



ON THE COVER
Photograph of Lake Clark in Lake Clark National Park and Preserve.
Photograph by Andy Nadeau, Saint Mary's University of Minnesota, Geospatial Services (2013).

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Natural Resource Condition Assessment

Natural Resource Report NPS/LACL/NRR—2016/1250

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Executive Summary

The Natural Resource Condition Assessment (NRCA) Program aims to provide documentation about the current conditions of important park natural resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. Findings from the NRCA will help Lake Clark National Park and Preserve (LACL) managers to develop near-term management priorities, engage in watershed or landscape scale partnership and education efforts, conduct park planning, and report program performance (e.g., Department of the Interior's Strategic Plan "land health" goals, Government Performance and Results Act).

The objectives of this assessment are to evaluate and report on current conditions of key park resources, to evaluate critical data and knowledge gaps, and to highlight selected existing stressors and emerging threats to resources or processes. For the purpose of this NRCA, staff from the National Park Service (NPS) and Saint Mary's University of Minnesota – GeoSpatial Services (SMUMN GSS) identified key resources, referred to as "components" in the project. The selected components include natural resources and processes that are currently of the greatest concern to park management at LACL. The final project framework contains 14 resource components, each featuring discussions of measures, stressors, and reference conditions.

This study involved reviewing existing literature and, where appropriate, analyzing data for each natural resource component in the framework to provide summaries of current condition and trends in selected resources. When possible, existing data for the established measures of each component were analyzed and compared to designated reference conditions. A weighted scoring system was applied to calculate the current condition of each component. Weighted Condition Scores, ranging from zero to one, were divided into three categories of condition: low concern, moderate concern, and significant concern. These scores help to determine the current overall condition of each resource. The discussions for each component, found in Chapter 4 of this report, represent a comprehensive summary of current available data and information for these resources, including unpublished park information and perspectives of park resource managers, and present a current condition designation when appropriate. Each component assessment was reviewed by LACL resource managers, NPS Southwest Alaska Network (SWAN) staff, or outside experts.

Existing literature, short- and long-term datasets, and input from NPS and other outside agency scientists support condition designations for components in this assessment. However, in some cases, data were unavailable or insufficient for several of the measures of the featured components. In other instances, data establishing reference condition were limited or unavailable for components, making comparisons with current information inappropriate or invalid. In these cases, it was not appropriate or not possible to assign condition for the components. Current condition was not able to be determined for 5 of the 14 components (35%) due to these data gaps.

For those components with sufficient available data, the overall condition varied. Four components were determined to be of low concern: brown bear, Dall's sheep, bald eagles, and salmon. One component, moose, was of moderate concern. Three components were considered to be of high

concern; caribou, climate, and glaciers. Detailed discussion of these designations is presented in Chapters 4 and 5 of this report.

Several park-wide threats and stressors influence the condition of priority resources in LACL. Those of primary concern include human use impacts and climate change. Understanding these threats, and how they relate to the condition of park resources, can help the NPS prioritize management objectives and better focus their efforts to maintain the health and integrity of the park ecosystem, as well as its cultural landscape.

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Acronyms and Abbreviations

AAR - Accumulation Area Ratio

ABG - Alaska Board of Game

ACRC - Alaska Climate Research Center

ADF&G - Alaska Department of Fish and Game

AHAP - Alaska High Altitude Photography

AIRMoN - Atmospheric Integrated Research Monitoring Network

AMNet - Atmospheric Mercury Network

ANILCA - Alaska National Interest Lands Conservation Act

ARD - Air Resources Division

BW – Black & White (imagery)

CAA - Clean Air Act

CASTNET - Clean Air Status and Trend Network

Cfs – cubic feet per second

CIR – Color Infrared (imagery)

CL - Condition Level

COY - Cubs of the Year

DDE - Dichlorodiphenyldichloroethylene

DDT - dichlorodiphenyltrichloroethane

DLP - Defense of Life or Property

DO – Dissolved Oxygen

dv - deciviews

ELA - Equilibrium line altitude (only one ref)

EPA - Environmental Protection Agency

EROS - Earth Resources Observation and Science Center

ETCCDMI - Expert Team for Climate Change Detection Monitoring and Indices (only one ref)

Acronyms and Abbreviations (continued)

FD - Yearly Frost Days

FNU – Formazin Nephelometric Unit

GIS - Geographic Information System

GMU - Game Management Unit

GPRA - Government Performance and Results Act

GPS - Global Positioning System

GSL - Yearly Growing Season Length (only one ref)

GSS - Geospatial Services

I&M - Inventory and Monitoring

ID - Yearly Ice Days

IMPROVE - Interagency Monitoring of Protected Visual Environments

ISQG – Interim Freshwater Sediment Quality Guideline

IRMA - Integrated Resource Management Application

KATM - Katmai National Park and Preserve

LACL - Lake Clark National Park and Preserve

MCH - Mulchatna Caribou Herd

MDN - Mercury Deposition Network

MRSGS - McNeil River State Game Sanctuary

NAAQS - National Ambient Air Quality Standards

NADP - National Atmospheric Deposition Program

NPS - National Park Service

NRCA - Natural Resource Condition Assessments

NSIDC - National Snow and Ice Data Center

NTN - National Trends Network

NTU – Nephelometric Turbidity Unit

Acronyms and Abbreviations (continued)

ORD - overt reaction distance

PAH - Polycyclic aromatic hydrocarbons

PCB - Polychlorinated biphenyls

PDO - Pacific Decadal Oscillation

pH – power/potential of hydrogen (acid/alkaline balance)

PEC – Probable Effect Concentration

PEL – Probable Effect Level

PMR - Pacific Meridian Resources

RAWS - Remote Automated Weather Station

SL - Significance Level

SMUMN - Saint Mary's University of Minnesota

SOCS - Semi-volatile organic chemicals

SWAN - Southwest Alaska Network

SWE - Snow depth/ice thickness and water equivalent

TEC – Threshold Effect Concentration

USFWS - U.S. Fish and Wildlife Service

USGS - U.S. Geological Survey

VIEWS - Visibility Information Exchange Web System

VOC - Volatile Organic Compounds

WCS - Weighted Condition Score

WRCC - Western Regional Climate Center

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." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

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

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*

- Are multi-disciplinary in scope;[1]
- Employ hierarchical indicator frameworks;[2]
- Identify or develop reference conditions/values for comparison against current conditions;[3]
- Emphasize spatial evaluation of conditions and GIS (map) products; [4]
- Summarize key findings by park areas; and [5]
- Follow national NRCA guidelines and standards for study design and reporting products.

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for

---

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 summaries 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. 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-up response (e.g., ecological thresholds or management "triggers").

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

[5] 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 an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.
Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves 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 existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the 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. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

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

Important NRCA Success Factors

- *Obtaining good input from park staff and other NPS subject-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*

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What an NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park's desired resource conditions and management

targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] 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 draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

NRCA Reporting Products…

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

- *Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations* ***(near-term operational planning and management)***
- *Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values* ***(longer-term strategic planning)***
- *Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public* ***("resource condition status" reporting)***

Over the next several years, the NPS plans to fund an NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information on the NRCA program, visit http://www.nature.nps.gov/water/nrca/index.cfm.

[6] An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

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

[8] The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

Chapter 2 Introduction and Resource Setting

2.1 Introduction

2.1.1 Enabling Legislation

Lake Clark National Park and Preserve (LACL) was designated a National Monument on 1 December 1978, from a presidential proclamation by Jimmy Carter (NPS 2013). LACL was later designated as a National Park and Preserve on 2 December 1980 by section 201(7) of the Alaska National Interest Lands Conservation Act (ANILCA) (Haertel 1984). ANILCA developed a mandate which stated the general purposes for establishing LACL (Haertel 1984):



Photo 1. Mount Iliamna in LACL (NPS photo).

> *To protect the watershed necessary for the perpetuation of the red salmon fishery in Bristol Bay; to maintain unimpaired the scenic beauty and quality of portions of the Alaska Range and the Aleutian Range, including volcanoes* (Photo 1)*, glaciers, wild rivers, lakes, waterfalls, and alpine meadows in their natural state; to protect habitats for and populations of fish and wildlife, including, but not limited to caribou, Dall sheep, brown/grizzly bears, bald eagles, and peregrine falcons* (Haertel 1984).

2.1.2 Geographic Setting

LACL is a part of the Southwest Alaska Network (SWAN) and is located in the Cook Inlet Region just 160 km (100 mi) southwest of Anchorage, Alaska. When LACL was first established it was approximately 1,619,779 ha (4,002,544 ac), but it now encompasses approximately 1,630,888 ha (4,030,006 ac) of land (Haertel 1984, NPS 2013). The extent of LACL is broken up into four sections: the park, park/wilderness, preserve, and preserve/wilderness areas (Plate 1). The park section is approximately 1,060,162 ha (2,619,713 ac). The national preserve section is approximately 570,726 ha (1,410,293 ac), located in the south and west portion of LACL. This area of the park and preserve can be geographically described as having abundant foothills, lakes, rivers, and tundra plains (Haertel 1984, NPS 2013).

LACL is known for its highly diverse landscapes and biotic communities (Bennett et al. 2006). It has been referred to as one park with four Alaska's inside its boundaries and is considered to be the most ecologically diverse park in the SWAN (Bennett et al. 2006). The Aleutian, Alaska, and Chigmit Mountain Ranges converge within LACL (Plate 2; NPS 2010). These mountain ranges include two active volcanoes: Redoubt (producing a large scale eruption in 2009) and Iliamna (Photo 1).

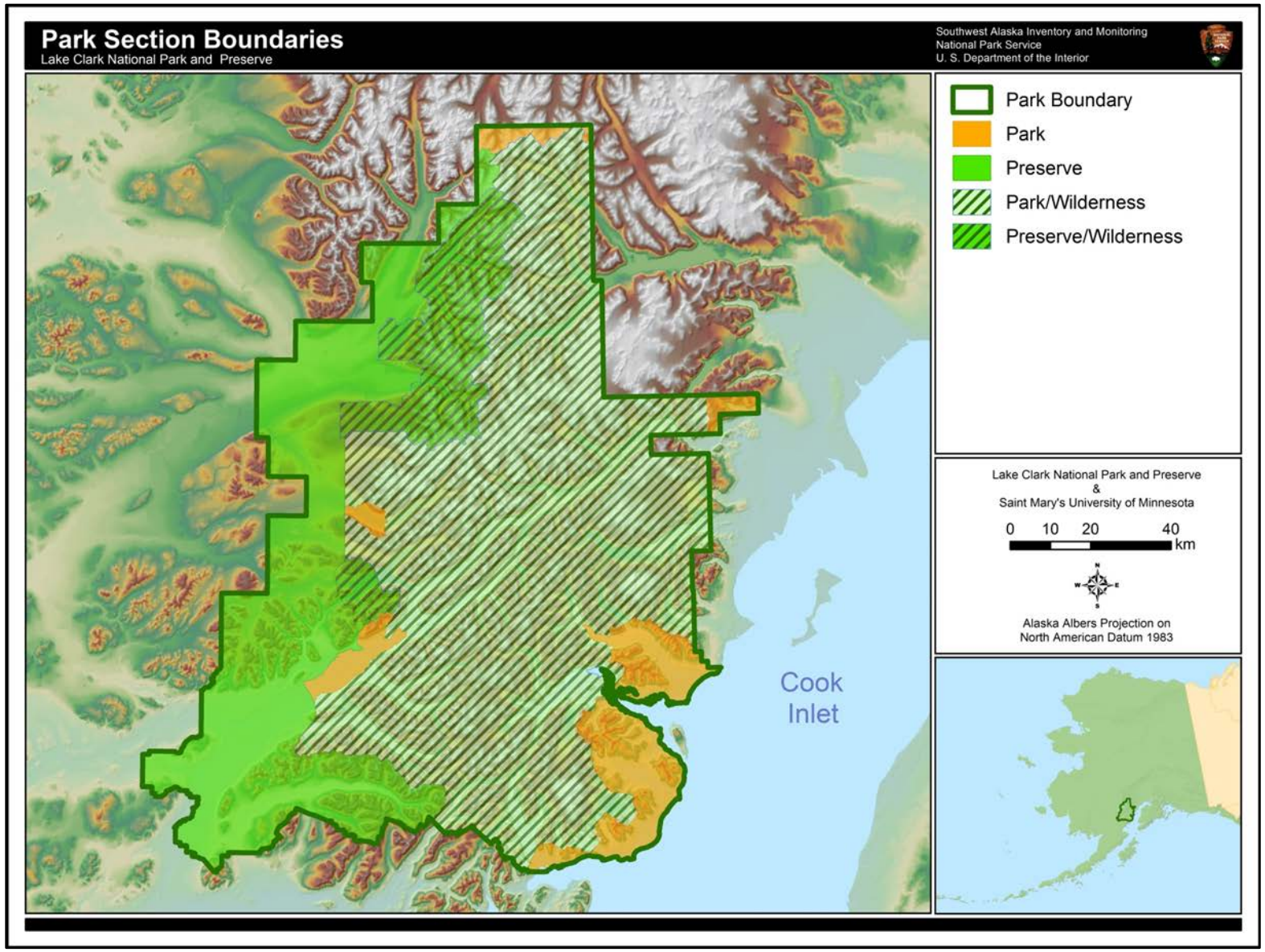


Plate 1. Section boundaries of LACL (NPS 2011, 2014b).

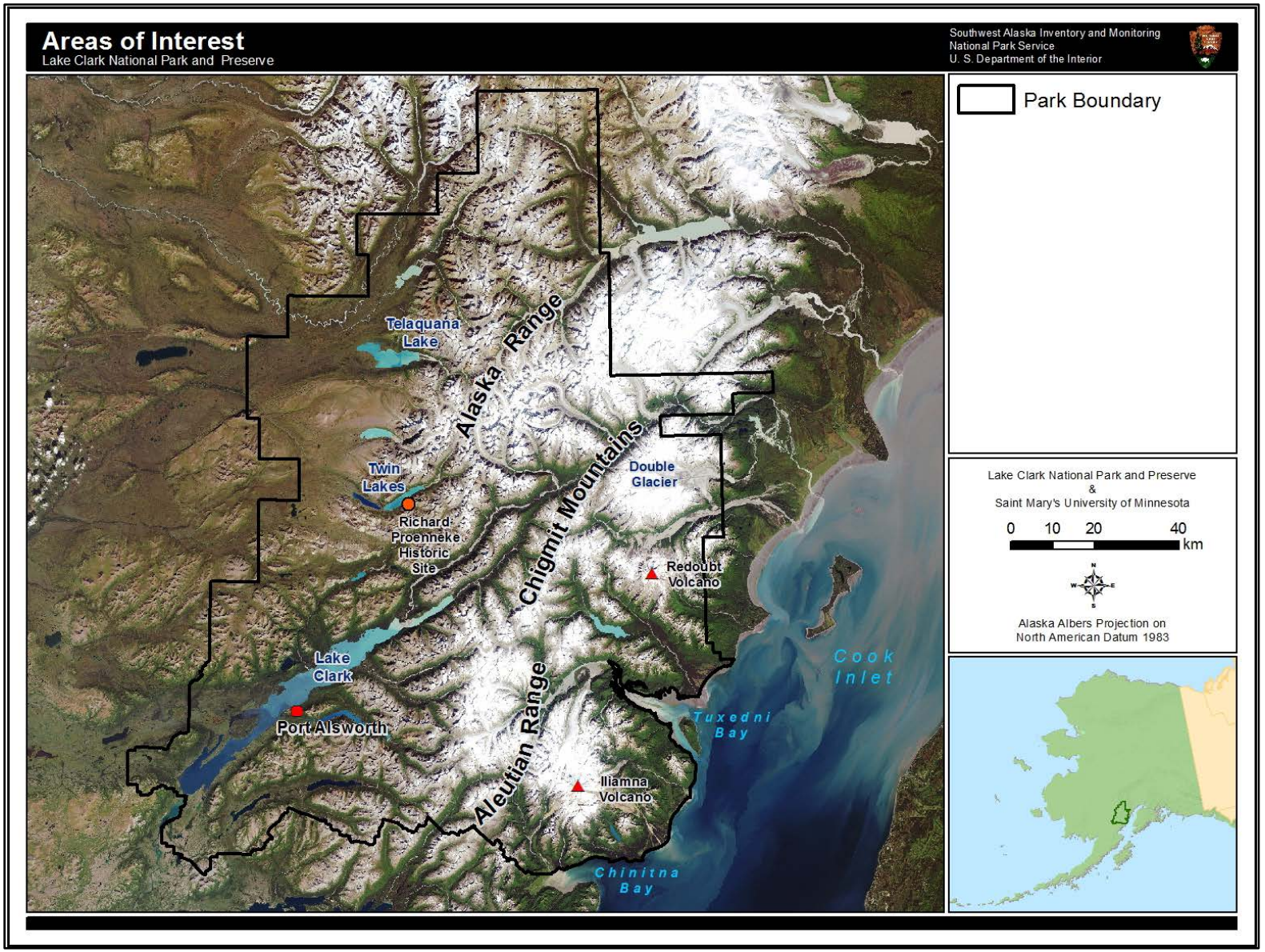


Plate 2. Areas of interest in LACL (NPS 2014b).

The climate in LACL is best described as boreal, continental, and maritime, as the climate to the west of the mountain range is boreal and continental, while the climate to the east of the mountain range (located along the coast) is maritime (Lindsay 2011). The maritime climate is wetter and milder than the continental climate, which experiences more seasonal variation. The average annual high and low temperatures of 7.1°C (44.8°F) and -2.6°C (27.3°F) degrees, respectively, are characteristic of the continental climate (NCDC 2015; Table 1). On average, 31.5 cm (12.4 in) of precipitation occurs per year, with the majority during the months of August and September (NCDC 2015).

Table 1. 30-year climate normals (1981 – 2010) for the Port Alsworth station. Climate normals include average monthly temperature, precipitation, and snow fall (NCDC 2014).

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Average Max Temperature (°C)	-4.8	-2.5	1.4	7.1	13.5	18.2	19.7	18.3	13.1	5.2	-0.9	-3.2	7.1
Average Min Temperature (°C)	-13.6	-12.3	-9.9	-3.5	2.1	6.7	9.1	7.8	4.1	-2.4	-8.2	-10.8	-2.6
Average Total Precipitation (cm)	2.1	2.1	1.7	1.2	1.0	1.9	3.4	4.8	5.6	3.8	3.7	2.3	31.5

2.1.3 Visitation Statistics

The primary way to access LACL is by air, with most visitors flying from communities around Anchorage or the Kenai Peninsula (Haertel 1984; Photo 2). Port Alsworth and Nondalton are common arrival sites for LACL visitors; however, traditional landing sites on lakes, moraines, coastal beaches, snowfields, and outwash or till plains are commonly used by charter and privately owned planes. Since its establishment, LACL has received an average of 6,558 recreational visitors per year (NPS 2015c). The highest visitation years were 1987 and 1988 with 16,418 and 18,863 visitors, respectively. In the last 5 years (2010–2014), LACL has received 11,166 recreational visitors per year on average. During that 5-year period, visitation peaked in 2014 when just over 16,000 people visited, which is well above the overall average (NPS 2015c). The majority of visitor use occurs in the months of June and September; all other months report less than 500 visitors (NPS 2015c). The main activities that attract visitors to LACL are camping and backpacking, fishing, kayaking, day hiking, rafting, and wildlife viewing (NPS 2015a; Photo 3).



Photo 2. Float planes on Lake Clark's Hardenburg Bay (NPS photo).



Photo 3. Visitors hiking up Hope Creek Valley in LACL (left), tent pitched near Turquoise Lake in the backcountry of LACL (right) (NPS photos).

2.2 Natural Resources

2.2.1 Ecological Units and Watersheds

The eastern portion of LACL falls within the Environmental Protection Agency's (EPA) Alaska Range Level III Ecoregion, while the western portion falls within the Interior Forested Lowlands and Uplands Level III Ecoregion. According to the EPA (2013, p. 19; Plate 3), the Alaska Range is characterized by rocky slopes, icefields, glaciers, and many areas barren of vegetation. At higher elevations where some vegetation exists, dwarf scrub communities are common. The Interior Forested Lowlands and Uplands Ecoregion is characterized by

> *a mantling of undifferentiated alluvium and slope deposits, a predominance of forests dominated by spruce and hardwood species, and a very high frequency of lightning fires. On this backdrop of characteristics is superimposed a finer grained complex of vegetation communities resulting from the interplay of permafrost, surface water, fire, local elevational relief, and hillslope aspect* (EPA 2013, p. 17).

LACL has extensive freshwater networks, including muti-lake systems, rivers, and the sixth largest lake in Alaska, Lake Clark. There are eight hydrologic units (watersheds) that intersect the park; these units include Lake Clark, Lake Iliamna, Mulchatna River, Redoubt-Trading Bays, South Fork Kuskokwim River, Stoney River, Tuxedni-Kamishak Bays, and Yentna River (Plate 4). Lake Clark, Lake Iliamna, Mulchatna River, South Fork Kuskokwim River, and Stoney River drain to the south and west of the park into Bristol Bay and Kuskokwim Bay. Redoubt-Trading Bays, Tuxedni-Kamishak Bays, and Yentna River drain to the east of the park into Cook Inlet and the Gulf of Alaska.

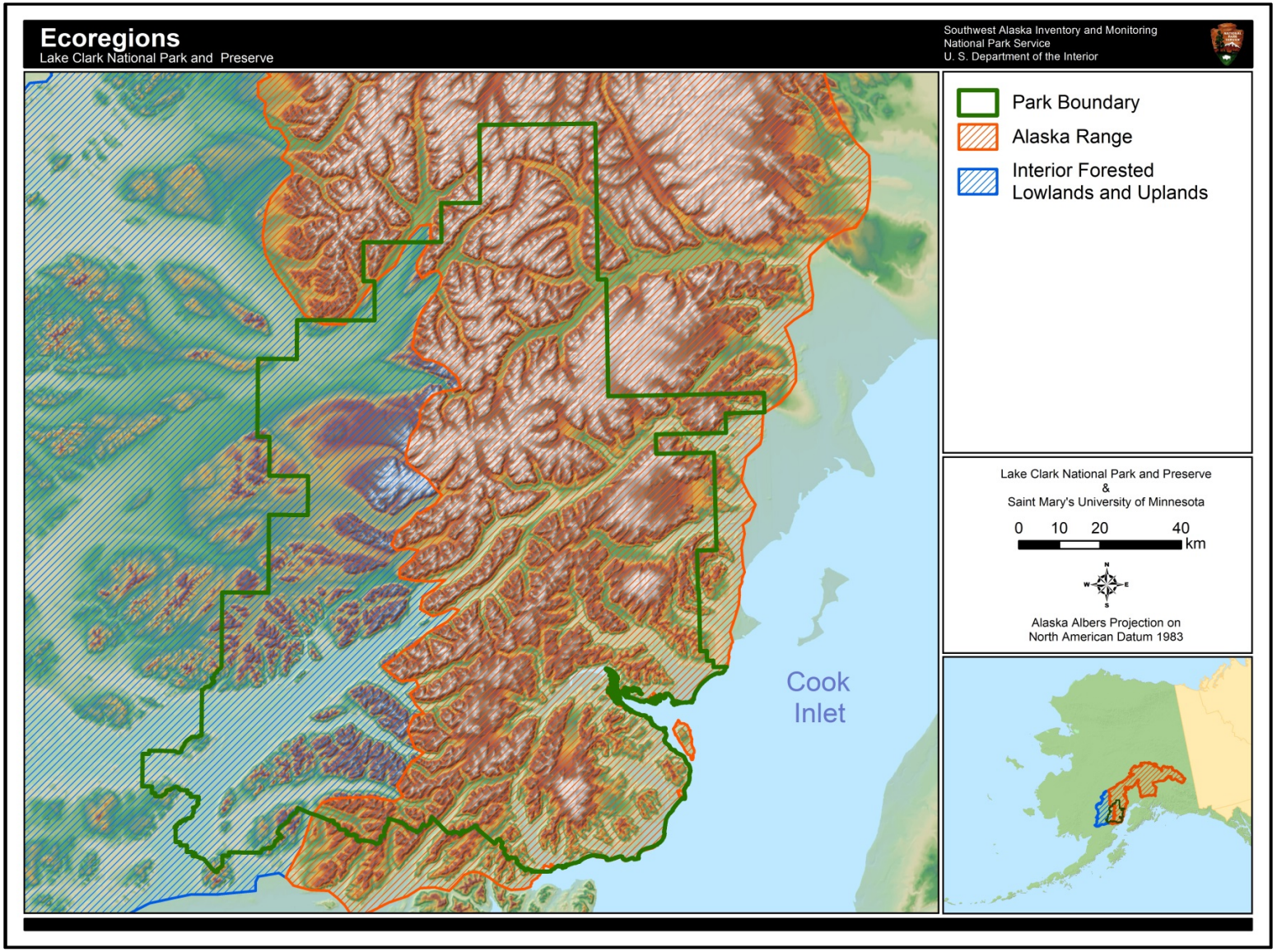


Plate 3. Ecoregions associated with LACL (EPA 2011, NPS 2014b).

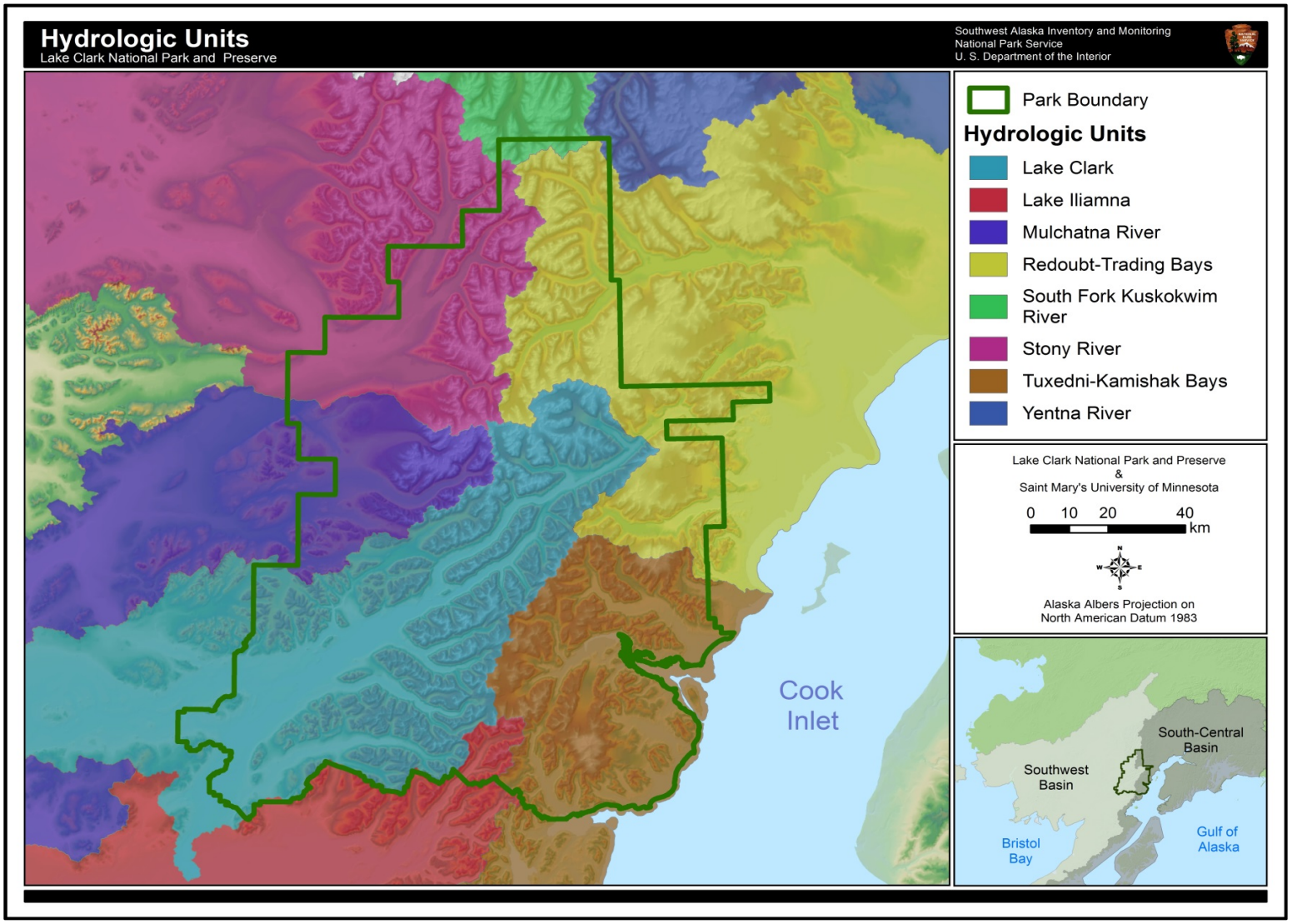


Plate 4. Hydrologic units associated with LACL (NPS 2014b).

2.2.2 Resource Descriptions

Animals

There are 37 terrestrial mammal species that are considered present or probably present in LACL (NPS 2015b). Over half of the terrestrial mammals in the park are considered small mammals (24 species), which include shrews, squirrels, voles, lemmings, weasels, and one bat species. Some large ungulates including moose (*Alces alces*) and caribou (*Rangifer tarandus*) are also common in LACL.



Photo 4. A brown bear along Silver Salmon Creek in LACL (NPS photo).

There are several predators in LACL. The largest predators in the park include the black bear (*Ursus americanus*) and brown bear (*Ursus arctos*; Photo 4); both are sought-after game animals for sport hunters and wildlife viewing enthusiasts. Other predators that are common in the park are gray wolves (*Canis lupus*), coyotes (*C. latrans*), and red foxes (*Vulpes vulpes*). Canada lynx (*Lynx canadensis*) and wolverines (*Gulo gulo*) are considered present in the park but are uncommon (NPS 2015b).

Five marine mammals have been confirmed as present in waters bordering the park; however, they are migratory species and sightings are considered uncommon or rare. The five marine mammal species include sea otters (*Enhydra lutris*), harbor seals (*Phoca vitulina*), killer whales (*Orcinus orca*), harbor porpoise (*Phocoena phocoena*), and Dall's porpoise (*Phocoenoides dalli*) (NPS 2015b).

Over 160 species of birds have been documented in LACL during some time of the year (NPS 2015b). Shorebirds, marine birds, and waterfowl account for 89 bird species present or probably present in the park. A majority of these bird species are traveling through on migration routes; however, some do utilize LACL for nesting or are year-round residents.

There are 18 raptor species that inhabit that park, although most are considered uncommon or rare to the park. The bald eagle (*Haliaeetus leucocephalus*) is the only raptor species considered common in LACL.

Common birds in the park include spruce grouse (*Falcipennis canadensis*), willow ptarmigan (*Lagopus lagopus*; Photo 5), horned lark (*Eremophila alpestris*), fox sparrow (*Passerella iliaca*), and hermit thrush (*Catharus guttatus*). Birds that occur rarely in the park include brant (*Branta bernicla*),

pectoral sandpiper (*Calidris melanotos*), bar-tailed godwit (*Limosa lapponica*), and sandhill crane (*Grus canadensis*) (NPS 2015b).



Photo 5. Willow ptarmigan (NPS photo).

A major reason for the establishment of LACL was to protect important fish habitat and populations. There are 46 species of fish that are present or probably present in the park (NPS 2015b). Salmon species found in the park include the Chinook (*Oncorhynchus tshawytscha*), sockeye (*O. nerka*; Photo 6), coho (*O. kisutch*), chum (*O. keta*), and pink (*O. gorbuscha*) (Kline et al. 1997).

The opportunity to catch sport fish or view salmon in pristine waters attracts many visitors to LACL each year. Salmon populations also help support a diverse population of sport fish including the arctic char (*Salvelinus alpinus*), arctic grayling (*Thymallus arcticus*), rainbow trout (*Oncorhynchus mykiss*), Dolly Varden (*Salvelinus malma*), northern pike (*Esox lucius*), and lake trout (*Salvelinus namaycush*).



Photo 6. Sockeye salmon swimming up river to spawn (NPS photo by D. Young).

The protection of sockeye salmon spawning grounds and travel passages remains at the forefront of park management goals. Salmon are considered vitally important to several species in LACL and spawn in all major rivers and streams. Salmon carcasses and eggs provide nutrients to the freshwater lakes, rivers and streams of LACL (Kline et al. 1997). These nutrients are utilized by the aquatic and terrestrial flora and fauna of LACL watersheds. The annual salmon runs support a variety of wildlife, from the park's largest predator the brown bear, down to the smallest aquatic invertebrates.

The wood frog (*Rana sylvatica*) is the only herptile present in LACL. It is most commonly found near large rivers or lakes in the park. Wood frogs survive in areas of Alaska where the temperature ranges from summer highs of 32°C (90°F) to winter lows of -50°C (-58°F). They survive through an overwintering adaptation allowing their body to freeze for several months during the winter and thaw when temperatures become tolerable in the spring (Larson et al. 2014).

Coastal Systems

Members of the marine intertidal community play important roles in the ecosystem. Marine plants, such as kelps and seagrasses, provide a filter for nutrients and form a canopy of vegetation that alters the flow of water and provides habitat for fish, clams, sea urchins, and planktivores. Crustaceans and fish also use marine plants for areas to spawn and nurse their young (Coletti et al. 2009, Bennett et al.

2006). SWAN has chosen kelp and eelgrass (*Zostera marina*) as a Vital Sign for their monitoring program.

Intertidal invertebrates serve as an indicator of disturbance in the ecosystem (Nagorski et al. 2010). Bivalve mollusks such as mussels and clams (Photo 7) assemble together to form thick beds and mats on rocky shores and soft sediments. This community modifies the nearshore environment by depositing organic matter, trapping sediments, and promoting the growth of marine plants. They are an important food source for birds, bears, fish, and sea otters (Coletti et al. 2009).



Photo 7. Baltic macomas (*Macoma balthica*), the most common clam observed in LACL (NPS photo).

For these reasons, SWAN has chosen marine intertidal invertebrates as a Vital Sign for their monitoring program. SWAN will monitor long-term trends in species richness at randomly sampled sites and document how the size distribution of limpets and mussels is changing annually. An estimate will be made of long-term trends in abundance of littleneck clams along marine coastlines along with documenting how size distributions and growth rates are changing annually. Monitoring of status and trends in the concentration of metals, organochlorides, polychlorinated biphenyls (PCBs), and mercury in mussel tissues at randomly sampled sites will also occur (Bennett et al. 2006).

According to Lees (2006), the LACL shoreline is mostly composed of mud flats and sandy beaches (exposed to semi-exposed): approximately 27% of the LACL shoreline consists of wide sand flats (Bennett 1996). There are at least 29 bivalve species that inhabit SWAN shorelines; three species were observed during 2004 sampling in LACL (Table 2). Little-neck (*Protothaca staminea*) and butter clams (*Saxidomus giganteus*) are also known to occur along tidal flats (NPS 2015d). Intertidal communities are sensitive to environmental changes (e.g., ocean acidification, sea level change) (NPS 2014a). Anthropogenic stressors, such as oil spills, may be negatively impacting the intertidal communities.

Table 2. Number of bivalve species observed in 40 samples at LACL (Lees 2006).

Scientific Name	Common Name	Number Observed
Macoma balthica	Baltic macoma	26
Mya arenaria	softshell clam	8
Spisula patula	Pacific razor clam	6

2.2.3. Resource Issues Overview

Several events in history, caused both by human-related activities and natural processes, have altered the resources of LACL. A federal mandate created by the Oil Pollution Act of 1990 was enacted to monitor the environmental impact that oil-related activities have on the broad intertidal flats and low-energy beaches which make up much of the LACL coastline (Bennett et al. 2006). Bennett et al. (2006) states the desire to quantify or, at the very least, explain the ecological impacts that disturbances caused by both natural processes (e.g., volcanic eruptions, climate variability, weather events, earthquakes) and human impacts (e.g., sport fishing/hunting, subsistence fishing/hunting, general visitor use) have on SWAN parks.

Air pollutants from sea-salt aerosol, long-range-transported anthropogenic aerosols, local soil dust and high concentrations of lead and bromide were observed during the monitoring of fine particulates in nearby Katmai National Park and Preserve (KATM) from 1987 to 1992. KATM is located approximately 96 km (60 mi) southwest of the LACL boundary. In an effort to monitor any impacts that mining, oil and gas operations, and the burning of fossil fuels in Cook Inlet may be having on SWAN parks, an Interagency Monitoring of Protected Visual Environments (IMPROVE) station was placed on the coast of LACL (Bennett et al. 2006).

Earthquakes and volcanic activity are constant threats to impose large scale landscape changes in LACL, as the park is located in a tectonically active region. Small scale disturbances including fire, avalanches, landslides, insect outbreaks, and hurricane-force winds can also quickly change park landscapes (Bennett et al. 2006).

Monitoring the negative impacts that human use has on the resources and landscapes of LACL is of high importance to park management. Visitor use issues on the interior areas of LACL include human waste issues have also inspired dialogue regarding toilet facilities. ANILCA also allows Alaska residents to hunt, trap, fish, and harvest wild plants from certain national parks, including LACL (Bennett et al. 2006).

Visitor impact issues on the coastal areas of LACL include wildlife disturbance, primarily to bears, from viewing activities. Some concerns also arise regarding the trampling of vegetation and soil disturbances from all visitor activities within LACL.

The largest potential human impact to the LACL region is resource development adjacent to the park. The proposed Pebble Mine is located between Lake Iliamna and LACL, which are included in the Bristol Bay region known as the most productive salmon fishery in the world. Mine operations could greatly affect this salmon fishery and other migratory mammals, birds, and native fish stocks of LACL. It is imperative to understand the impacts and disturbances on the flora and fauna of the park system before management directives and strategic monitoring plans can be defined or implemented.

2.3 Resource Stewardship

2.3.1 Management Directives and Planning Guidance

The main goals for resource management of LACL, found in the general management plan, (Haertel 1984, p. 4) are:

- Management and use of existing wilderness, which includes nearly all of Lake Clark National Park.

- Management of fish and wildlife populations and habitat, primarily in reference to subsistence uses and sport fishing within the park and preserve (including wilderness lands), and sport hunting within the preserve; the relationship of this management to subsistence uses and sport hunting and trapping on adjoining state lands and native corporation lands; and overall ecosystem management within the park and preserve and on adjacent lands.

- Management of three wild and scenic rivers within the park and preserve boundaries - the Chilikadrotna, the Mulchatna, and the Tlikakila - and cooperative agreement for management of downstream segments outside of the park and preserve.

- Management of watersheds crossing park and preserve boundaries.

- Management of wild fire.

- Management and protection of cultural and archeological resources and the opportunity for subsistence lifestyles by local rural residents.

Bennett et al. (2006) states that the NPS and the Alaska Department of Fish and Game (ADF&G) are responsible for cooperative management and maintenance of fish and wildlife species found in national preserves. The ADF&G also oversees sport fishing and hunting activities that occur in preserve areas.

Fish management goals include maintaining all native and wild fish stocks in LACL by not introducing hatchery raised fish into any water body (Haertel 1984). Specific wildlife management goals are detailed in Haertel (1984) and include the following:

- The NPS will maintain habitat and natural and healthy populations of wildlife species occurring in Lake Clark National Park and Preserve.

- Under ANILCA, the Park Service will provide the opportunity for subsistence hunting and trapping in the park and sport hunting and trapping in the preserve.

- Cooperation between public agencies and adjacent landowners will be sought to ensure protection of wildlife habitat and mitigation of effects from future land development on habitat and species composition.

The goals identified in the LACL general management plan regarding visitor use and interpretations are to provide facilities and services easily accessed by visitors within the park and preserve as well as adjacent areas, and to identify how and by whom these facilities and services will be provided (Haertel 1984). Visitor use areas and impact concerns are outlined by the inventory and monitoring program for the various regions of LACL (Monz 2006).

The management goals for LACL watersheds are to allow the natural processes which have created current physical characteristics and fish stocks/distributions to persist without human impact (Haertel 1984). NPS (2010a) stresses the importance of protecting LACL freshwater streams and lakes to preserve vital sockeye salmon stocks which travel through these waterways to spawn.

2.3.2 Status of Supporting Science

The SWAN identifies key resources (Vital Signs) network-wide and for each of its parks that can be used to determine the overall health of the parks (Table 3). In 2006, the SWAN completed and released the Vital Signs Monitoring Plan, which outlined the Vital Signs selected for monitoring in LACL (Bennett et al. 2006).

Table 3. SWAN Vital Signs selected for monitoring in LACL (Adapted from Bennett et al. 2006).

Category	LACL Vital Signs
Air and Climate	weather and climate[A]
Geology and Soils	glacier extent[A]
Water	surface hydrology, freshwater chemistry[A]
Biological Integrity	resident lake fish, bald eagle, brown bear, moose, vegetation composition and structure,sensitive vegetation communities[A]
Human Use	visitor use[B]
Landscapes Ecosystem	landscape processes[A]

A - Vital Signs that the SWAN is working independently or jointly with a network park, federal, state, or private partner to develop and implement monitoring protocols using funding from the Vital Signs or water quality monitoring programs (also in bold).

B - Monitored independently of SWAN by a network park, another NPS program, or another federal, state, or private agency (also in italics).

2.4 Landcover and Landscape Processes

Landcover datasets do not lend themselves to assessment, due to their variability regarding the definition of landcover classes from one data set year to the next. However, some general observations between data set years can be made, as well as statements regarding the importance of how natural processes shape the LACL landscape.

2.4.1 LACL Landcover Datasets

Landcover data sets for LACL were created for both 1989 and 1998. The dataset in 1989 was not a complete representation of LACL, as 63% of the park and preserve area (1,041,794 ha [2,574,319 ac]) were classified as “no data” (Plate 5). The classified landcover areas within LACL were compiled from the Tyonek and Lake Clark landcover data sets, with the Lake Clark dataset representing most of the 589,948 classified hectares. The Lake Clark landcover data sets were created by the U.S. Geological Survey Earth Resources Observation and Science Center (USGS EROS) and were developed from satellite imagery in support of the Bristol Bay Landcover Mapping Project (USGS 1989); a total of 19 landcover classes were included (Table 4). The most prevalent

landcover class was snow/cloud/light barren, covering 157,026.8 ha (388,020.1ac; 9.6%) of the total classified park area.

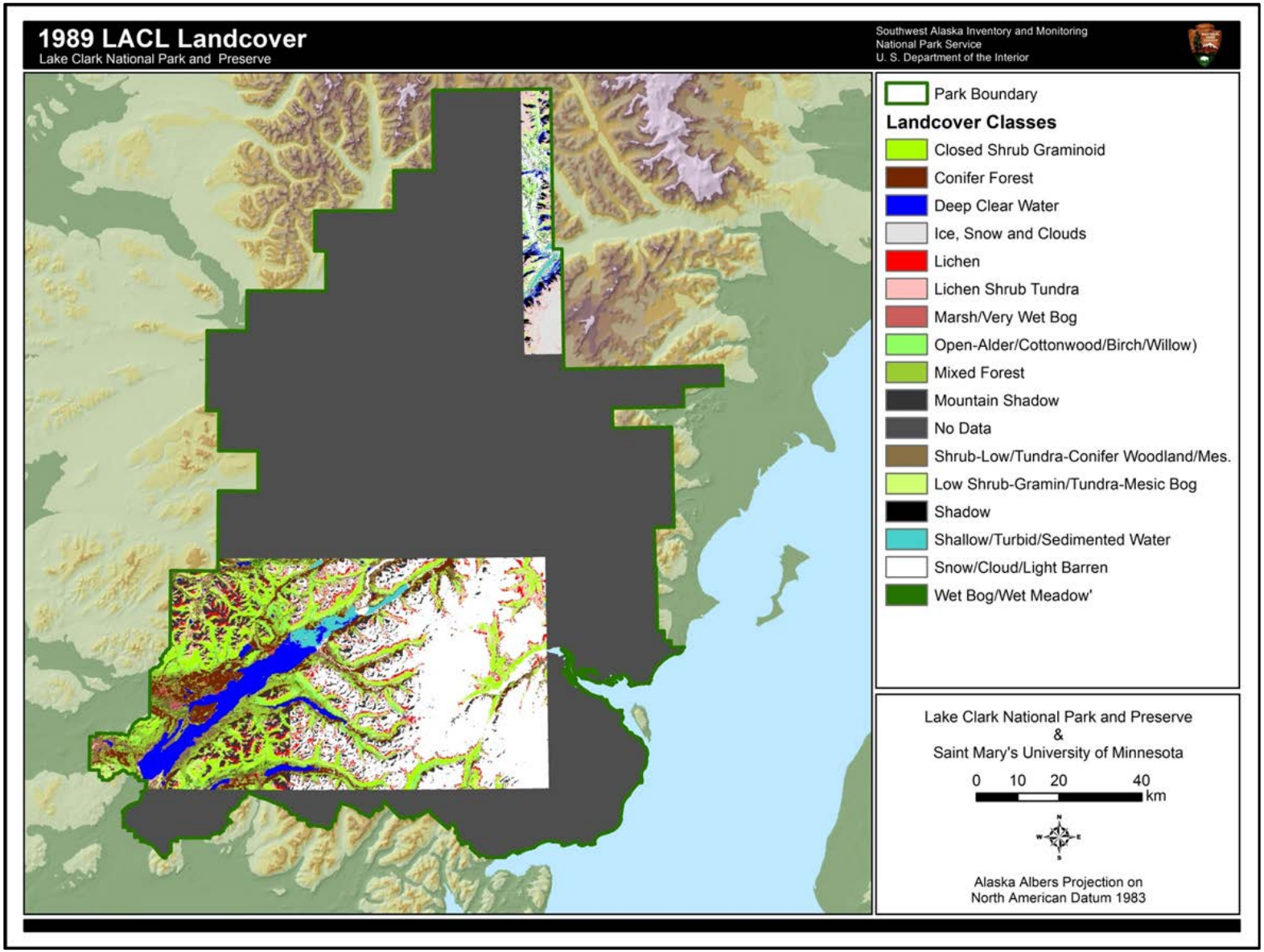


Plate 5. Landcover classes and coverage for LACL 1989. Landcover classes combined from original data for display purposes (USGS 1989).

Table 4. 1989 landcover classes and coverage areas for LACL (USGS 1989).

Landcover Class	Hectares	% Landcover
No Data	1,041,794.3	63.8
Snow/Cloud/Light Barren	157,026.8	9.6
Snow/Cloud/Light Barren	57,023.3	3.5
Mixed Forest	47,142.5	2.9
Open Low Shrub Gramin./Mesic Bog/Gramin. Shrub Tundra	41,426.3	2.5
Closed Shrub Graminoid	38,946.5	2.4
Mountain Shadow	37,945.3	2.3
Conifer Forest	37,071.8	2.3
Deep Clear Water	36,059.5	2.2
Open Low Shrub Eric./Conifer Woodland/Mes.Bog/Eric.Shrub Tundra	32,030.3	2.0
Lichen Shrub Tundra	27,116.5	1.7
Miscellaneous Deciduous (Open Alder, Cottonwood, Birch, Willow)	21,993.8	1.3
Lichen	19,882.0	1.2
Ice, Snow and Clouds	12,512.5	0.8
Shallow/Sedimented Water	8,041.3	0.5
Marsh/Very Wet Bog	5,364.3	0.3
Shadow	4,609.8	0.3
Wet Bog/Wet Meadow'	4,510.0	0.3
Turbid and/or Shallow Water	1,245.8	0.1
Total	**1,631,742.0**	**100.0**

The 1998 landcover dataset was completed in fulfillment of an NPS contract to define the landcover of LACL in order to meet park management needs (Plate 6). Pacific Meridian Resources (PMR) utilized spot multispectral imagery to create a landcover map of LACL which included 31 landcover classes (Plate 6) (NPS 1997). The map was then refined with field observations, aerial photography, and other GIS data. The 1998 landcover class dataset for LACL is represented with a 50-m (164 ft) cell size and defined as having an overall accuracy of 83%. The most prevalent landcover class was ice and snow, covering 324,167.1 ha (801,031.1 ac; 19.9 %) of the total park area (Table 5).

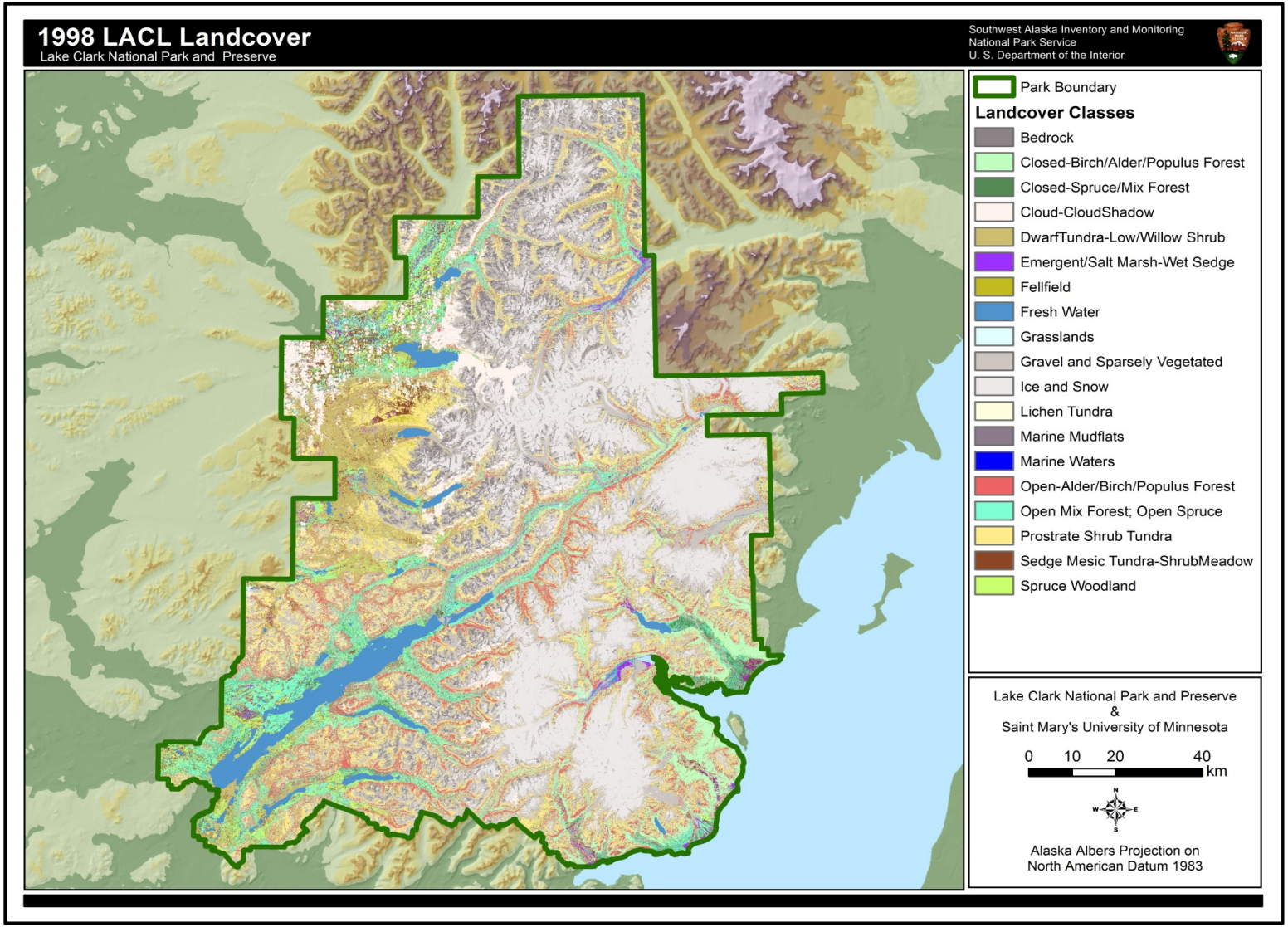


Plate 6. Landcover classes and coverage for LACL 1998. Landcover classes combined from original data for display purposes (NPS 1997).

Table 5. 1998 landcover classes and coverage areas for LACL (NPS 1997).

Landcover Class	Hectares	% Landcover
Ice and Snow	324,167.1	19.9
Gravel and Sparsely Vegetated	291,368.8	17.9
Prostrate Shrub Tundra	171,973.0	10.5
Closed Alder	129,589.1	7.9
Open Alder	118,827.1	7.3
Bedrock	102,825.7	6.3
Cloud & Cloud Shadow	57,874.1	3.5
Dwarf Shrub Tundra	55,033.6	3.4
Open Spruce	49,754.4	3.0
Fresh Water-Clear	47,962.0	2.9
Low Shrub	42,878.1	2.6
Open Mix Forest	41,569.2	2.5
Spruce Woodland	39,012.3	2.4
Sedge & Shrub Bog Meadow	28,658.6	1.8
Closed Mix Forest	19,425.0	1.2
Willow shrub	18,618.3	1.1
Lichen Tundra	18,025.2	1.1
Grasslands	16,958.8	1.0
Water - Silty and/or Shallow	13,575.3	0.8
Close Birch Forest	8,384.6	0.5
Wet Sedge Meadow	7,861.4	0.5
Open Birch Forest	6,108.2	0.4
Closed Populus Forest	4,101.4	0.3
Sedge Dominated Mesic Tundra	3,944.7	0.2
Open Populus Forest	3,639.5	0.2
Closed Coastal Spruce	3,570.1	0.2
Closed Interior Spruce	2,460.3	0.2
Fellfield	1,291.3	0.1
Salt Marsh	1,267.6	0.1
Emergent Marsh	727.6	0.0

Table 5 (continued). 1998 landcover classes and coverage areas for LACL (NPS 1997).

Landcover Class	Hectares	% Landcover
Marine Mudflats	144.2	0.0
Marine Waters	130.8	0.0
Total	**1,631,727.4**	**100.0**

2.4.2 Dominant Landscape Processes

Insect Outbreak Effects

Outbreaks of various insect and worm species including beetles, sawflies, bud worms, and defoliators have caused major landscape changes to some regions in Alaska (Wittwer 2005). Recent outbreaks of spruce beetle (*Dendroctonus rufipennis*) were noted in LACL along Lake Tazimina beginning in the mid-2000s (USFS 2007, 2009). Beetle activity was also detected around Kontrashibuna Lake and in the Tlikakila and Chokotonk River Valleys (USFS 2011). By 2012, spruce beetle damage was still detected at LACL but appeared to be declining (USFS 2013).

Volcanic Activity

LACL was largely formed by tectonic plate movements and volcanic activity (Haertel 1984). The area is still volcanically active and includes two volcanoes, Iliamna and Redoubt (Photo 8). Redoubt produced large scale eruptions in 1990 (Bennett et al. 2006) and again in 2009 (Shaefer 2012). Large-scale eruptions cause significant disturbances to the landscape and vegetation of LACL through debris, lava flows, avalanches, and other geologic changes. Lava flows and strong volcanic blasts transform vegetation-rich landcover classes to barren landscapes.



Photo 8. Steam rising from the lava dome on Redoubt Volcano (NPS photo by S. Huffman).

Permafrost/Climate Change

Osterkamp (2007a) describes a warming trend in Alaskan permafrost over the twentieth century that coincides with observations of higher average temperatures and snow fall totals. Higher snow fall totals, possibly caused by warmer temperatures, insulate the permafrost and may be the cause for increased surface and core permafrost temperatures over regions of coastal and inland Alaska. A myriad of other variables can influence permafrost temperatures including the area's topography, hydrology, geology, vegetation coverage, and human, animal, or fire disturbance. These variables affect permafrost over various timescales ranging from the effects of a fire, observed in days, to factors that can be tracked over centuries, including climate or geologic changes (Osterkamp 2007). Therefore, tracking and identifying the causes of permafrost temperature changes are extremely difficult (Osterkamp 2007). Although no data describing surface or core permafrost temperature

trends in LACL are available, the region has shown increased temperatures and precipitation over the twentieth century (Lindsay 2011). Given that these increases have caused surface and core permafrost temperatures to rise in other Alaskan regions, this process may be occurring in LACL.

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Chapter 3 Study Scoping and Design

This NRCA is a collaborative project between the NPS and SMUMN GSS. Project stakeholders include the LACL resource management team and SWAN Inventory and Monitoring Program staff. Before embarking on the project, it was necessary to identify the specific roles of the NPS and SMUMN GSS. Preliminary scoping meetings were held, and a task agreement and a scope of work document were created cooperatively between the NPS and SMUMN GSS.

3.1 Preliminary Scoping

A preliminary scoping meeting was held from 7-8 May 2013. At this meeting, SMUMN GSS and NPS staff confirmed that the purpose of the LACL NRCA was to evaluate and report on current conditions, critical data and knowledge gaps, and selected existing and emerging resource condition influences of concern to LACL managers. Certain constraints were placed on this NRCA, including the following:

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

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

- Develop near-term management priorities (how to allocate limited staff and funding
- resources);
- Engage in watershed or landscape scale partnership and education efforts;
- Consider new park planning goals and take steps to further these;
- Report program performance (e.g., Department of Interior Strategic Plan "land health" goals, Government Performance and Results Act [GPRA]).

Specific project expectations and outcomes included the following:

- For key natural resource components, consolidate available data, reports, and spatial information from appropriate sources including: LACL resource staff, the NPS Integrated Resource Management Application (IRMA) website, Inventory and Monitoring Vital Signs program, and available third-party sources. The NRCA report will provide a resource assessment and summary of pertinent data evaluated through this project.

- When appropriate, define a reference condition so that statements of current condition may be developed. The statements will describe the current state of a particular resource with respect to an agreed upon reference point.

- Clearly identify "management critical" data (i.e., those data relevant to the key resources). This will drive the data mining and gap definition process.

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

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

3.2 Study Design

3.2.1 Indicator Framework, Focal Study Resources and Indicators

Selection of Resources and Measures

As defined by SMUMN GSS in the NRCA process, a "framework" is developed for a park or preserve. This framework is a way of organizing, in a hierarchical fashion, bio-geophysical resource topics considered important in park management efforts. The primary features in the framework are key resource components, measures, stressors, and reference conditions.

"Components" in this process are defined as natural resources (e.g., birds, plant communities), ecological processes or patterns (e.g., natural fire regime), or specific natural features or values (e.g., geological formations) that are considered important to current park management. Each key resource component has one or more "measures" that best define the current condition of a component being assessed in the NRCA. Measures are defined as those values or characterizations that evaluate and quantify the state of ecological health or integrity of a component. In addition to measures, current condition of components may be influenced by certain "stressors," which are also considered during assessment. A "stressor" is defined as any agent that imposes adverse changes upon a component. These typically refer to anthropogenic factors that adversely affect natural ecosystems, but may also include natural processes or disturbances such as floods, fires, or predation (adapted from GLEI 2010).

During the LACL NRCA scoping process, key resource components were identified by NPS staff and are represented as "components" in the NRCA framework. While this list of components is not a comprehensive list of all the resources in the park, it includes resources and processes that are unique to the park in some way, or are of greatest concern or highest management priority in LACL. Several measures for each component, as well as known or potential stressors, were also identified in collaboration with NPS resource staff.

Selection of Reference Conditions

A "reference condition" is a benchmark to which current values of a given component's measures can be compared to determine the condition of that component. A reference condition may be a historical condition (e.g., flood frequency prior to dam construction on a river), an established

ecological threshold (e.g., EPA standards for air quality), or a targeted management goal/objective (e.g., a bison herd of at least 200 individuals) (adapted from Stoddard et al. 2006).

Reference conditions in this project were identified during the scoping process using input from NPS resource staff. In some cases, reference conditions represent a historical reference before human activity and disturbance was a major driver of ecological populations and processes, such as "pre-fire suppression." In other cases, peer-reviewed literature and ecological thresholds helped to define appropriate reference conditions.

Finalizing the Framework

An initial framework was adapted from the organizational framework outlined by the H. John Heinz III Center for Science's "State of Our Nation's Ecosystems 2008" (Heinz Center 2008). Key resources for the park were adapted from SWAN's Vital Signs monitoring plan (Bennet et al. 2006). This initial framework was presented to park resource staff to stimulate meaningful dialogue about key resources that should be assessed. Significant collaboration between SMUMN GSS analysts and NPS staff was needed to focus the scope of the NRCA project and finalize the framework of key resources to be assessed.

The NRCA framework was finalized in summer 2013 following acceptance from NPS resource staff. It contains a total of 14components (Table 6) and was used to drive analysis in this NRCA. This framework outlines the components (resources), most appropriate measures, known or perceived stressors and threats to the resources, and the reference conditions for each component for comparison to current conditions.

Table 6. Lake Clark National Park and Preserve natural resource condition assessment framework.

Lake Clark National Park and Preserve
Natural Resource Condition Assessment Framework

	Component	Experts	Data Sources	Measures or Specific Analysis	Stressors	Reference Condition
Biotic Composition						
Ecological Communities						
	Salt Marsh Communities	Amy Miller	Hi-res 2010 aerial. Shorezone obliques.	Physiography, Landscape formation, Landscape change class		N/A
Mammals						
	Brown Bear	Buck Mangipane	State/NPS project (2010 coastal data), 2003/2004 coastal survey, 2000 southern interior survey (density estimate), coastal trend counts - salt marshes (~2003-present), harvest data may be useful (subsistence/personal), coastal trend count GIS data, 2003/2004 GIS data, TL photo data, meadow use and human influence	Population Size (2), Population density (2), Recruitment (through cohorts) (3), sex ratios (2), female survival (3)	Sport and subsistence hunting/DLP kills, human habituation, salmon escapement	Natural and Healthy (authorizing language); stable level of harvest which does not negatively impact the measures outlined in this document
	Caribou	Buck Mangipane	population photo census 1990-present (ADFG), composition counts, collared tracking for distribution (GIS location data), bull recruitment research (ADFG), ABR work (investigate)	Population Size (2), Recruitment (by cohort) (3), Sex ratios (2), Female survival (3)	Disease (hoof rot), habitat quality, winter ice events, predation	ADFG goals
	Black Bear	Buck Mangipane	State/NPS project (2010 coastal data), 2003/2004 coastal survey, 2000 southern interior survey (density estimate), coastal trend counts - salt marshes (~2003-present), harvest data may be useful (personal/sport/DLP), coastal trend count GIS data, 2003/2004 GIS data	Population size and density (2), Recruitment (through cohorts) (3), sex ratios (2), female survival (3)	Sport and subsistence hunting/DLP kills, human habituation, salmon escapement	Natural and Healthy (authorizing language); Insufficient information to define quantitative reference conditions
	Dall Sheep	Buck Mangipane	Aerial survey data (NPS; 1978-2012) with GIS data, Mineral lick monitoring (NPS, one summer, on-ground observations, Bennett before NPS), 2005-2008 RC data in southern park (70k locations), subsistence harvest data, ADFG harvest data	Population Size (2), Population Density (2), Lamb-Ewe Ratios (3), Sex Ratios (2), Ram Composition (3), Survival Data (2)	Harvest, climate/vegetation change	Lamb:ewe ratio for stable population is 27 lambs:100 ewes; Reference condition could not be defined for other measures
	Moose	Buck Mangipane	Survey data - ADFG trend counts, 1990s Gasaway method, 2003 sightability model, 2003-2012 survey data for moose, 1998-2002 RC adult data for survival and sightability model, 2003-2005 calf RC data. Sport harvest data.	Population Size (2), Population Density (2), Sex Ratios (2), Calf:Cow Ratios (3), Bull Composition (2), Female Survival (3)	Habitat change and succession, predation, sport harvest	ADFG goals
Birds						
	Bald Eagles	Buck Mangipane	occupancy and productivity surveys from ~1990-present (coast and interior), USFWS surveys on the coast (possible), GIS model for habitat	Nest occupancy (3), productivity (3)	Human activities (e.g., tourism, fishing, timber harvest, oil spills), contaminants, extreme weather	Occupancy: 20-year historic average, Productivity: Sprunt et al. (1973)'s productivity threshold for a stable bald eagle population
Fish						
	Salmon	Dan Young	Escapement reports/database, Examine Cook Inlet streams, Crescent River 1979-present sonar, Kvichak/Nushagak, commercial set net reports, sport fishing, mail-in survey data, guide logbook data, subsistence data for Lake Clark by community, TEK reports, Lake Clark subsistence harvest, University of Washington data since 1963 (68-83 aerial surveys), Tilaquana Lake escapement (3 years), Silver Salmon Creek project, genetics data locational summary, run timing related to genetics, salmon telemetry data, juvenile distribution data (1960s, 1980s, present), age/size at maturity data, growth rates over time (otolith sampling, historic and present), creel surveys	Escapement - including Newhaven (3), Percent harvest (2), Harvest (3), Run Timing (MDOE) (2), Run duration (2) [data transfer to database - possible]	Commercial harvest, PDO variability, oceanic changes	Escapement goals (Kvichak, Naknek, Nushagak, Kuskokwim), compare and discuss
	Resident Fish	Dan Young	Focused data on specific species: fish inventory (pre-park 1978-79), Dan's project data. Biological data: age/size, growth rates. Telemetry data. Contaminants data.	Fish inventory/catch data, contaminants	Mercury deposition sources, Synthetic organic pollutants	Specific thresholds for particular contaminants (EPA), relative to species sampled
Environmental Quality						
	Air Quality	Paul Burger, DENA AQ specialist	IMPROVE - Silver Salmon Creek. NADP King Salmon. Stairstep moss/lichen sampling. Swan Moss Contaminants Sampling (M. Shephard).	**No condition assessment.** Provide summary of available data	Pollutants from mining operations, oil and gas development, long-range transport of contaminants	NPS ARD standards
	Water Quality	Jeff Shearer	I&M Lake profile data, past limnology sampling, USGS monitoring projects (graphs, tables), past fishery projects work. Evan Booher - data contact.	**No condition assessment.** Provide summary of data available for the particular site	Climatic changes, human influences (barges, development, etc.)	State fish and wildlife WQ standards (temp, DO), rearing standards vs migratory/resident standards
	Water Quantity	Jeff Shearer	USGS gauge data - RTWQ website, instantaneous measurements through SWAN & USGS, lake level data 1999-present	**No condition assessment.** Compile data and create yearly flows/charts for different sites. Using USGS, NWIS database, and others available. Coastal watershed assessment data.	Climatic changes, human influence (development, proposed mining)	Natural and Healthy Flows (undefined, in process of developing data)

Table 6 (continued). Lake Clark National Park and Preserve natural resource condition assessment framework.

Lake Clark National Park and Preserve
Natural Resource Condition Assessment Framework

Component	Experts	Data Sources	Measures or Specific Analysis	Stressors	Reference Condition
Physical Characteristics					
Climate	Chuck Lindsay	PALW, ILI Data. Rclimdex and indices. Snow course data (~20 years of data). Lake ice data. Examine snow monitoring sites west of the park. FAA - weather observation instrumentation in the future (mention in the document).	Temperature, precipitation, snow depth/ice thickness and water equivalent	Climate change (especially warming)	30-year climate normals will be used for this assessment
Glaciers	Chuck Lindsay	Extent dataset comparisons. UAF Surface elevation transects. USGS data - glacial freshwater contribution. Ask Chuck about aerial obliques of glaciers and videos of change at weather stations.	Area, rate of terminus retreat, mass balance (surface elevation)	Climate change (increasing temperatures)	

3.2.2 General Approach and Methods

This study involved gathering and reviewing existing literature and data relevant to each of the key resource components included in the framework. No new data were collected for this study; however, where appropriate, existing data were further analyzed to provide summaries of resource condition or to create new spatial representations. After all data and literature relevant to the measures of each component were reviewed and considered, a qualitative statement of overall current condition was created and compared to the reference condition when possible.

Data Mining

The data mining process (acquiring as much relevant data about key resources as possible) began at the initial scoping meeting, at which time LACL staff provided data and literature in multiple forms, including: NPS reports and monitoring plans, reports from various state and federal agencies, published and unpublished research documents, databases, tabular data, and charts. GIS data were also provided by NPS staff. Additional data and literature were acquired through online bibliographic literature searches and inquiries on various state and federal government websites. Data and literature acquired throughout the data mining process were inventoried and analyzed for thoroughness, relevancy, and quality regarding the resource components identified at the scoping meeting.

Data Development and Analysis

Data development and analysis was highly specific to each component in the framework and depended largely on the amount of information and data available for the component, as well as recommendations from NPS reviewers and sources of expertise including NPS staff from LACL and the SWAN. Specific approaches to data development and analysis can be found within the respective component assessment sections located in Chapter 4 of this report.

Scoring Methods and Assigning Condition

Significance Level

A set of measures are useful in describing the condition of a particular component, but all measures may not be equally important. A "Significance Level" represents a numeric categorization (integer scale from 1-3) of the importance of each measure in assessing the component's condition; each Significance Level is defined in Table 7.This categorization allows measures that are more important for determining condition of a component (higher Significance Level) to be more heavily weighted in calculating an overall condition. Significance Levels were determined for each component measure in this assessment through discussions with park staff and/or outside resource experts.

Table 7. Scale for a measure's Significance Level in determining a components overall condition.

Significance Level (SL)	Description
1	Measure is of low importance in defining the condition of this component.
2	Measure is of moderate importance in defining the condition of this component.
3	Measure is of high importance in defining the condition of this component.

Condition Level

After each component assessment is completed (including any possible data analysis), SMUMN GSS analysts assign a Condition Level for each measure on a 0-3 integer scale (Table 8). This is based on all the available literature and data reviewed for the component, as well as communications with park and outside experts.

Table 8. Scale for Condition Level of individual measures.

Condition Level (CL)	Description
0	Of **NO** concern. No net loss, degradation, negative change, or alteration.
1	Of **LOW** concern. Signs of limited and isolated degradation of the component.
2	Of **MODERATE** concern. Pronounced signs of widespread and uncontrolled degradation.
3	Of **HIGH** concern. Nearing catastrophic, complete, and irreparable degradation of the component.

Weighted Condition Score

After the Significance Levels (SL) and Condition Levels (CL) are assigned, a Weighted Condition Score (WCS) is calculated via the following equation:

$$WCS = \frac{\sum_{i=1}^{\#\ of\ measures} SL_i * CL_i}{3 * \sum_{i=1}^{\#\ of\ measures} SL_i}$$

The resulting WCS value is placed into one of three possible categories: good condition (WCS = 0.0 – 0.33); condition of moderate concern (WCS = 0.34 - 0.66); and condition of significant concern (WCS = 0.67 to 1.0). Figure 1 displays all of the potential graphics used to represent a component's condition in this assessment. The colored circles represent the categorized WCS; red circles signify a significant concern, yellow circles a moderate concern and green circles that a resource is in good condition. White circles are used to represent situations in which SMUMN GSS analysts and park staff felt there were currently insufficient data to make a statement about the condition of a

component. For example, condition is not assessed when no recent data or information are available, as the purpose of an NRCA is to provide a "snapshot-in-time" of current resource conditions. The arrows inside the circles indicate the trend of the condition of a resource component, based on data and literature from the past 5-10 years, as well as expert opinion. An upward pointing arrow indicates the condition of the component has been improving in recent times. A horizontal arrow indicates an unchanging condition or trend, and an arrow pointing down indicates deterioration in the condition of a component in recent times. These are only used when it is appropriate to comment on the trend of condition of a component. In situations where the trend of the component's condition is currently unknown, no arrow is given.

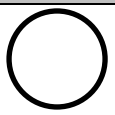
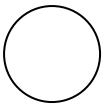
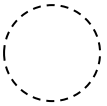
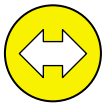
Condition Status		Trend in Condition		Confidence in Assessment	
	Resource is in Good Condition		Condition is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Medium
	Warrants Significant Concern		Condition is Deteriorating		Low

Figure 1. Description of symbology used for individual component assessments.

Examples of how the symbols should be interpreted:



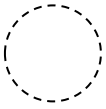
Resource is in good condition; its condition is improving; high confidence in the assessment.



Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.



Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.



Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment.

Preparation and Review of Component Draft Assessments

The preparation of draft assessments for each component was a highly cooperative process among SMUMN GSS analysts and LACL and SWAN staff. Though SMUMN GSS analysts rely heavily on peer-reviewed literature and existing data in conducting the assessment, the expertise of NPS resource staff also plays a significant and invaluable role in providing insights into the appropriate

direction for analysis and assessment of each component. This step is especially important when data or literature are limited for a resource component.

The process of developing draft documents for each component began with a detailed phone or e-mail conversation with an individual or multiple individuals considered local experts on the resource components under examination. These conversations were a way for analysts to verify the most relevant data and literature sources that should be used and also to formulate ideas about current condition with respect to the NPS staff opinions. Upon completion, draft assessments were forwarded to component experts for initial review and comments.

Development and Review of Final Component Assessments

Following review of the component draft assessments, analysts used the review feedback from resource experts to compile the final component assessments. As a result of this process, and based on the recommendations and insights provided by LACL resource staff and other experts, the final component assessments represent the most relevant and current data available for each component and the sentiments of park resource staff and outside resource experts.

Format of Component Assessment Documents

All resource component assessments are presented in a standard format. The format and structure of these assessments is described below.

Description

This section describes the relevance of the resource component to the park and the context within which it occurs in the park setting. For example, a component may represent a unique feature of the park, it may be a key process or resource in park ecology, or it may be a resource that is of high management priority. Also emphasized are interrelationships that occur among the featured component and other resource components included in the NRCA.

Measures

Resource component measures were defined in the scoping process and refined through dialogue with resource experts. Those measures deemed most appropriate for assessing the current condition of a component are listed in this section, typically as bulleted items.

Reference Conditions/Values

This section explains the reference condition determined for each resource component as it is defined in the framework. Explanation is provided as to why specific reference conditions are appropriate or logical to use. Also included in this section is a discussion of any available data and literature that explain and elaborate on the designated reference conditions. If these conditions or values originated with the NPS experts or SMUMN GSS analysts, an explanation of how they were developed is provided.

Data and Methods

This section includes a discussion of the data sets used to evaluate the component and if or how these data sets were adjusted or processed as a lead-up to analysis. If adjustment or processing of data involved an extensive or highly technical process, these descriptions are included in an appendix for

the reader or a GIS metadata file. Also discussed is how the data were evaluated and analyzed to determine current condition (and trend when appropriate).

Current Condition and Trend
This section presents and discusses in-depth key findings regarding the current condition of the resource component and trends (when available). The information is presented primarily with text but is often accompanied by detailed maps or plates that display different analyses, as well as graphs, charts, and/or tables that summarize relevant data or show interesting relationships. All relevant data and information for a component is presented and interpreted in this section.

Threats and Stressor Factors
This section provides a summary of the threats and stressors that may impact the resource and influence to varying degrees the current condition of a resource component. Relevant stressors were described in the scoping process and are outlined in the NRCA framework. However, these are elaborated on in this section to create a summary of threats and stressors based on a combination of available data and literature, and discussions with resource experts and NPS natural resources staff.

Data Needs/Gaps
This section outlines critical data needs or gaps for the resource component. Specifically, what is discussed is how these data needs/gaps, if addressed, would provide further insight in determining the current condition or trend of a given component in future assessments. In some cases, the data needs/gaps are significant enough to make it inappropriate or impossible to determine condition of the resource component. In these cases, stating the data needs/gaps is useful to natural resources staff seeking to prioritize monitoring or data gathering efforts.

Overall Condition
This section provides a qualitative summary statement of the current condition that was determined for the resource component using the WCS method. Condition is determined after thoughtful review of available literature, data, and any insights from NPS staff and experts, which are presented in the Current Condition and Trend section. The Overall Condition section summarizes the key findings and highlights the key elements used in determining and justifying the level of concern, if any, that analysts attribute to the condition of the resource component. Also included in this section are the graphics used to represent the component condition.

Sources of Expertise
This is a listing of the individuals (including their title and affiliation with offices or programs) who had a primary role in providing expertise, insight, and interpretation to determine current condition (and trend when appropriate) for each resource component.

Literature Cited
This is a list of formal citations for literature or datasets used in the analysis and assessment of condition for the resource component. Note, citations used in appendices and plates referenced in each section (component) of Chapter 4 are listed in that component's "Literature Cited" section.

3.3 Literature Cited

Great Lakes Environmental Indicators Project (GLEI). 2010. Glossary, Stressor. http://glei.nrri.umn.edu/default/glossary.htm (accessed 31 January 2013).

The H. John Heinz III Center for Science, Economics, and the Environment. 2008. The state of the nation's ecosystems 2008: Measuring the land, waters, and living resources of the United States. Island Press, Washington, D.C.

Stoddard, J. L., D. P. Larsen, C. P. Hawkins, R. K. Johnson, and R. J. Norris. 2006. Setting expectations for the ecological condition of streams: the concept of reference condition. Ecological Applications 16(4):1267-1276.

Chapter 4 Natural Resource Conditions

This chapter presents the background, analysis, and condition summaries for the 14 key resource components in the project framework. The following sections discuss the key resources and their measures, stressors, and reference conditions. The summary for each component is arranged around the following sections:

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

The order of components follows the project framework (Table 6):

4.1 Salt Marsh Communities

4.2 Brown Bear

4.3 Caribou

4.4 Black Bear

4.5 Dall's Sheep

4.6 Moose

4.7 Bald Eagles

4.8 Salmon

4.9 Resident Fish

4.10 Air Quality

4.11 Water Quality

4.12 Water Quantity

4.13 Climate

4.14 Glaciers

4.1 Salt Marsh Communities

4.1.1 Description

The geomorphology of coastal areas in LACL has been shaped by a variety of erosional and depositional processes that are a function of waves, winds and currents (Jorgenson et.al. 2010). Salt marsh communities represent one type of coastal geomorphic unit in LACL and are characterized by tidal flats interspersed with channels, levees, basins and pools (Jorgenson et.al. 2010).

Despite salt marsh communities occupying less than one percent of the total land area of LACL, they are considered to have great importance to the park's ecosystems (NPS 2014). Salt marshes are among the most productive ecosystems in the world and provide habitat and food for a variety of the park's species including coastal brown bears, salmon, and resident and migratory birds (NPS 2014). The critical relationship between salt marshes and the wildlife they support has prompted the SWAN I&M to label them as "sensitive communities" and identify them as a Vital Sign for LACL (Nagorski et al. 2008). These communities are primarily congregated on a 200 km (124 mi) stretch of coastline from Chinitna Bay to Redoubt Point (Bennett 1996), including Tuxedni Bay. The specific areas analyzed within this assessment are illustrated in Figure 2.

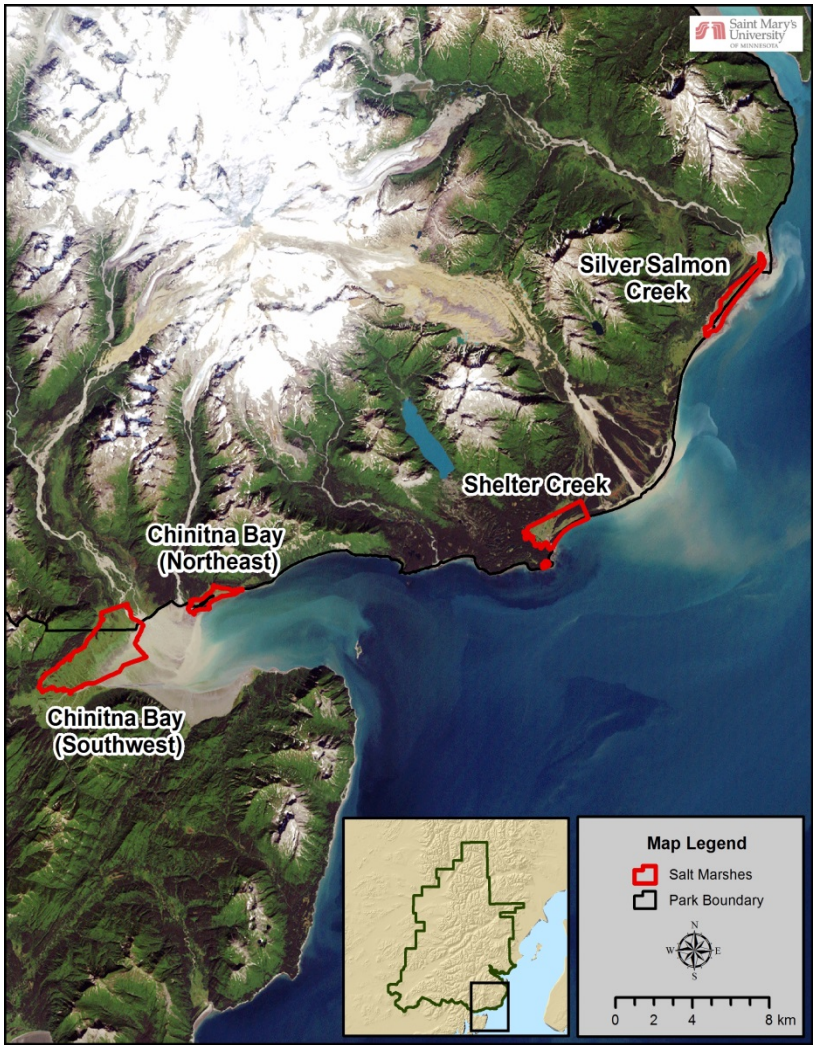


Figure 2. Three coastal salt marsh areas mapped and delineated in LACL. From left to right Chinitna Bay Southwest. Chinitna Bay Northeast, Shelter Creek, and Silver Salmon Creek.

As part of this NRCA, photo interpretation was used to better understand and identify the changes that occur over extended periods of time within the salt marshes of LACL. By utilizing imagery from 1950, 1980, and 2010 we can delineate vegetation, mudflat, and other features of the salt marshes at a point in time as a reference point. This reference point can then be compared to others giving us an indication of the change that has occurred. The line work, shown in red in all of the figures denotes what the photo interpreter delineated as the physiography and landscape formation of all three year classes. Each polygon has a specific physiography, landscape formation, and landscape change class for each year. This assessment focused on three salt marsh communities which include: Silver Salmon Creek, Chinitna Bay, and Shelter Creek. Silver Salmon Creek (Figure 3) is easily accessible and is well known to LACL visitors for its fishing, bear viewing, clam digging, backpacking, and hiking. This salt marsh hosts Coho (silver) salmon and humpback (pink) salmon as well as a Dolly Varden run in the late summer. Visitors can also walk the tidal flats which are filled with razor, little-neck, and butter clams (NPS 2015b). Silver Salmon Creek salt marsh makes up 203.5 ha (502.3 ac) along LACL's shoreline.

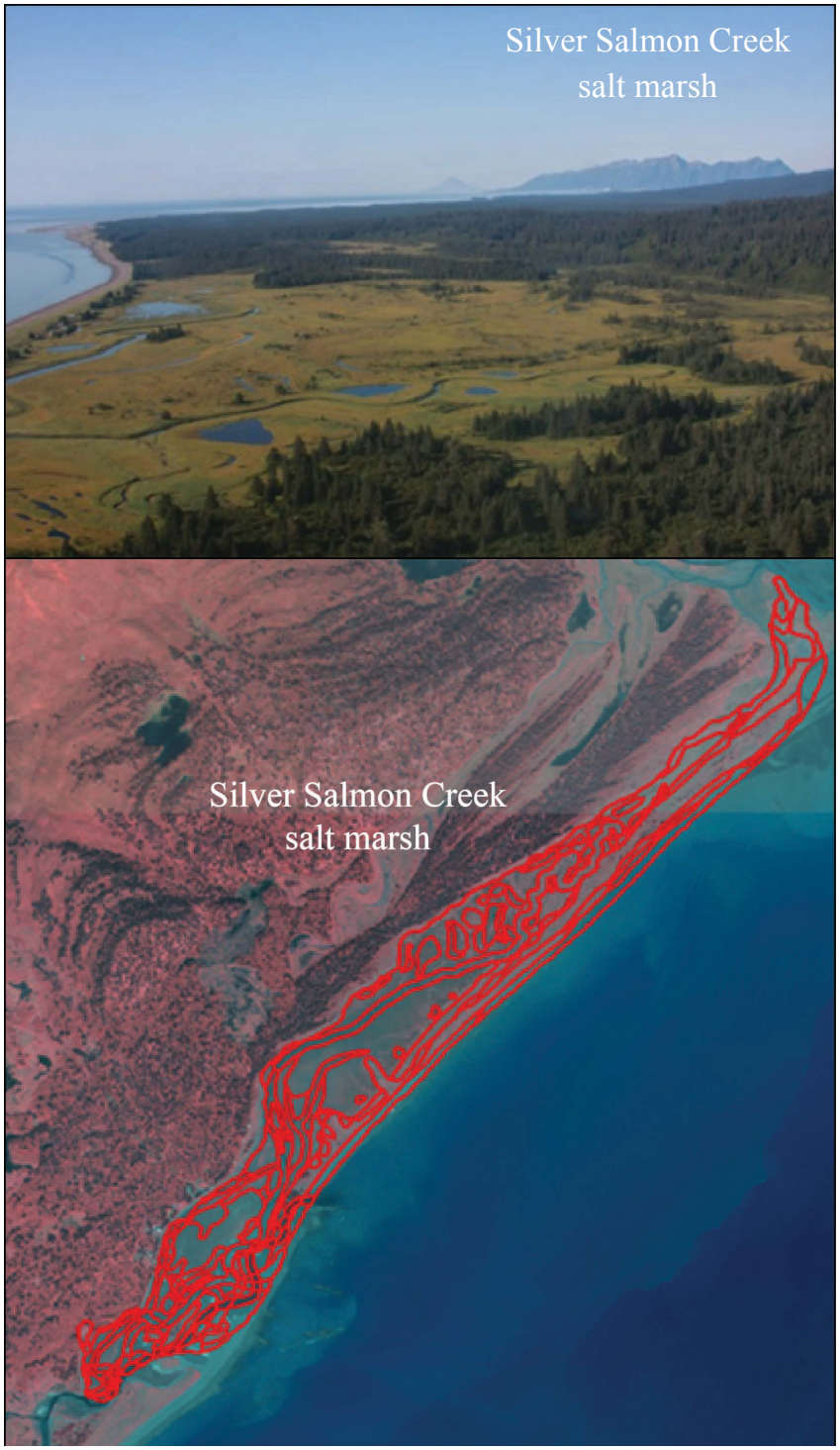


Figure 3. Above: Aerial photo of Silver Salmon Creek salt marsh (NPS photo by K. Jalone). Below: IKONOS (2010) imagery of Silver Salmon Creek with delineation lines.

Chinitna Bay (Figure 4) is well known by visitors for its brown bear viewing. The bears congregate in high numbers in the estuaries where rivers flowing out of the mountains meet the sea in Chinitna Bay. Late spring through mid-summer bears feed on sedges that are high in protein as well as other edible plants that grow in the salt marshes (NPS 2015a). For the purpose of this project, Chinitna Bay was split into two areas: Chinitna Bay South West (Figure 4) and Chinitna Bay North East (Figure 4). The Southwestern portion comprises 1,122.7 ha (2,774.2 ac) of shoreline area and the Northeastern part makes up 124.8 ha (307.1 ac).

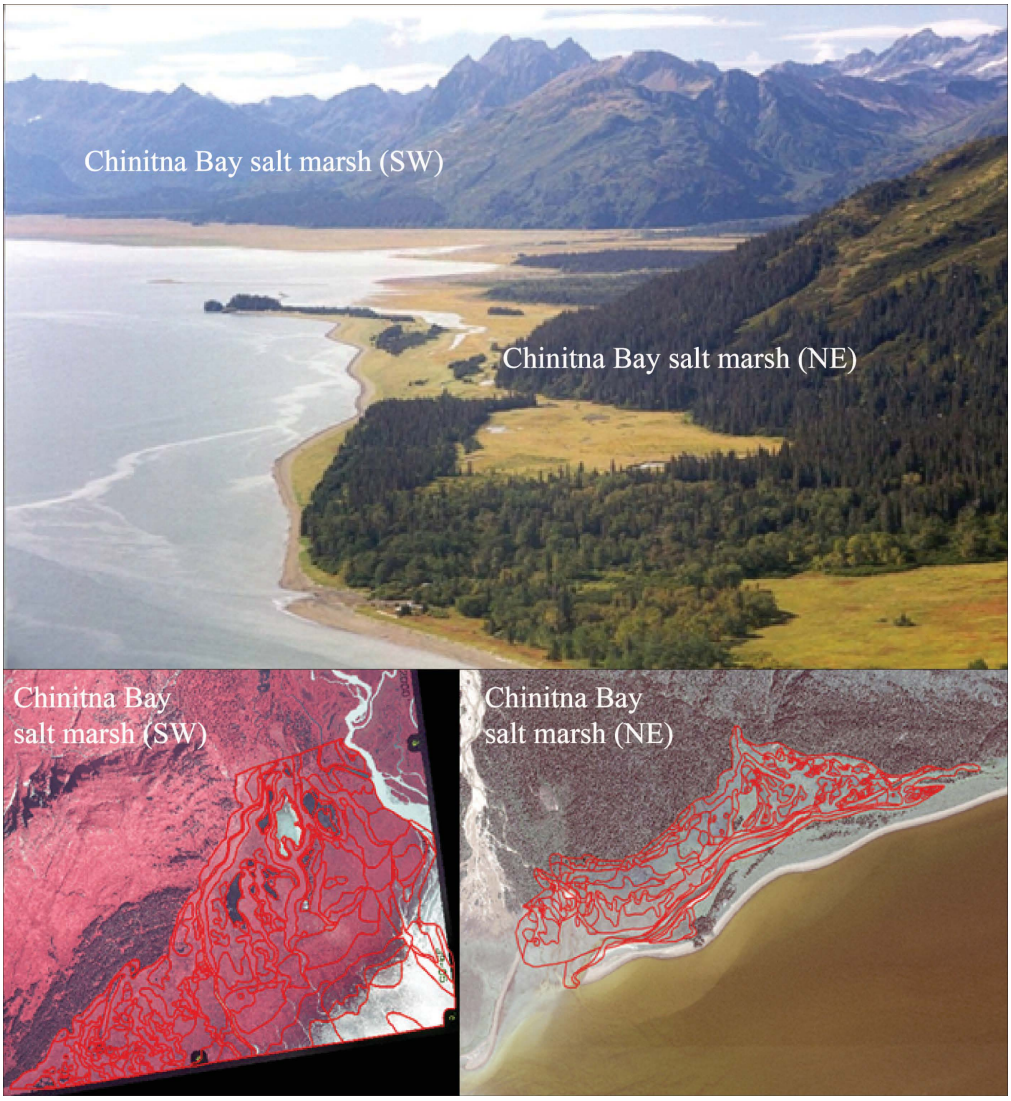


Figure 4. Above: Aerial Photo of the northeast and southwest Chinitna Bay salt marshes. Bottom left: IKONOS (2010) imagery of Chinitna Bay (SW) with delineation lines. Bottom Right: IKONOS (2010) imagery of Chinitna Bay (NE) with delineation lines.

Finally, Shelter Creek (Figure 5) is a more difficult salt marsh to access for LACL's visitors, making it less frequently visited as compared to the other salt marshes listed. Shelter Creek comprises 343.4 ha (848.5 ac) of the LACL shoreline.

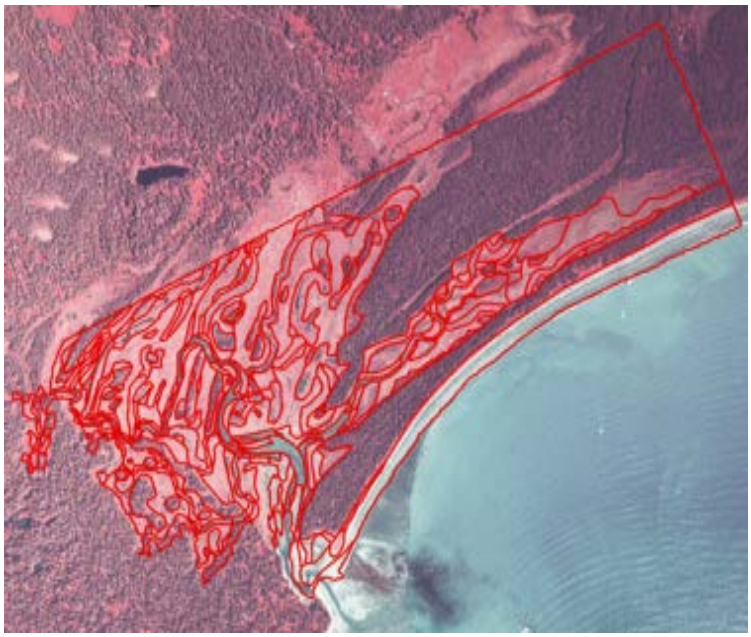


Figure 5. IKONOS (2010) imagery of Shelter Creek with salt marsh delineations.

4.1.2 Measures

- Physiography
- Landscape Formation
- Landscape Change Class

Physiography

A term describing geologic and/or the physical landscape. In this analysis physiography is synonymous with the geographic position of a certain feature on the landscape.

Landscape Formation

A term describing landscape features such as "Mudflat" or "Meadow." This description allows the user to mentally visualize or identify the physical feature being referred to.

Landscape Change Class

A classification system was used to describe the change that has occurred in the landscape over a period of time. In this analysis the landscape change class was derived from interpretations for each individual time step such that changes over time were characterized at several levels. For example, the transition "Mudflat and Panne" to "Meadow" was classified as "Vegetation Development/Expansion in Intertidal Area." Potential change classes were expected to include vegetation change (e.g., shrub establishment, shrub closure, spruce expansion) as well as geomorphic change (e.g., glacial retreat, channel migration, pond drying, mass wasting), both of which often occurred in concert. The development of change classes was a joint effort between NPS staff and image analysts from SMUMN (Burchiel et al. 2014).

4.1.3 Reference Conditions/Values

This salt marsh community inventory project does not contain an identified reference condition as it was not part of the scope of this inventory-oriented project. The project goal was to identify physiographic, landscape formation, and landscape change between three series of aerial/satellite photography from the 1950s, the 1980s, and the 2010s. These changes would then be presented as a component in this NRCA.

4.1.4 Data and Methods

Data were digitally photo interpreted using the photography from three different time steps: the 1950s (BW/1952-1957), the 1980s (CIR/1978-1980), and an IKONOS (CIR/2005-2009) and SPOT5 (CIR/2011) image composite. The 1950s imagery was black and white with some pixilation and of medium to low quality. This imagery was viewed at a scale of 1:15,000 in ArcMap during the interpretation process. The 1980s Alaska High Altitude Photography (AHAP) imagery was color infrared; this imagery was interpreted at 1:10,000 scale. The 2010's data, high-resolution, IKONOS/SPOT5 composite color infra-red satellite imagery was interpreted at a scale of 1:5,000.

The mapping and classification of the salt marshes delineated for this assessment were adapted from Tande (1996). Specific attributes interpreted for each marsh were limited by the quality of the aerial imagery and included physiography type, site moisture, and landscape formation values (Table 9).

Table 9. Possible classification/identification values for salt marshes (adapted from Tande 1996).

Physiography	Site Moisture	Landscape Formation
Upland	Moist	Upland
Coastal High Marsh	Wet	Meadow
Coastal Mid Marsh	Wet	Levee Meadow
Coastal Low & Mid Marsh	Wet	Levee
Coastal Low Marsh	Wet	Interlevee Basin & Channel Basin
	Wet	Interlevee Ponded Basin
	Wet	Interlevee Pond
	Wet	Interlevee Basin Meadow
	Wet	Pond or Lake
	Wet	Mudflat
	Wet	Mudflat and Panne
	Wet	Open Water
	Wet	Unconsolidated Shore
	Wet	Eroding Levee Meadow

4.1.5 Current Condition and Trend

Physiography

The physiographic location for each polygon that was delineated within the salt marshes was assessed at each of the three time steps to identify changes that had occurred. As per Tande (1996), "Barren" values were assigned to physiography that had a landscape formation value of "Mudflat" since this community was not considered to be a category of the vegetated salt marsh

community. Geospatial Services assigned a physiography of "Ocean" to community types that changed from salt marsh to water.

Silver Salmon Creek

The most common physiographic change in Silver Salmon Creek (Table 10) between the 1950s to 1980s time steps was "Upland" to "Barren" which comprised 6.29% of the area of Silver Salmon Creek. Figure 6 shows the physiographic change from 1950 to 1980 which was "Barren" to "Coastal Mid Marsh", perhaps due to uplift following the 1964 earthquake (Amy E. Miller, SWAN Ecologist, email communication, 21 April 2015). The analysis demonstrates that 67.29% of the area did not change from a physiographic perspective between these two time steps.

Table 10. Types of physiographic change from 1950s to 1980s in Silver Salmon Creek.

Physiography 1950	Physiography 1980	Area(ha)	Percent Area
No Change	No Change	123.15	67.29%
Upland	Barren	11.51	6.29%
Coastal Low & Mid Marsh	Coastal Mid Marsh	10.07	5.50%
Barren	Coastal Mid Marsh	8.91	4.87%
Barren	Upland	5.77	3.15%
Barren	Coastal Low Marsh	5.68	3.10%

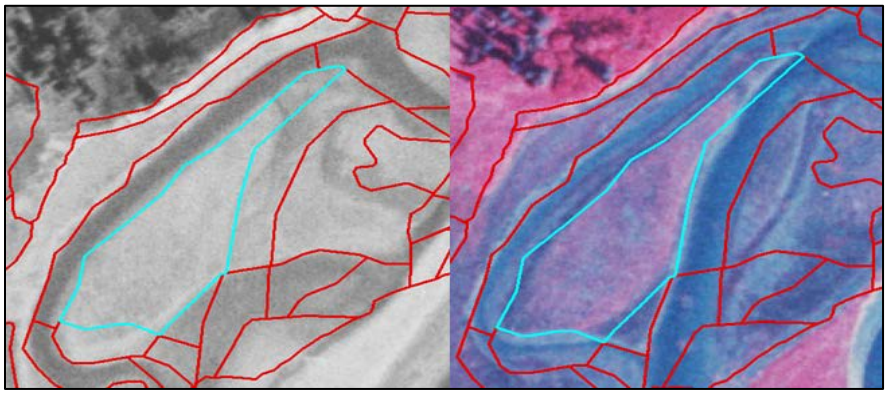


Figure 6. The presence of vegetation growth allowed for a physiographic change in Silver Salmon Creek from Barren in 1950 (left) to Coastal Mid Marsh in 1980 (right) at a scale of 1:2,000.

Results in Table 11 illustrate that the change from "Ocean" to "Barren" was the most common physiographic change between the time steps of the 1980s and 2010s but only involved 4.24% of the Silver Salmon Creek area. This analysis demonstrates that 78.40% of the physiography did not experience any change between these two time steps. Figure 7 shows representation of "Mass Wasting" from 1980 to 2010 where the physiography was "Upland" and then changed to "Ocean."

Table 11. Types of physiographic change from 1980s to 2010s in Silver Salmon Creek.

Physiography 1980	Physiography 2010	Area(ha)	Percent Area
No Change	No Change	143.72	78.40%
Ocean	Barren	7.75	4.24%
Coastal Low Marsh	Barren	5.62	3.07%
Upland	Barren	4.52	2.47%
Barren	Upland	4.34	2.38%
Barren	Coastal Low Marsh	2.58	1.41%

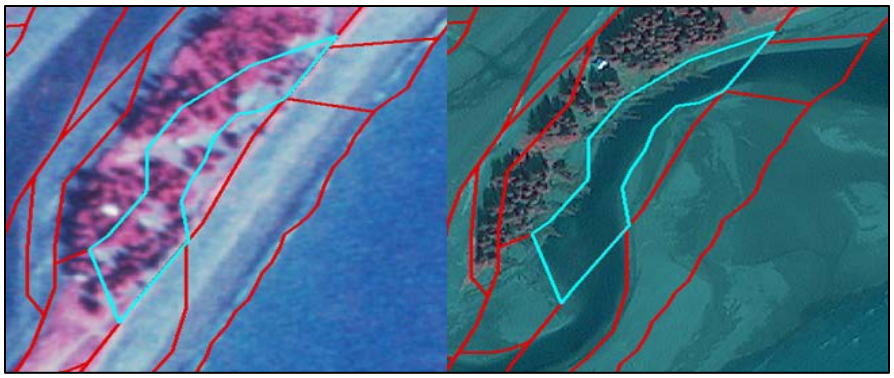


Figure 7. Physiographic change in Silver Salmon Creek from Upland in 1980 (left) to Ocean in 2010 (right) at a scale of 1:2,000.

The complete results on the type of physiographic change in Silver Salmon Creek can be seen in Appendix A, Appendix B, and Appendix C. Individual classifications of physiography for each year can be seen in Appendix D.

Chinitna Bay

The most common physiographic change in Chinitna Bay South West between the 1950s and the 1980s time steps was "Barren" to "Coastal Low Marsh" (Figure 8). This change made up 12.4% of the overall change to physiography in Chinitna Bay South West (Table 12). The analysis demonstrated that 85.23% of the area was unchanged from a physiographic standpoint between these time steps.

Table 12. Types of physiographic change from 1950 to 1980 in Chinitna Bay South West.

Physiography 1950	Physiography 1980	Area(ha)	Percent Area
No Change	No Change	737.91	85.23%
Barren	Coastal Low Marsh	107.32	12.40%
Barren	Coastal Low & Mid Marsh	13.14	1.52%
Coastal Low & Mid Marsh	Coastal Mid Marsh	4.13	0.48%
Coastal High Marsh	Barren	3.27	0.30%

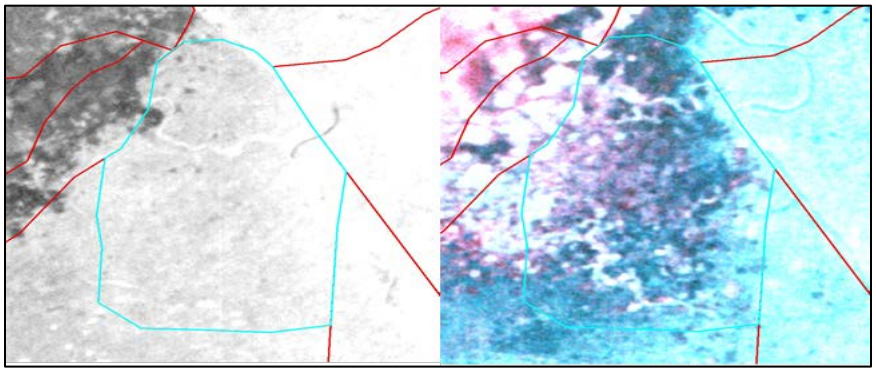


Figure 8. The expansion of vegetation within the mudflat allowed for a physiographic change in Chinitna Bay South West from Barren in 1950 (left) to Coastal Low Marsh in 1980 (right) at a scale of 1:2,000.

Similar results can be seen in Table 13 where 78.14% of the physiography area did not experience any change between the 1980s and the 2010s time steps in Chinitna Bay South West. The most common physiographic change in Chinitna Bay South West between the 1980s and the 2010s time steps was from "Coastal Low Marsh" to "Coastal Low & Mid Marsh" at 10.77% (Table 13).

Table 13. Types of physiographic change from 1980 to 2010 in Chinitna Bay South West.

Physiography 1980	Physiography 2010	Area (ha)	Percent Area
No Change	No Change	676.55	78.14%
Coastal Low Marsh	Coastal Low & Mid Marsh	93.23	10.77%
Barren	Coastal Low & Mid Marsh	64.93	7.50%
Coastal High Marsh	Barren	10.64	1.23%
Barren	Coastal Low Marsh	8.19	0.90%
Coastal Mid Marsh	Coastal High Marsh	3.72	0.43%

Table 14 shows the most common change in Chinitna Bay North East between the 1950s and the 1980s time steps was "Mudflat" (null) to "Coastal Low Marsh." This land cover change made up 9.22% of the overall change to physiography in Chinitna Bay South West. The analysis demonstrated that 84.98% of the physiography did not change between these time steps.

Table 14. Types of physiographic change from 1950 to 1980 in Chinitna Bay North East.

Physiography 1950	Physiography 1980	Area (ha)	Percent Area
Coastal Low Marsh	Ocean	1.27	1.02%
Barren	Ocean	1.35	0.84%
Coastal Low Marsh	Coastal Low & Mid Marsh	4.53	3.77%

Table 14 (continued). Types of physiographic change from 1950 to 1980 in Chinitna Bay North East.

Physiography 1950	Physiography 1980	Area (ha)	Percent Area
Barren	Coastal Low & Mid Marsh	4.41	3.66%

Similar results can be seen in Table 15 where 76.46% of the physiography area did not experience change between the 1980s and the 2010s time steps in Chinitna Bay North East. The most common physiographic change in Chinitna Bay North East between the 1980s and the 2010s time steps was "Coastal High Marsh" to "Upland" (Figure 9) at 4.74% (Table 15).

Table 15. Types of physiographic change from 1980 to 2010 in Chinitna Bay North East.

Physiography 1980	Physiography 2010	Area (ha)	Percent Area
No Change	No Change	91.85	76.46%
Coastal High Marsh	Upland	5.69	4.74%
Coastal Mid Marsh	Coastal High Marsh	5.62	4.68%
Coastal Mid Marsh	Upland	3.21	2.67%
Barren	Coastal Low Marsh	3.13	2.61%
Barren	Coastal Low & Mid Marsh	2.81	2.34%

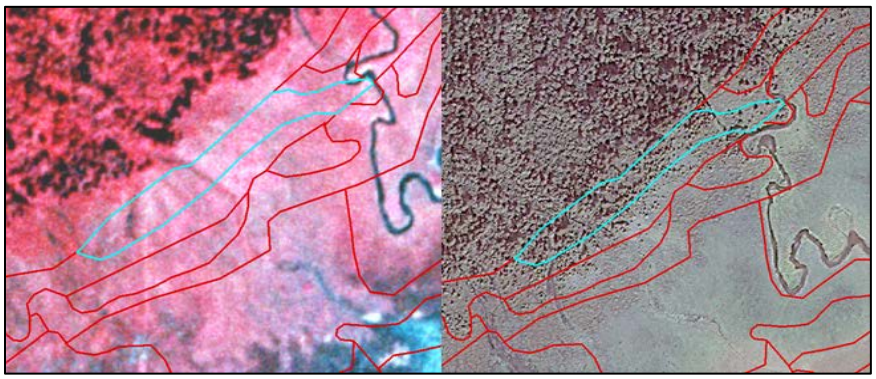


Figure 9. Although there is some image shift in the 1980 (left) photo, a physiographic change from Chinitna Bay North East Coastal High Marsh in 1980 (left) to Upland in 2010 (right) can still be seen at a scale of 1:2,000.

The complete results on the type of physiographic change in Chinitna Bay South West can be seen in Appendix K, Appendix L, and Appendix M. Complete results for Chinitna Bay North East can be seen in Appendix O, Appendix P, and Appendix Q. Individual classifications of physiography for each year can be seen in Appendix N for Chinitna Bay South West and in Appendix R for Chinitna Bay North East.

Shelter Creek

Table 16 illustrates the most common change in Shelter Creek from the 1950s to the 1980s time step. "Coastal Mid Marsh" to "Coastal Low & Mid Marsh" was the most common land cover change, in the particular instance shown, stream formation caused the physiographic change (Figure 10). This change occurred in only 2.43% of the overall physiography of the Shelter Creek area. The analysis demonstrates that 91.09% of the physiography did not change between these time steps.

Table 16. Types of physiographic change from 1950 to 1980 in Shelter Creek.

Physiography 1950	Physiography 1980	Area (ha)	Percent Area
No Change	No Change	293.22	91.09%
Coastal Mid Marsh	Coastal Low & Mid Marsh	7.81	2.43%
Coastal High Marsh	Coastal Mid Marsh	4.01	1.25%
Coastal Mid Marsh	Coastal High Marsh	2.66	0.83%
Coastal High Marsh	Coastal Low & Mid Marsh	2.65	0.83%
Barren	Coastal Low Marsh	2.46	0.77%

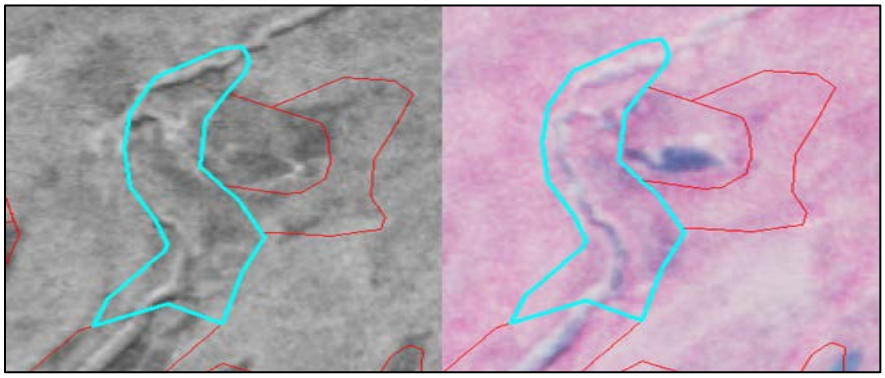


Figure 10. The presence of stream formation allowed for a physiographic change in Shelter Creek from Coastal Mid Marsh in 1950 (left) to Coastal Low & Mid Marsh in 1980 (right) at a scale of 1:2,000.

Results in Table 17 illustrate that the change from "Coastal Mid Marsh" to "Upland" was the most common physiographic change between the time steps of the 1980s and 2010s at only 1.76% of the Shelter Creek area. Figure 11 shows the obvious expansion of shrub and sapling between the two year classes. This analysis demonstrates that 91.70% of the physiography did not experience any change between these two time steps.

Table 17. Types of physiographic change from 1980 to 2010 in Shelter Creek.

Physiography 1980	Physiography 2010	Area(ha)	Percent Area
No Change	No Change	295.11	91.70%
Coastal Mid Marsh	Upland	5.66	1.76%
Coastal Low & Mid Marsh	Coastal Mid Marsh	4.59	1.43%
Coastal High Marsh	Upland	4.11	1.28%
Ocean	Barren	2.64	0.82%
Barren	Coastal Low Marsh	1.77	0.55%

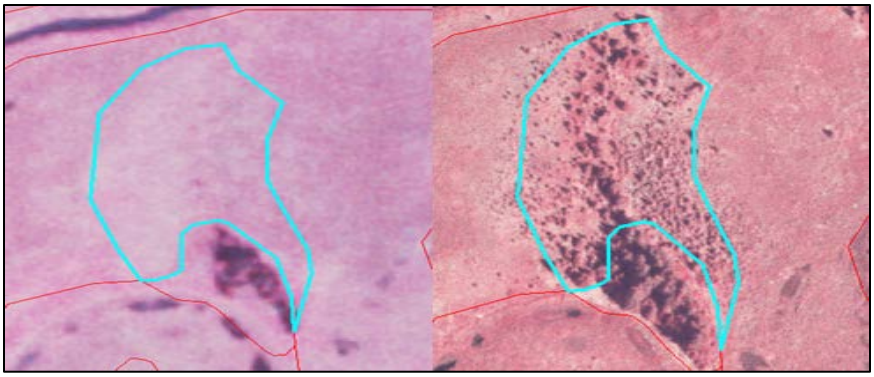


Figure 11. Physiographic change in Shelter Creek from Coastal Mid Marsh in 1980 (left) to Upland in 2010 (right) at a scale of 1:2,000.

The complete results on the type of physiographic change in Shelter Creek can be seen in Appendix EE, Appendix FF, and Appendix GG. Individual classifications of physiography for each year can be seen in Appendix HH.

Landscape Formation

Using the data collected, change was assessed at each of the three time steps to identify habitat establishment or loss. The assessment codes were adapted from Tande's (1996) land cover codes that were field verified.

Silver Salmon Creek

The Landscape within Silver Salmon Creek experienced noticeable change between the 1950s and the 1980s time steps (Table 18). The largest single landscape formation change that was identified was "Upland" to "Mudflat" due to mass wasting from tide and water expansion, (Figure 12) this occurred in 6.29% of the area of Silver Salmon Creek. This change was due primarily to mass wasting along the shore line. The analysis demonstrated that 63.76% of the landscape did not change between these time steps.

Table 18. Types of landscape formation changes from 1950 to 1980 in Silver Salmon Creek.

Landscape Formation 1950	Landscape Formation 1980	Area(ha)	Percent Area
No Change	No Change	116.72	63.76%
Upland	Mudflat	11.51	6.29%

Table 18 (continued). Types of landscape formation changes from 1950 to 1980 in Silver Salmon Creek.

Landscape Formation 1950	Landscape Formation 1980	Area(ha)	Percent Area
Mudflat	Interlevee Basin Meadow	10.12	5.53%
Open Water	Open Water	6.85	3.74%
Meadow	Interlevee Ponded Basin	5.59	3.06%
Mudflat	Upland	5.39	2.95%

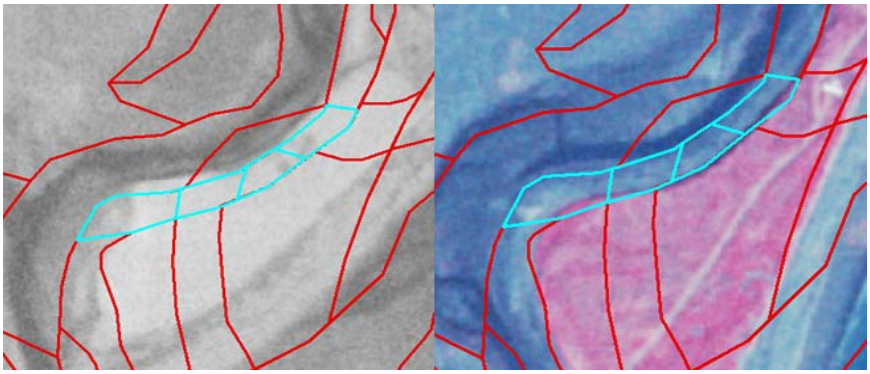


Figure 12. The river actively cutting away at the shoreline allowed for a landscape formation change in Silver Salmon Creek from Upland in 1950 (left) to Mudflat in 1980 (right), viewed at a scale of 1:2,000.

Between the 1980s and the 2010s time steps (Table 19), most change occurred from sediment deposition and changed "Open Water" to "Mudflat" (Figure 13). This change occurred in 4.24% of the area of Silver Salmon Creek. The analysis demonstrated that 70.83% of the landscape did not change between these time steps.

Table 19. Types of landscape formation changes from 1980 to 2010 in Silver Salmon Creek.

Landscape Formation 1980	Landscape Formation 2010	Area (ha)	Percent Area
No Change	No Change	129.65	70.83%
Open Water	Mudflat	7.76	4.24%
Interlevee Ponded Basin	Interlevee Ponded Basin	5.87	3.21%
Mudflat and Panne	Mudflat	5.62	3.07%
Upland	Mudflat	4.53	2.47%
Mudflat	Upland	4.35	2.38%

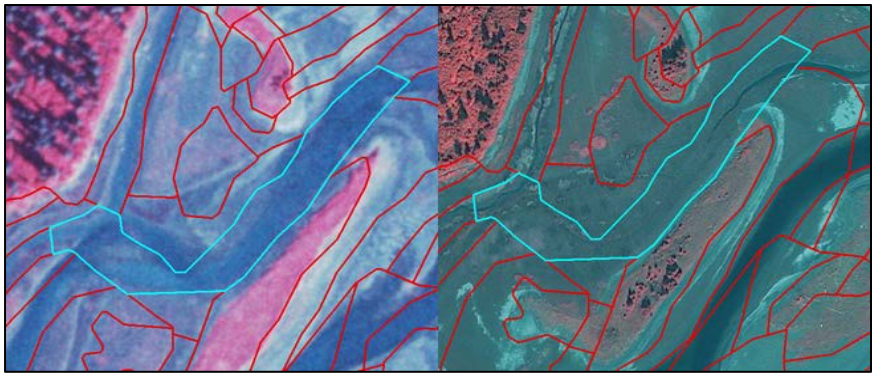


Figure 13. Landscape formation change in Silver Salmon Creek from Open Water in 1980 (left) to Mudflat in 2010 (right) at a scale of 1:2,000.

The complete results on landscape formation change in Silver Salmon Creek can be seen in Appendix E, Appendix F, and Appendix G. Individual landscape formation change for each year can be seen in Appendix H.

Chinitna Bay

The largest single landscape formation change (Table 20) for Chinitna Bay South West between the 1950s and the 1980s time steps was "Mudflat" to "Mudflat and Panne" (Figure 14). This change occurred in 12.4% of the area in Chinitna Bay South West. The analysis demonstrated that 77.22% of the landscape did not change between these time steps.

Table 20. Types of landscape formation change from 1950 to 1980 in Chinitna Bay South West.

Landscape Formation 1950	Landscape Formation 1980	Area(ha)	Percent Area
No Change	No Change	668.60	77.22%
Mudflat	Mudflat and Panne	107.33	12.40%
Interlevee Ponded Basin	Meadow	26.05	3.01%
Unconsolidated Shore	Mudflat and Panne	21.84	2.52%
Meadow	Interlevee Ponded Basin	16.22	1.87%
Mudflat	Interlevee Ponded Basin	13.14	1.52%

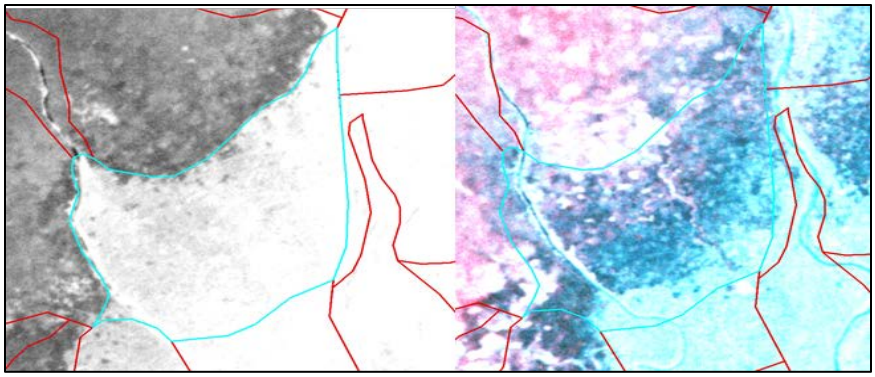


Figure 14. Landscape formation change in Chinitna Bay South West from Mudflat in 1950 (left) to Mudflat and Panne in 1980 (right) at a scale of 1:2,000.

Greater change was visible between the 1980s and the 2010s in Chinitna Bay South West, where roughly 30% of the area experienced landscape formation change Table 21. The most common landscape changes between the 1980s and the 2010s time steps were the formation of "Interlevee Ponded Basins" (e.g., from "Mudflat" to "Interlevee Ponded Basin" (7.88%) and "Mudflat and Panne" to "Interlevee Ponded Basin" (7.52%)) and meadow development (e.g., from "Interlevee Ponded Basin" to "Meadow" [3.84%] and "Mudflat and Panne" to "Meadow" [2.45%]).

Table 21. Types of landscape formation change from 1980 to 2010 in Chinitna Bay South West.

Landscape Formation 1980	Landscape Formation 2010	Area (ha)	Percent Area
No Change	No Change	606.13	70.01%
Mudflat	Interlevee Ponded Basin	68.21	7.88%
Mudflat and Panne	Interlevee Ponded Basin	65.14	7.52%
Interlevee Ponded Basin	Meadow	33.23	3.84%
Mudflat and Panne	Meadow	21.23	2.45%
Unconsolidated Shore	Mudflat and Panne	13.89	1.60%

Changes in Chinitna Bay North East were comparable to those in Chinitna Bay South West. Table 22 illustrates the most common change in Chinitna Bay North East between the 1950s and the 1980s time steps, was "Mudflat" to "Mudflat and Panne." This change occurred in 9.22% of the area in Chinitna Bay North East. The analysis demonstrated that 76.79% of the landscape did not change between these time steps.

Table 22. Types of landscape formation change from 1950 to 1980 in Chinitna Bay North East.

Landscape Formation 1950	Landscape Formation 1980	Area(ha)	Percent Area
No Change	No Change	92.27	76.79%
Mudflat	Mudflat and Panne	11.08	9.22%
Mudflat	Interlevee Basin & Channel Basin	4.87	4.05%
Mudflat and Panne	Interlevee Basin & Channel Basin	4.69	3.90%
Interlevee Ponded Basin	Interlevee Pond	2.22	1.85%
Mudflat	Open Water	1.36	1.13%

Similar results can be seen in Table 23 where 73.12% of the area did not experience any landscape formation change between the 1980s and the 2010s time steps in Chinitna Bay North East (Figure 15). In contrast to Chinitna Bay South West, the most common landscape change between the 1980s and the 2010s time steps was "Meadow" to "Upland" accounting for 6.51% of the landscape formation change that occurred in Chinitna Bay North East. The analysis demonstrated that 73.12% of the landscape did not change between these time steps.

Table 23. Types of landscape formation change from 1980 to 2010 in Chinitna Bay North East.

Landscape Formation 1980	Landscape Formation 2010	Area(ha)	Percent Area
No Change	No Change	87.86	73.12%
Meadow	Upland	7.82	6.51%
Mudflat and Panne	Interlevee Basin & Channel Basin	6.94	5.77%
Mudflat	Interlevee Basin & Channel Basin	4.14	3.45%
Interlevee Ponded Basin	Interlevee Basin & Channel Basin	2.11	1.76%
Open Water	Mudflat	1.60	1.33%

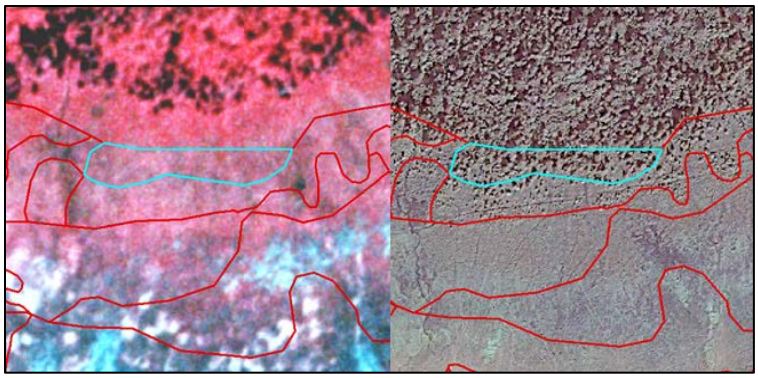


Figure 15. Some image shift occurred in the 1980 (left) photo but the landscape formation change in Chinitna Bay North East still showed change from Meadow in 1980 (left) to Upland in 2010 (right) at a scale of 1:2,000.

The complete results on the type of physiographic change in Chinitna Bay South West can be seen in Appendix S, Appendix T, and Appendix U. Complete results for Chinitna Bay North East can be seen in Appendix W, Appendix X, and Appendix Y. Individual classifications of physiography for each year can be seen in Appendix V for Chinitna Bay South West and in Appendix Z for Chinitna Bay North East.

Shelter Creek

The Landscape within Shelter Creek did not experience significant change between the 1950s and the 1980s time steps (Table 24). The largest single landscape formation change occurring from "Meadow" to "Interlevee Basin & Channel Basin" (Figure 16) only occurred in 1.8% of the area of Shelter Creek. This change was primarily due to the channel formation seen in Figure 16. The analysis demonstrated that 89.36% of the landscape did not change between these time steps.

Table 24. Types of landscape formation change from 1950 to 1980 in Shelter Creek.

Landscape Formation 1950	Landscape Formation 1980	Area (ha)	Percent Area
No Change	No Change	287.59	89.36%
Meadow	Interlevee Basin&Channel Basin	5.78	1.80%
Interlevee Ponded Basin	Interlevee Basin&Channel Basin	4.67	1.45%
Meadow	Interlevee Ponded Basin	2.45	0.76%
Interlevee Basin&Channel Basin	Interlevee Ponded Basin	2.45	0.76%
Interlevee Ponded Basin	Meadow	2.15	0.67%

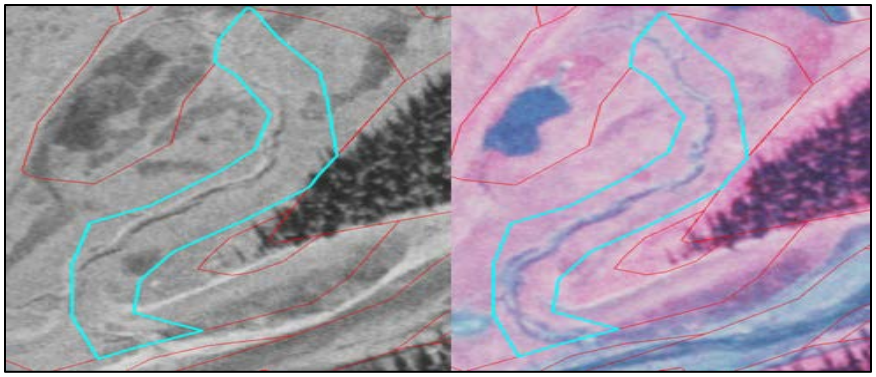


Figure 16. Due to the expansion of the stream and the percentage of the polygon it makes up a landscape formation change in Shelter Creek from Meadow in 1950 (left) to Interlevee Basin & Channel Basin in 1980 (right) can be seen, viewed at a scale of 1:2,000.

Between the 1980s and the 2010s time steps, Table 25 shows that the most change occurred due to uplift from "Meadow" to "Upland" (Figure 17). This change occurred in 3.22% of the area of Shelter Creek. The analysis demonstrated that 82.49% of the landscape did not change between these time steps. The relative stability of the Shelter Creek complex may be due to the greater proportion of the area in uplands (ca. 43%), relative to the other areas of interest (Silver Salmon Creek, Chinitna Bay), and the forested shoreline which likely protects the interior marshes from storm surges and other incursion (Miller, email communication, 21 April 2015).

Table 25. Types of landscape formation change from 1980 to 2010 in Shelter Creek.

Landscape Formation 1980	Landscape Formation 2010	Area (ha)	Percent Area
No Change	No Change	265.47	82.49%
Meadow	Upland	10.37	3.22%
Open Water	Open Water	9.65	3.00%
Levee Meadow	Levee Meadow	7.40	2.30%
Interlevee Ponded Basin	Interlevee Basin Meadow	4.72	1.47%
Open Water	Mudflat	2.65	0.82%

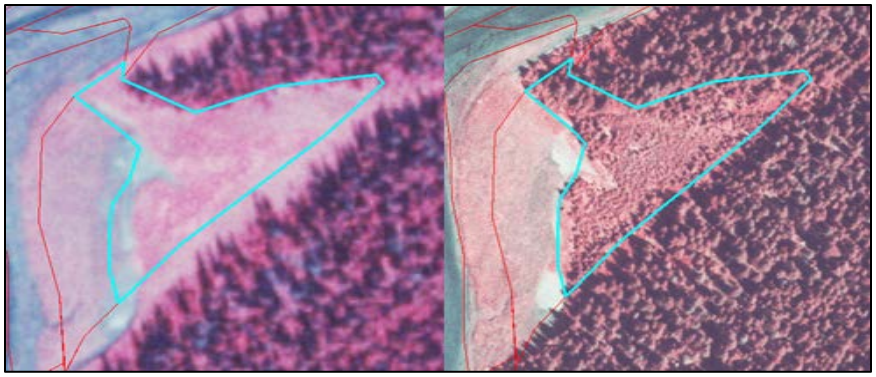


Figure 17. Landscape formation change in Shelter Creek from Meadow in 1980 (left) to Upland in 2010 (right) at a scale of 1:2,000.

The complete results for landscape formation change at Shelter Creek can be seen in Appendix II, Appendix JJ, and Appendix KK. Individual landscape formation for each year can be seen in Appendix LL.

Landscape Change

Landscape change codes were assigned where landscape formation change occurred between two time steps. This code reflects the type of change and was at the discretion of the photo interpreter. Codes were adapted from the LACL land cover report (Burchiel et al. 2014) and can be seen in Table 26.

Table 26. Types of landscape formation change from 1980 to 2010 in Shelter Creek.

Landscape Change	Landscape Change
Spruce Closure	Alluvial Deposit
Spruce Establishment/Expansion	Pond/Lake Formation
Spruce Dieback	Colluvial Deposit
Shrub Closure	Rill Formation
Shrub Establishment	Rill Abandonment
Shrub Loss	Vegetation Development/Expansion in Intertidal Area
Hardwood Forest Closure	Ice Loss/Glacial Retreat
Hardwood Forest Establishment	Aquatic Bed Formation/Expansion in Palustrine Area
Hardwood Forest Dieback	Open Water Formation/Marine Intrusion
Channel Formation	Beaver Activity
Channel Abandonment	Annual Snow Increase

Table 26 (continued). Types of landscape formation change from 1980 to 2010 in Shelter Creek.

Landscape Change	Landscape Change
Pond Drying	Annual Snow Decrease
Wetland Loss	Perennial Snow Increase
Wetland Creation	Perennial Snow Decrease
Mass Wasting	Vegetation Loss/Decrease in Intertidal Area
Coastal Subsidence/Flooding	Lake Drainage
Coastal Uplift	Mixed Forest Establishment
Ash Deposit	Shadows/Mosaic/Image Shift/Image Smear

Silver Salmon Creek

The most common landscape changes within Silver Salmon Creek between the 1950s and the 1980s time steps can be seen in Table 27. The largest single landscape change being "Vegetation Development/Expansion in Intertidal Area" involving 13.29% of the area in Silver Salmon Creek (Figure 18). The analysis demonstrated that 72.73% of the landscape did not change between these time steps.

Table 27. Types of land change from 1950 to 1980 in Silver Salmon Creek.

Change Code from 1950 to 1980	Area(ha)	Percent Area
No Change	133.15	72.73%
Vegetation Development/Expansion in Intertidal Area	24.34	13.29%
Vegetation Loss/Decrease in Intertidal Area	12.86	7.03%
Wetland Creation	5.59	3.06%
Channel Abandonment	4.19	2.29%
Channel Formation	2.44	1.33%
Spruce Establishment/Expansion	0.49	0.27%

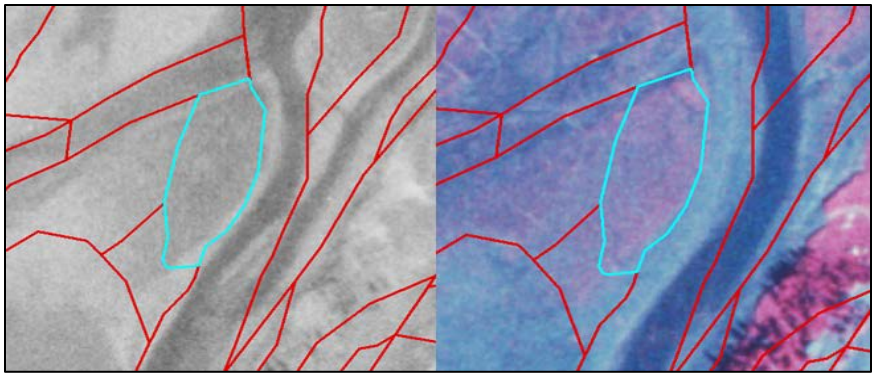


Figure 18. A change code of Vegetation Development/Expansion in Intertidal Area in Silver Salmon Creek from 1950 (left) to 1980 (right) at a scale of 1:2,000.

Between the 1980s and the 2010s time steps, the most common landscape changes are contained in Table 28. The largest single landscape change being "Vegetation Development/Expansion in Intertidal Area" involving 6.68% of the area in Silver Salmon Creek (Figure 19). The analysis demonstrated that 78.96% of the landscape did not change between these time steps. A table describing time landscape changes between the time series steps can be seen in Appendix I and Appendix J.

Table 28. Types of land change from 1980 to 2010 in Silver Salmon Creek.

Change Code from 1980 to 2010	Area(ha)	Percent Area
No Change	144.54	78.96%
Vegetation Development/Expansion in Intertidal Area	12.24	6.68%
Vegetation Loss/Decrease in Intertidal Area	10.65	5.82%
Mixed Forest Establishment	4.24	2.31%
Wetland Creation	4.05	2.21%
Channel Abandonment	3.97	2.17%
Channel Formation	3.37	1.84%

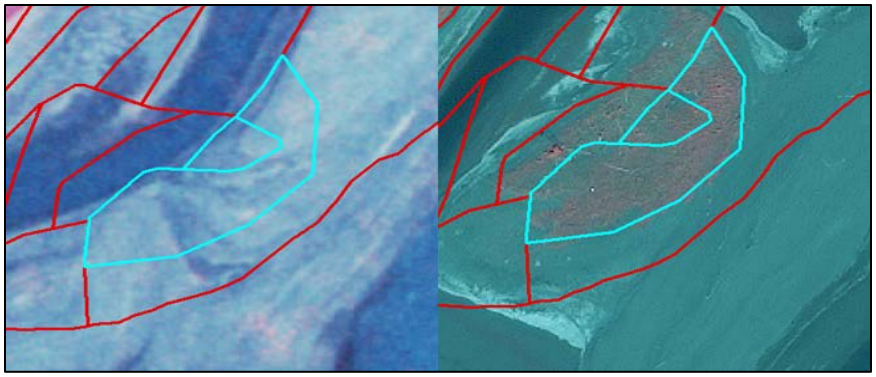


Figure 19. A change code of Vegetation Development/Expansion in Intertidal Area in Silver Salmon Creek from 1980 to 2010 at a scale of 1:2,000.

Chinitna Bay

The most common landscape changes within Chinitna Bay South West between the 1950s and the 1980s time steps can be seen in Table 29. The largest single landscape change being "Vegetation Development/Expansion in Intertidal Area" involving 14.92% of the area in Chinitna Bay South West (Figure 20). The analysis demonstrated that 78.77% of the landscape did not change between these time steps.

Table 29. Types of land change from 1950 to 1980 in Chinitna Bay South West.

Change Code from 1950 to 1980	Area (ha)	Percent Area
No Change	682.03	78.77%
Vegetation Development/Expansion in Intertidal Area	129.17	14.92%
Wetland Loss	26.05	3.01%
Wetland Creation	18.07	2.09%
Pond/Lake Formation	7.24	0.84%
Pond Drying	3.28	0.38%

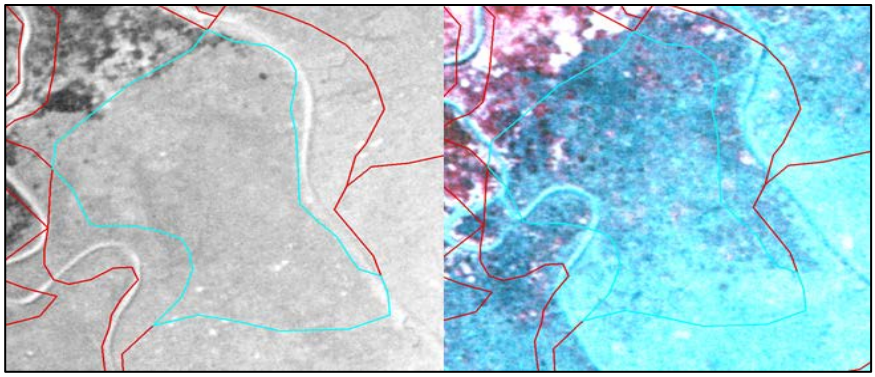


Figure 20. A change code of Vegetation Development/Expansion in Intertidal Area from 1950 (left) to 1980 (right) in Chinitna Bay South West.

Between the 1980s and the 2010s time steps the most common landscape changes are contained in Table 30. The largest single landscape change was "Wetland Creation" involving 15.53% of the area in Chinitna Bay South West. The analysis demonstrated that 73.66% of the landscape did not change between these time steps. The complete tables of landscape change at Chinitna Bay South West can be seen in Appendix AA and Appendix DD.

Table 30. Types of land change from 1980 to 2010 in Chinitna Bay South West.

Change Code from 1980 to 2010	Area (ha)	Percent Area
No Change	637.75	73.66%
Wetland Creation	134.50	15.53%
Vegetation Development/Expansion in Intertidal Area	50.54	5.84%
Pond Drying	19.96	2.31%
Wetland Loss	17.61	2.03%
Pond/Lake Formation	2.84	0.33%
Spruce Establishment/Expansion	2.62	0.30%

The most common landscape changes within Chinitna Bay North East between the 1950s and the 1980s time steps can be seen in Table 31. The largest single landscape change being "Vegetation Development/Expansion in Intertidal Area" involving 17.46% of the area in Chinitna Bay North East. The analysis demonstrated that 72.99% of the landscape did not change between these time steps.

Table 31. Types of land change from 1950 to 1980 in Chinitna Bay North East.

Change Code from 1950 to 1980	Area (ha)	Percent Area
No Change	87.71	72.99%
Vegetation Development/Expansion in Intertidal Area	20.98	17.46%
Mixed Forest Establishment	11.37	9.46%
Aquatic Bed Formation/Expansion in Palustrine Area	0.10	0.08%

Between the 1980s and the 2010s time steps the most common landscape changes are contained in Table 32. The largest single landscape change being "Vegetation Development/Expansion in Intertidal Area" involving 26.69% of the area in Chinitna Bay North East (Figure 21). The analysis demonstrated that 57.15% of the landscape did not change between these time steps. The complete tables of landscape change at Chinitna Bay North East can be seen in Appendix CC and Appendix DD.

Table 32. Types of land change from 1980 to 2010 in Chinitna Bay North East.

Change Code from 1980 to 2010	Area (ha)	Percent Area
No Change	68.67	57.15%
Vegetation Development/Expansion in Intertidal Area	32.07	26.69%
Mixed Forest Establishment	19.43	16.17%

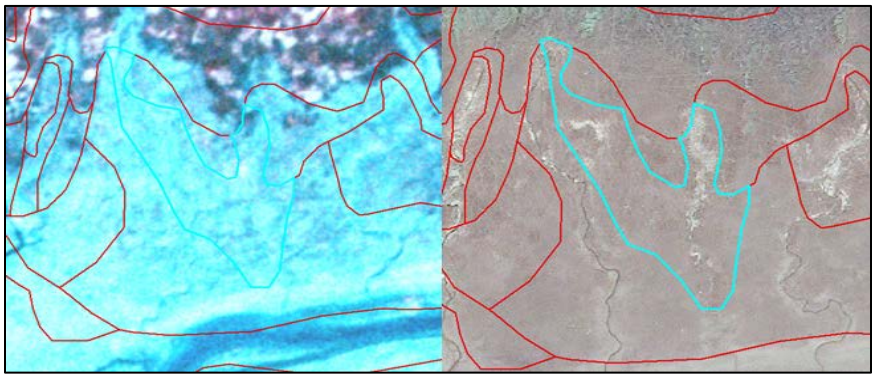


Figure 21. A change code of Vegetation Development/Expansion in Intertidal Area from 1980 (left) to 2010 (right) in Chinitna Bay North East.

Shelter Creek

The most common landscape changes within Shelter Creek between the 1950s and the 1980s time steps can be seen in Table 33. The largest single landscape change being "Channel Formation" (Figure 22) involving 3.53% of the area in Shelter Creek. The analysis demonstrated that 91.14% of the landscape did not change between these time steps.

Table 33. Type of land change from 1950 to 1980 in Shelter Creek.

Change Code from 1950 to 1980	Area (ha)	Percent Area
No Change	293.33	91.14%
Channel Formation	11.37	3.53%
Vegetation Development/Expansion in Intertidal Area	8.15	2.53%
Open Water Formation/Marine Intrusion	1.90	0.59%
Pond/Lake Formation	1.63	0.51%
Wetland Creation	1.62	0.50%

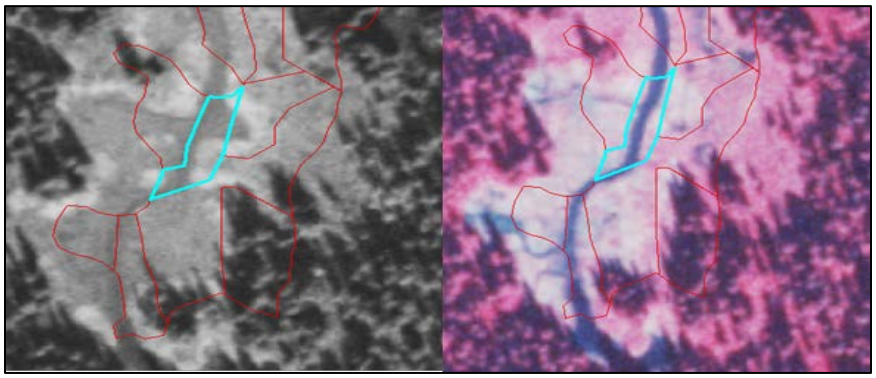


Figure 22. A change code of Channel Formation in Shelter Creek from 1950 (left) to 1980 (right) at a scale of 1:2,000.

Between the 1980s and the 2010s time steps the most common landscape changes are contained in Table 34. The largest single landscape change being "Vegetation Development/Expansion in Intertidal Area" (Figure 23) involving 3.33% of the area in Shelter Creek. The analysis demonstrated that 91.48% of the landscape did not change between these time steps. The complete results for landscape change in Shelter Creek can be seen in Appendix MM and Appendix NN.

Table 34. Type of land change from 1980 to 2010 in Shelter Creek.

Change Code From 1980 to 2010	Area (ha)	Percent Area
No Change	294.43	91.48%
Vegetation Development/Expansion in Intertidal Area	10.70	3.33%
Coastal Subsidence/Flooding	3.02	0.94%
Channel Abandonment	2.97	0.92%
Pond/Lake Formation	2.58	0.80%
Aquatic Bed Formation/Expansion in Palustrine Area	1.74	0.54%

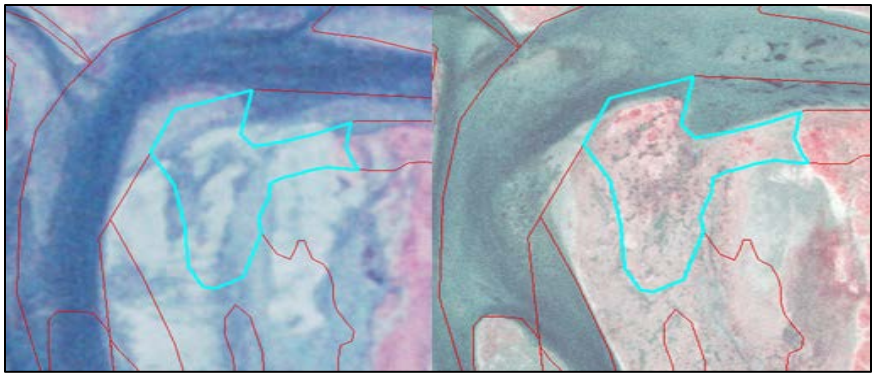


Figure 23. A change code of Vegetation Development/Expansion in Intertidal Area in Shelter Creek from 1980 (left) to 2010 (right) at a scale of 1:2,000.

Threats and Stressor Factors

The salt marsh community component of this NRCA is a non-traditional component type. It was undertaken as inventory project of LACL salt marshes and as such threats and stressor were not assessed for this project.

Data Needs/Gaps

The salt marsh community component of this NRCA is a non-traditional component type. As such data needs/gaps were not identified for this component.

4.1.6 Sources of Expertise

Amy Miller, SWAN Ecologist

4.1.7 Literature Cited

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4.2 Brown Bear

4.2.1 Description

The brown bear (*Ursus arctos*) (Photo 9) is a prominent mammal species in LACL (Olson and Putera 2007). The species utilizes much of LACL, with larger concentrations in the coastal and lake ecosystems. During the summer and fall, brown bears gravitate towards rivers, lakes, and coastal areas which support salmon runs (Sowl 1988). Mating generally occurs from May to mid-July, and one to four cubs are typically born in the mid-winter months. Litter intervals are typically three years, and cubs remain with their mother for the first two years.



Photo 9. Brown bear sow and cub in a marshy area near Silver Salmon Creek in LACL (NPS photo).

Alaskan Peninsula brown bear males average 350 kg (770 lbs) and females average 225 kg (500 lbs) (Miller and Sellers 1992). Brown bears primarily feed on salmon from July through September although some late sockeye runs sustain bears into November in the upper Lake Clark drainage. Sedges, berries, and clams comprise some of their diet in spring/early summer. LACL brown bears will also consume caribou and moose; juveniles and neonatals of both species are predominantly targeted (Boertje et al. 1987). Denning usually takes place from October to May, although bears closer to more arid coastal areas may den as late as December (Goldstein et al. 2010).

The ADF&G (Butler 2009) defines Game Management Units (GMUs) across Alaska in an effort to assess regional game populations and define hunting regulations. Portions of five individual GMUs extend over LACL, including units 09A, 09B, 16B, 17B, and 19B (Plate 7).

The Alaskan Peninsula as a whole, and specifically the region within and around LACL, is world-renowned for its high bear densities (Olson and Putera 2007). LACL is ecologically similar to KATM (80 km [50 mi] away) and the McNeil River State Game Sanctuary (MRSGS, northeast of KATM), as all these locations provide refuge for one of the world's most dense brown bear populations. The brown bear population within national parks and the MRSGS in unit 09 alone is estimated to be between 2,000 and 2,500 individuals (Butler 2009). The large protected coastal brown bear population of southeastern LACL provides visitors the opportunity to view bears in a natural setting. The establishment of a bear viewing camp in 1997 increased the visitation to one coastal salt marsh in LACL from 30 people in 1995 to over 500 people by the mid-2000s. Bear viewing also occurs at in-land Crescent Lake (Olson and Putera 2007).

Sport and subsistence hunting within LACL are authorized in sections 201 and 203 of ANILCA (Haertel 1984). Only subsistence hunting for brown bears is permitted within the park portion of LACL; however, both sport and subsistence harvest of bears is legal, subject to state and federal regulations, within the preserve portion of LACL (Plate 8, Haertel 1984). Alternating hunting seasons were established in the 1980s in order to aid in population recovery. For example, during

odd-numbered years (e.g., 2011) there is a fall bear harvest and during even-numbered years (e.g., 2012) there is a spring bear harvest (Butler 2009). The combination of a fall and spring bear harvest defines a regulatory year (e.g., the regulatory year of 2011-2012). Generally, greater harvest occurs during the fall season than in the spring season (Butler 2009). Alternating hunting seasons are only practiced in GMU 9 within LACL, GMU's 16, 17, and 19 do not have this pattern.

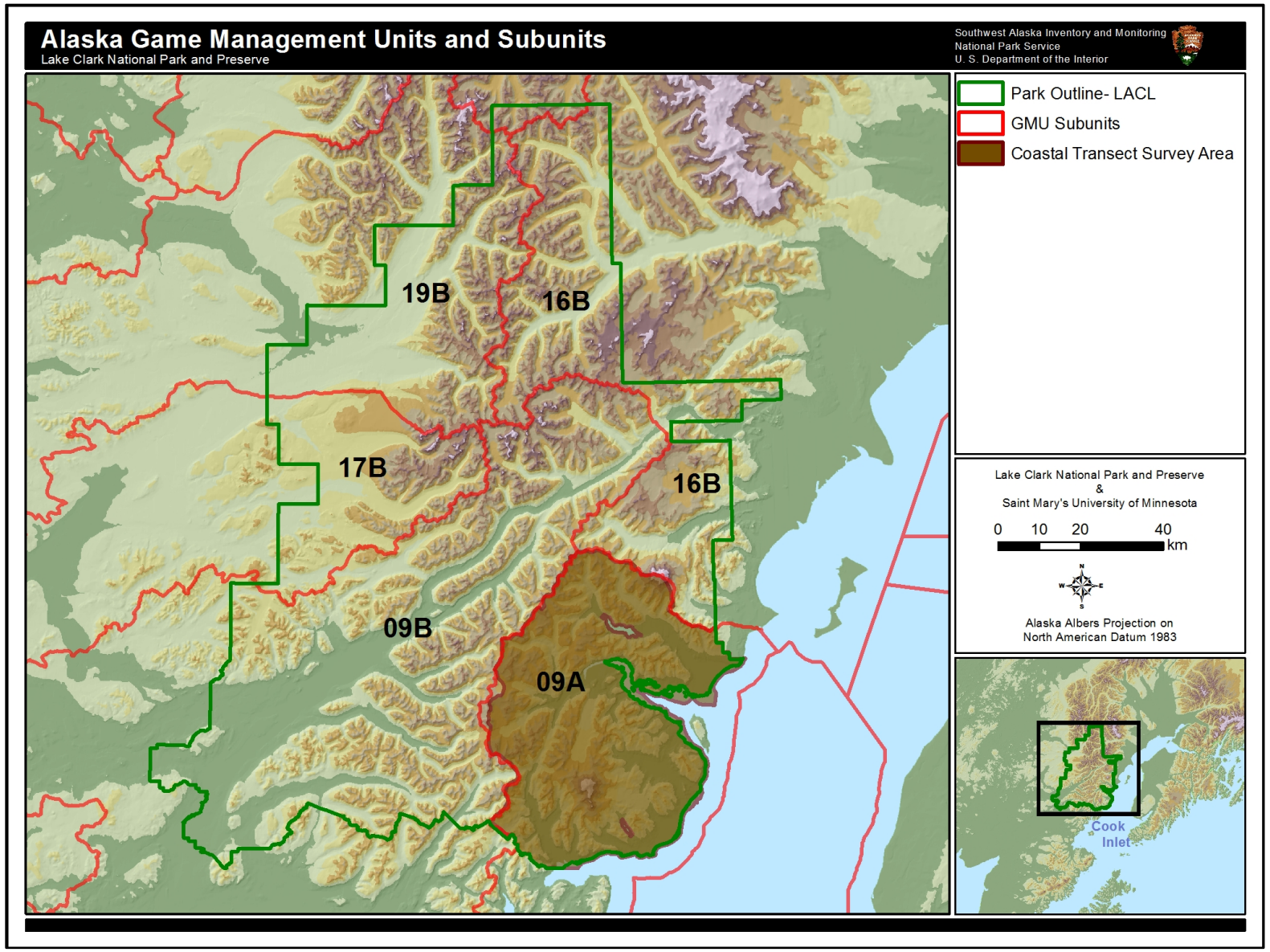


Plate 7. Game Management Unit boundaries and brown bear coastal transect survey area.

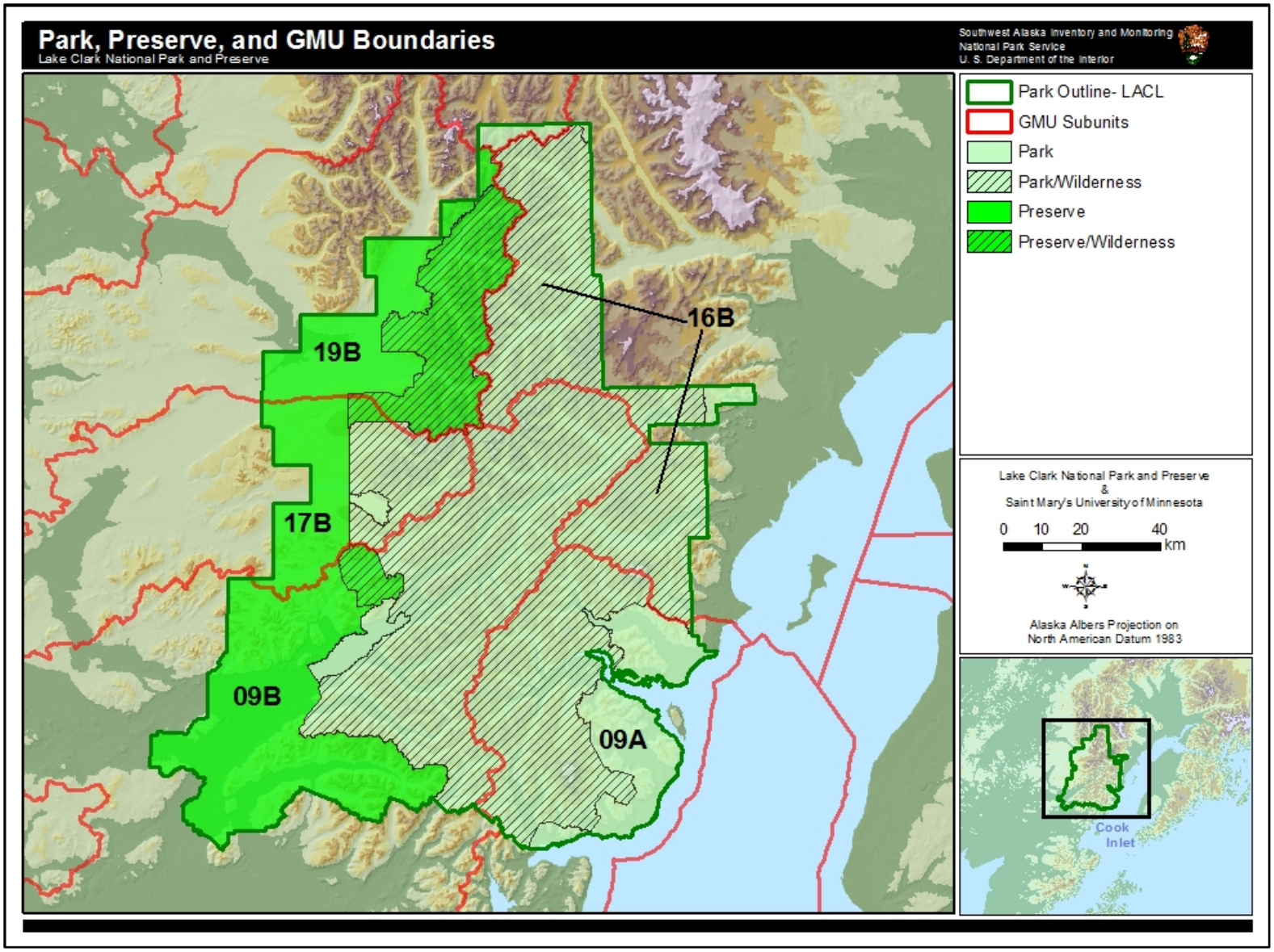


Plate 8. Game Management Unit boundaries and coresponding park and preserve areas within LACL.

4.2.2 Measures

- Population size/density
- Recruitment (through cohorts)
- Sex ratios
- Female survival

4.2.3 Reference Conditions/Values

The brown bear population dynamics within LACL are primarily driven by natural forces (Buck Mangipane, LACL Wildlife Biologist, written communication, 30 July 2013). Humans are the one non-natural force potentially affecting the brown bear population through sport and subsistence harvest as well as defense of life and property (DLP) events. Tracking these harvests through more consistent reporting will allow for a more informed evaluation of their impact to the population. After these data have been consistently gathered for a reasonable time period they can be evaluated and a "stable" level of human-caused mortality could be considered as a reference condition for the species (Mangipane, written communication, 30 July 2013).

4.2.4 Data and Methods

For the purpose of this analysis, the five GMU subunits within LACL were grouped into two extents (coastal and interior) in an effort to be accurate and concise regarding the assessment for both coastal and interior brown bear populations. The interior brown bear population extent includes units 09B, 16B (northern portion), 17B, and 19B, while the coastal brown bear assessment extent includes unit 09A and 16B (southern portion).

NPS (2013) coastal bear trend count data collected along the intertidal, salt marsh, and tributary areas of the LACL coastline from 2004 to 2013 (2006 being omitted from the data set) provides the primary data source to assess the park's coastal brown bear population. Surveys were conducted by aircraft for a majority of the months of June and July during the aforementioned survey years. Five primary survey areas are defined within the coastal transit survey area: Chinitna Bay, Shelter Creek, Silver Salmon Creek, South Tuxedni Bay, and North Tuxedni Bay (Plate 9). Partitions within the coastal bear trend survey area allow for definition of temporal and spatial trends regarding brown bear usage of specific sensitive areas (e.g., salt marches and tributaries supporting salmon runs) along the LACL coastline. Survey of brown bear usage of these areas over time could serve as an indicator of both the health of area resources and brown bear populations.

Butler (2009) provides the primary assessment of the measures regarding the interior brown bear population of GMUs 09B, 16B, 17B, and 19B within LACL. Assessment of brown bear population size, density, recruitment, and sex ratios have been conducted utilizing line transit surveys of these regions. An experimental line transect/double count survey provides data for brown bears in unit 09A in the spring of 2003 and 2004, and the northern portion of unit 09B (within LACL) in the spring of 1999 and 2000.

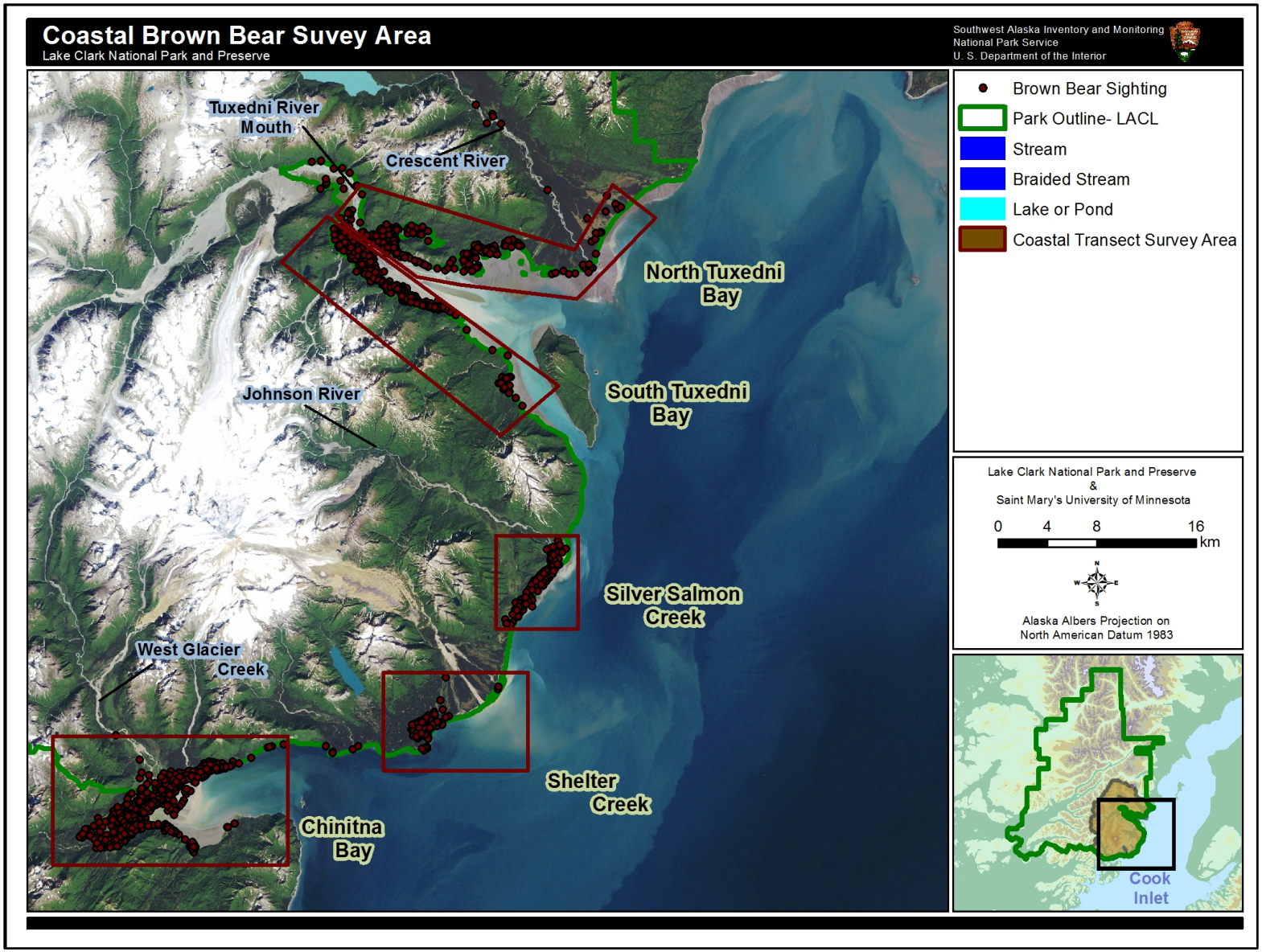


Plate 9. Brown bear coastal transect survey areas in LACL, with brown bear sightings (2004-2013).

4.2.5 Current Condition and Trend

Population Size and Density

Specific population estimates and densities for the interior brown bear population of LACL are not available. However, regional estimates from the GMU's which converge in the park provide some assessment on these measures. Recent transect surveys flown between 1999 and 2005 suggest the interior brown bear density of LACL to be 1 bear/ 9 km^2 (3.5 mi^2) within the northern portion of GMU 9B (Butler 2009). Northern areas of the park within units 16B and 19B report bear density estimates ranging between 1 bear/37 km^2 (14.3 mi^2) and 1 bear/13 km^2 (5 mi^2) respectively (Butler 2009). Current data regarding the population size and density are not available for unit 17B; however, the regional brown bear population is estimated to be stable or increasing (Butler 2009).

GMU 9A and the southern portion of GMU 16B define the geographic area used to describe the LACL coastal brown bear population. Density estimates within 16B are thought to be similar to the densities found in bordering unit 9A of 150 bears/1000 km^2. Coastal bear trend counts in LACL, between the years of 2004-2013, peaked in July 2008 and June 2009 at 219 bears (Table 35). Since this peak, a general downward trend has been reported, with the most recent count in 2013 reporting 63 bears. Historically, brown bears have gathered in the greatest densities along the Chinitna and South Tuxedni Bay regions. Over 75% of the brown bear sightings within the five marsh survey areas in 2012 were recorded in these regions. The marsh areas of Chinitna and South Tuxedni both reported higher brown bear usage percentages in 2012 than averages calculated since the transect survey began in 2004 (Table 36). The remaining marsh areas of North Tuxedni Bay, Shelter Creek, and Silver Salmon Creek all reported lower brown bear usage in 2012 compared to averages calculated since 2004.

Table 35. Total number of brown bears counted within the LACL coastal transect survey area between 2004 and 2013 (NPS 2013).

Date	Total Bears	Date	Total Bears
06/21/04	146	07/15/09	193
07/12/04	76	06/23/10	177
06/15/05	216	06/23/11	152
06/23/05	190	07/13/11	216
07/13/05	58	06/21/12	132
07/20/05	27	07/20/12	144
06/18/07	162	06/12/13	78
06/27/08	199	06/25/13	180
07/10/08	219	07/09/13	180
06/24/09	219	07/26/13	63

Table 36. Percentage of observed brown bears within the five main survey/marsh areas of the coastal transect survey region (NPS 2013).

Date	Chinitna Bay	North Tuxedni Bay	Shelter Creek	Silver Salmon Creek	South Tuxedni Bay
06/21/04	41.57%	19.10%	11.24%	6.74%	21.35%
07/12/04	37.50%	10.00%	25.00%	7.50%	20.00%
06/15/05	38.39%	17.86%	13.39%	3.57%	26.79%
06/23/05	38.10%	12.38%	13.33%	6.67%	29.52%
07/13/05	46.34%	4.88%	12.20%	9.76%	26.83%
07/20/05	52.94%	17.65%	11.76%	17.65%	0.00%
06/18/07	45.00%	16.00%	12.00%	4.00%	23.00%
06/27/08	47.20%	16.80%	6.40%	4.00%	25.60%
07/10/08	45.11%	18.05%	7.52%	6.77%	22.56%
6/24/09	42.34%	13.14%	4.38%	7.30%	32.85%
07/15/09	68.52%	6.48%	7.41%	11.11%	6.48%
06/23/10	44.83%	18.10%	3.45%	6.90%	26.72%
06/23/11	43.30%	15.46%	4.12%	8.25%	28.87%
07/13/11	43.85%	11.54%	4.62%	9.23%	30.77%
06/21/12	45.98%	16.09%	3.45%	6.90%	27.59%
07/20/12	52.26%	13.57%	4.02%	5.03%	25.13%
06/12/13	37.50%	20.45%	7.95%	3.41%	25.00%
06/25/13	48.02%	16.34%	3.47%	5.45%	17.82%
07/09/13	51.78%	14.72%	5.08%	9.14%	15.74%
07/26/13	65.08%	3.17%	3.17%	14.29%	7.94%

Recruitment (through cohorts)

Line transit surveys conducted within the northern portion of unit 9B indicated that recruitment of the interior brown bear population was lower in 1999 than 2000. The average litter size of cubs of the year (COY) in 1999 and 2000 was 1.5 and 2 respectively, while the litter size of yearling cubs was 1.4 and 1.7 respectively (NPS 2012). Lower litter sizes in 1999 were likely a reflection of poor salmon runs in 1997 and 1998 (NPS 2012).

Recruitment data for the coastal brown bear population within LACL is provided by the coastal brown bear transit survey (Table 37, NPS 2012). Generally, June surveys show a lower count for the COY field and a higher count for yearling and >yearling fields than the July survey of the same year.

This difference stresses the importance to survey in both June and July every year to achieve the greatest accuracy regarding the assessment of brown bear recruitment. The most recent survey in 2012 presents the lowest total cub values during both June and July since 2005 (Table 37). Approximately 25% of the total bears observed in 2012 were defined as being in a family group; this number is lower than all previous survey years.

Table 37. Brown bear recruitment within the LACL coastal transect survey area from 2004 to 2013 (NPS 2013).

Date	Total Bears	% Bears in Family Groups	Total Cubs	%Cubs	%COY	%Yearling	%>Yearling
06/21/04	146	48.6%	47	32%	14.9%	51.1%	34.0%
07/12/04	76	67.1%	32	42%	18.8%	50.0%	31.3%
06/15/05	216	53.7%	79	37%	--	--	--
06/23/05	190	50.0%	63	33%	28.6%	47.6%	23.8%
07/13/05	58	31.0%	11	19%	0.0%	45.5%	54.5%
07/20/05	27	33.3%	6	22%	66.7%	33.3%	0.0%
06/18/07	162	28.4%	31	19%	0.0%	71.0%	29.0%
06/27/08	199	28.1%	35	18%	20.0%	48.6%	31.4%
07/10/08	219	36.5%	52	24%	50.0%	30.8%	19.2%
06/24/09	219	25.6%	36	16%	13.9%	69.4%	16.7%
07/15/09	193	43.5%	57	30%	70.2%	19.3%	10.5%
06/23/10	177	36.7%	41	23%	26.8%	56.1%	17.1%
06/23/11	152	36.2%	33	22%	12.1%	54.5%	33.3%
07/13/11	216	43.5%	57	26%	36.8%	50.9%	12.3%
06/21/12	132	24.2%	20	15%	15.0%	60.0%	25.0%
07/20/12	144	27.8%	25	17%	32.0%	32.0%	36.0%
06/12/13	78	12.80%	6	8%	0.0%	100.0%	0.0%
06/25/13	180	26.7%	31	17%	35.5%	54.8%	9.7%
07/09/13	180	21.7%	39	22%	59.0%	33.3%	7.7%
07/26/13	63	28.6%	18	29%	44.4%	55.6%	0.0%

Sex Ratios

Current data regarding the sex ratio of the interior brown bear population of LACL do not exist. However, the majority of the brown bear population in LACL resides within the coastal transit survey area. Therefore, sex ratios for the coastal brown bear population of LACL should accurately

reflect the "natural" sex ration status of brown bears and will be used regarding this measure. A total of 59% of the brown bears recorded for the duration of the survey were sows (females). Generally, the percentage of observed bears which are sows is higher during July compared to the June survey. This difference stresses the importance to survey in both June and July every year to achieve the greatest accuracy regarding the assessment of brown bear sex ratios.

Table 38. Brown bear sex ratios within the LACL coastal transect survey area from 2004 to 2013. (NPS 2013).

Date	Boar	Sow	Total Bears	% Sows
06/21/04	15	24	39	62
07/12/04	5	19	24	79
06/15/05	27	37	64	58
06/23/05	25	32	57	56
07/13/05	8	7	15	47
07/20/05	1	3	4	75
06/18/07	18	15	33	45
06/27/08	32	21	53	40
07/10/08	19	28	47	60
06/24/09	22	20	42	48
07/15/09	13	27	40	68
06/23/10	22	24	46	52
06/23/11	17	22	39	56
07/13/11	14	37	51	73
06/21/12	20	12	32	38
07/20/12	4	15	19	79
06/12/13	15	10	25	40
06/25/13	23	48	71	68
07/09/13	10	39	49	80
07/26/13	1	18	19	95
Average	**16**	**23**	**38**	**61**

Female Survival

The LACL landscape provides large expanses of high quality brown bear habitat, most of which is protected or receives very little hunting pressure. Female survival within the park is therefore likely only affected by natural processes given this general lack of human influence on the population.

Kovach (2006) reported a 90-97% survival rate of female brown bears over the age of five during a 10-year study conducted in southwestern Alaska. Given that this study was conducted on a hunted population and in a region of similar or possibly lesser quality brown bear habitat, female survival within LACL is likely within this range.

Threats and Stressor Factors

Human Habituation

Human habituation may pose a problem to the safety and wellbeing of bears and humans alike. When a bear's overt reaction distance (ORD) decreases (the distance at which a bear will avoid or flee humans), the likelihood of bear-human interaction increases. Bears and people come into contact with each other most commonly in the bear transect survey area of southeastern LACL (Plate 9). This area has the highest bear density in LACL (1 bear/7km^2). Tributary streams flowing into the Cook Inlet attract both bears and fisherman, causing interactions between the two. Two designated bear viewing sites are also located on the northern shores of Chinitna Bay, where park visitors can view brown bears in their natural environments (Plate 10). The aforementioned activities as well as hiking and camping in LACL increase the opportunity for bear-human interactions, which have the potential to cause stress on individual bears.

Salmon Escapement

Historically, the coastal tributaries of LACL have supported strong salmon runs; however, when poor runs do occur in some or many of these tributaries bears are forced to travel greater distances in search of stronger salmon runs or alternative food sources. The inability to obtain access to a sustainable salmon source can greatly stress coastal brown bear populations, which include larger individuals with greater reproductive success than interior populations subjected to diets of plant materials and terrestrial meat (Hilderbrand et al. 1999). Natural variation in salmon runs as well as overfishing from commercial vessels are factors that can contribute to poor salmon runs in LACL.

Sport and Subsistence Hunting/Defense of Life and Property Kills (DLP)

Sport and subsistence hunting occur within LACL with a majority of the hunting pressure taking place in the southwestern portion of the park (unit 09B) (Mangipane, written communication, 30 July 2013). Liberal hunting regulations greatly decreased brown bear populations on the southwestern Alaskan Peninsula in the 1970s. Given the long reproductive cycle of brown bears (longer than most terrestrial mammals at 3 years), it is important to monitor population trends, especially since harvest rates in the units encompassing LACL have been generally increasing since 2000 (Butler 2009). Local residents have petitioned the Board of Game to increase the brown bear harvest over some areas of the southwest Alaskan peninsula in an effort to increase moose and caribou populations. Butler (2009) does not suggest a harvest increase upon this population; however, the threat of an increase persists. Unreported DLP kills and illegal harvests of brown bears can also negatively affect populations on the southwestern Alaskan peninsula. Table 39 displays the subsistence harvest data for brown bears in LACL.

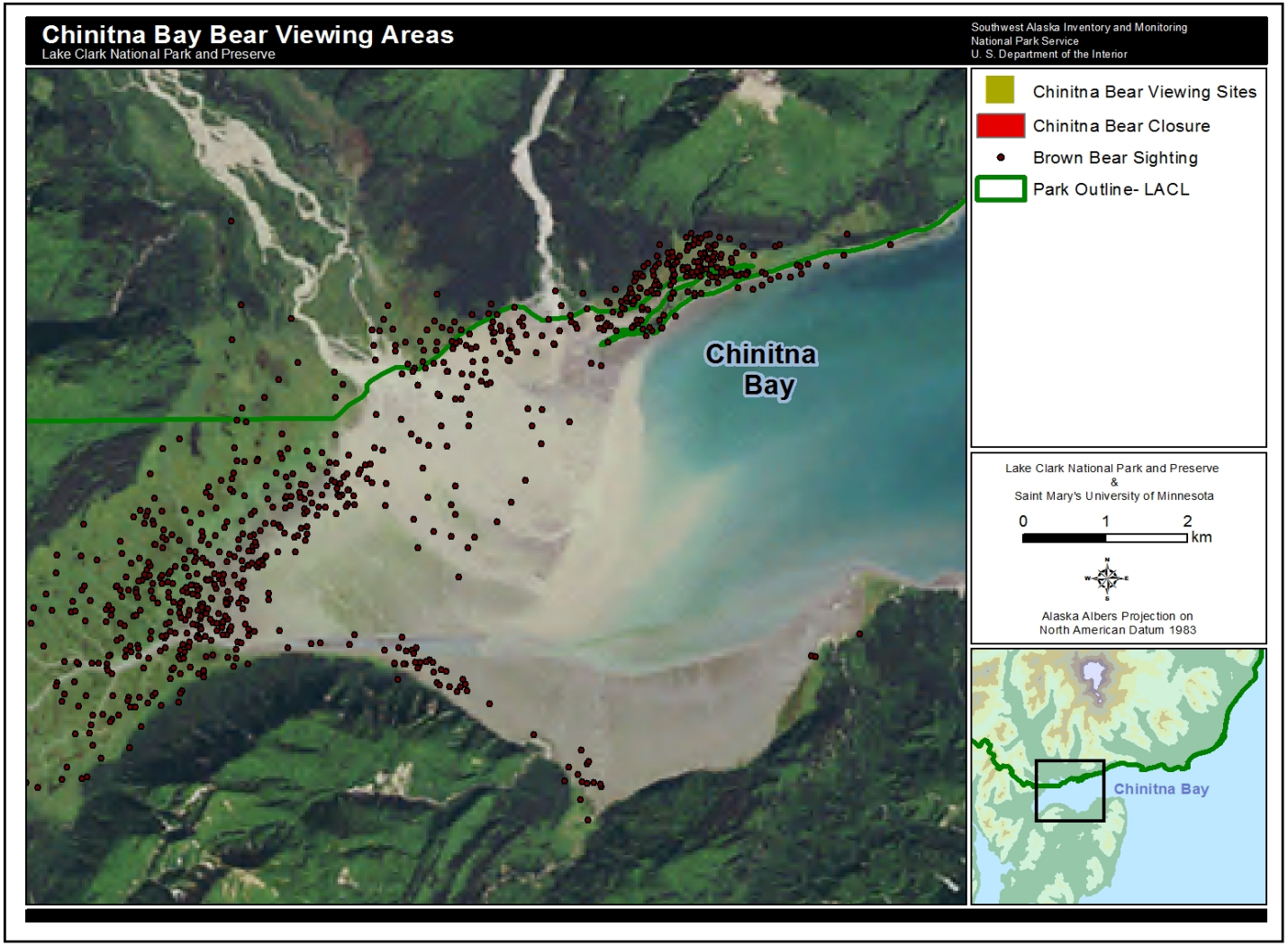


Plate 10. Designated bear viewing areas at northern Chinitna Bay. The marsh and meadow areas of the Chinitna bear closure are closed to visitors.

Table 39. Subsistence harvest of brown bears within LACL (NPS 2012).

RegYear	StateRes Issued	Hunted	Kill	Male	Female	Days Hunted
1996	3	0	0	0	0	0
1997	7	3	3	2	1	5
1998	7	5	2	1	1	13
1999	5	3	2	0	2	6
2000	4	0	0	0	0	0
2005	8	2	0	0	0	27
2006	7	3	1	0	1	31
2007	10	2	1	1	0	7
2008	8	4	1	1	0	31
2009	3	0	0	0	0	0
2010	10	6	4	1	3	30
2011	5	1	0	0	0	20
2012	5	0	0	0	0	0

Data Needs/Gaps

It is important to note that the more dense coastal brown bear population and the interior populations within LACL are thought to intermix to some degree. Quantitative data on the subject are not available at this time; future plans exist to define the travel extents of interior LACL brown bears. Dispersal between populations is thought to be minimal, as both the interior and coastal regions of LACL produce strong salmon runs, minimizing the need for bears to travel long distances in search of sustainable food sources (Mangipane, written communication, 30 July 2013).

Data gaps exist within the NPS (2013) coastal bear survey, most notably in the absence of bear counts for all of 2006, July 2007, and July 2010. Adverse weather conditions and lack of sufficient funding to perform the survey are the primary reasons for these gaps. However, since 2006, a concerted effort has been made to survey consistently. Consistency regarding the coastal survey data could be very beneficial in the assessment of population dynamics and overall health of LACL coastal brown bear populations and resources (Mangipane, written communication, 30 July 2013).

Data gaps exist within the NPS (2012) subsistence harvest summary in the form of a complete absence of data from 2001-2004. The reason for the lack of data for these years is unknown (Mangipane, written communication, 30 July 2013). Several factors are now in place which will greatly assist in achieving a more accurate assessment of the total number of brown bears harvested annually.

Research to assess the female survival of brown bears within LACL has never been conducted. However, park researchers are hoping to conduct a female survival study in beginning in 2014 and lasting through 2016 (Mangipane, written communication, 30 July 2013).

Overall Condition

All the measures reported in this document excluding female survival met or exceeded the standard for the reference condition for this resource and may be judged to be in excellent condition (*Condition Level* = 0). The condition level for female survival was not assigned due to the lack of information regarding this measure within LACL.

Population Size and Density

The *Significance Level* for this measure is 2. Brown bear population estimates and observations within LACL and the surrounding region indicate that the population is stable. A large portion of the park is closed to sport hunting. Considering that the largest and most dense brown bear population, located in the southwestern part of the park is within the protected area, this stable condition is likely to continue. As a result, brown bear population size and density was assigned a Condition Level of 0, or of no concern.

Recruitment (through cohorts)

The *Significance Level* for this measure is 3. NPS (2013) reports that lower than normal recruitment rates for both COY and yearling brown bear cubs were recorded for unit 9B in 1999. However, recruitment is generally not a concern for Alaskan Peninsula brown bears; the lower than normal recruitment rate in 1999 is most likely a reflection of poor salmon runs in both 1997 and 1998. Coastal transect survey data from 2012 and 2013 within LACL observed the lowest total cubs count since 2005. The percentage of bears in family groups during 2012 and 2013 (approximately 25%) and the percentage of cubs greater than yearlings in 2013 both recorded lower values than all previous survey years dating back to 2004. As a result, recruitment was assigned a *Condition Level* of 0, or of no concern.

Sex Ratios

The *Significance Level* for this measure is 2. Generally, the percentage of observed sows is higher during July compared to the June survey. A total of 59% of the brown bears recorded for the duration of the survey were sows. Recently, 76% of the brown bears surveyed during the July 2012 counts were sows, a ratio among the highest observed since 2004. As a result, sex ratio was assigned a *Condition Level* of 0, or of no concern.

Female Survival

The *Significance Level* for this measure is 3. Considering the high quality brown bear habitat, lack of hunting pressure and large protected areas within LACL, brown bear sow survival is likely high, between 90 to 97% annually. Sow survival within LACL could be considered on the higher end of this range given the favorable conditions within the park. Due to the lack of quantitative data on female survival, this measure was not assigned a *Condition Level.*

Weighted Condition Score

The *Weighted Condition Score* (*WCS*) (see Chapter 3 for methodology) for brown bears in LACL was 0.00. A *WCS* of 0.00 represents an overall condition of low concern. Overall, the trend of this resource is considered stable.

Brown Bears			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.00**
Population Size/Density	2	0	
Recruitment	3	0	
Sex Ratios	2	0	
Female Survival	3	n/a	

4.2.6 Sources of Expertise

Buck Mangipane, LACL Wildlife Biologist

Jeff Shearer, LACL Chief of Natural Resources

4.2.7 Literature Cited

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4.3 Caribou

4.3.1 Description



Photo 10. Caribou bull in LACL (NPS photo).

Caribou (*Rangifer tarandus*) (Photo 10) were once a prominent species in LACL. Today, caribou occasionally utilize the west and southwest portions of the park. An Alaskan adult bull caribou can weigh up to 318 kg (700 lbs), but average between 160-180 kg (350-400 lbs); adult cows weigh on average 80-120 kg (175-225 lbs) (Rausch et al. 2008). Caribou bulls can grow massive antlers. Cows also grow antlers but they are much shorter and smaller. Antlers grow each spring and remain covered in velvet until late August when the antler hardens. Caribou are herbivores, eating willow leaves, sedges, flowering tundra plants and mushrooms in the summer (May-September) and then supplementing their diet with dried sedges, small shrubs, and lichens during the winter (Rausch et al. 2008).

Cows generally reach sexual maturity at 28 months of age, although individuals in exceptional condition may breed at 16 months (Rausch et al. 2008). The breeding season or rut starts in early September and peaks towards the end of the month. Fighting between bulls is common but generally brief; occasionally serious bouts unfold and result in injury or death. Cows give birth to a single calf (twins are rare) around mid to late May. Shortly after calving, "post calving aggregations" form, which provide protection from predators; the location the herd chooses protects them from insects (Mangipane, personal communication, 12 November 2013). Caribou disperse in August to feed heavily before migrating. Caribou herds spend much of the year traveling between summer calving grounds and wintering areas. Migration is thought to be triggered by changing weather patterns, as caribou migrations generally precede cold fronts and snowstorms. Caribou often travel 80 km (50 mi) a day during peak migration times (Rausch et al. 2008).

LACL caribou are part of the Mulchatna Caribou Herd (MCH), one of the 32 designated herds in Alaska. The MCH is currently functioning as two distinct herds (East and West). Herds may intermix at wintering grounds but calving grounds are separate and historically remain in the same general area; wintering grounds and migration routes may change suddenly from historic locations to routes and areas with more favorable nutritional resources (Rausch et al. 2008). Mountainous areas and treeless tundra are preferred caribou habitat year round, with preference shown for open coastal areas and mountains for calving areas and boreal forests as wintering grounds (Rausch et al. 2008). The traditional calving grounds of the MCH have been the upper reaches of the Mulchatna River and the Bonanza Hills that are located southwest and west of LACL, respectively. Lesser used areas include Jack Rabbit Hills, Koktuli Hills, Mosquito River, and Kilbuck Mountains (Woolington 2009b, 2011b). The traditional calving grounds have been used sparingly since 1988. Calving now occurs most commonly between Kemuk Mountain and the Nushagak River; some calving also occurs west of LACL, near Tundra Lake between the Stoney River and Hoholitna River (Woolington 2009b,

2011b). Plate 11 – Plate 16 display the areas utilized by caribou throughout the year, such as calving areas, post-calving areas, fall migration, wintering areas, and spring migration, respectively.

4.3.2 Measures

- Population size
- Recruitment (by cohort)
- Sex ratios
- Female survival

4.3.3 Reference Conditions/Values

The ADF&G defines the management goals for caribou in each GMU. The MCH herd occupies GMUs 9B, 17, 18, and 19B (Plate 17). Within these units, ADF&G outlines management goals for the MCH regarding population size and population composition. The management goal for population size of the MCH is set at 30,000-80,000 caribou (Woolington 2011b). The management goal for population composition is the maintenance of a minimal sex ratio of at least 35 bulls:100 cows (Woolington 2011b). Management goals presented by ADF&G do not necessarily coincide with NPS goals and, therefore, used with caution in defining and describing condition.

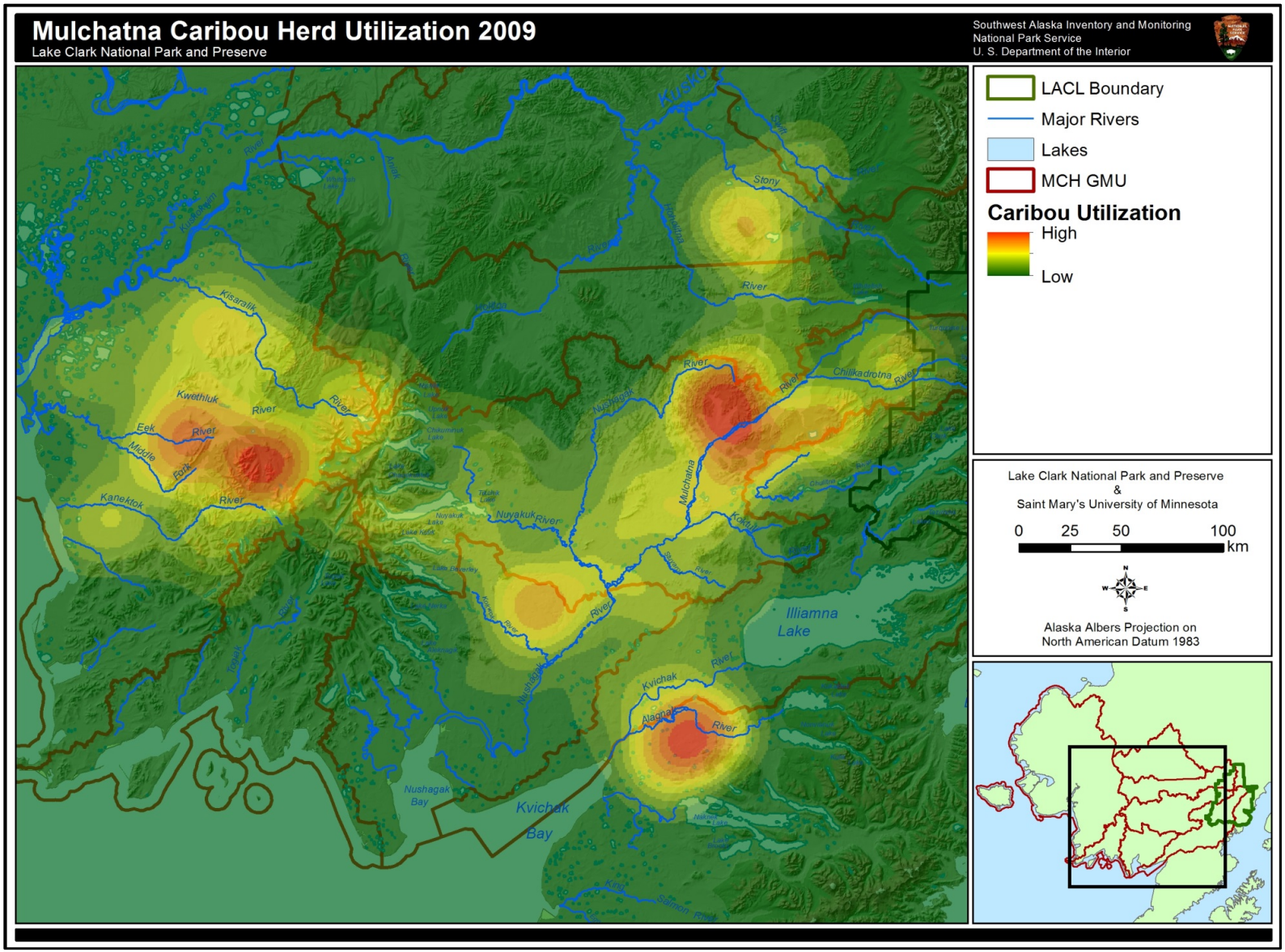


Plate 11. MCH utilization within the herd's range in 2009 (NPS 2010).

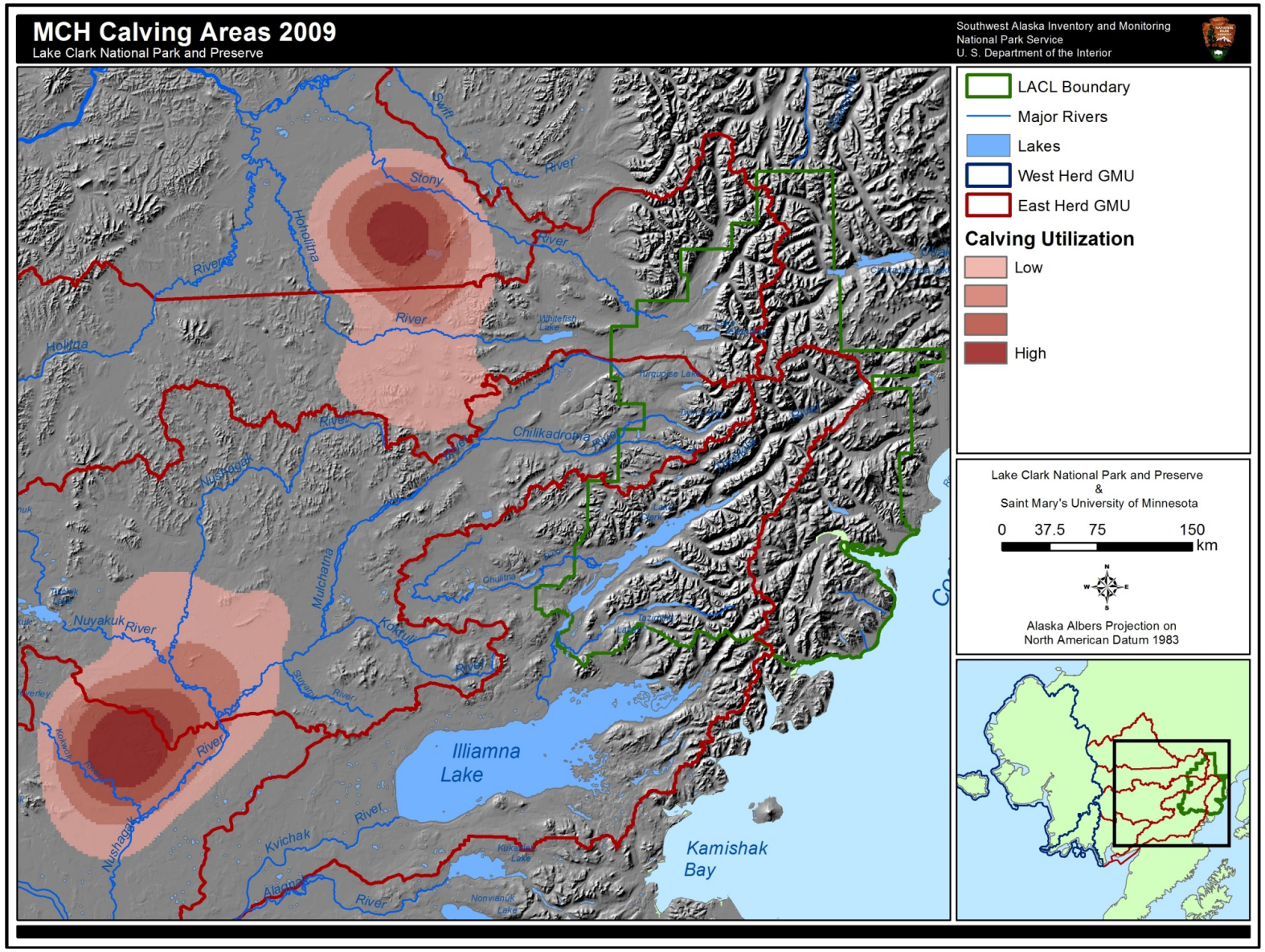


Plate 12. MCH calving areas and density.

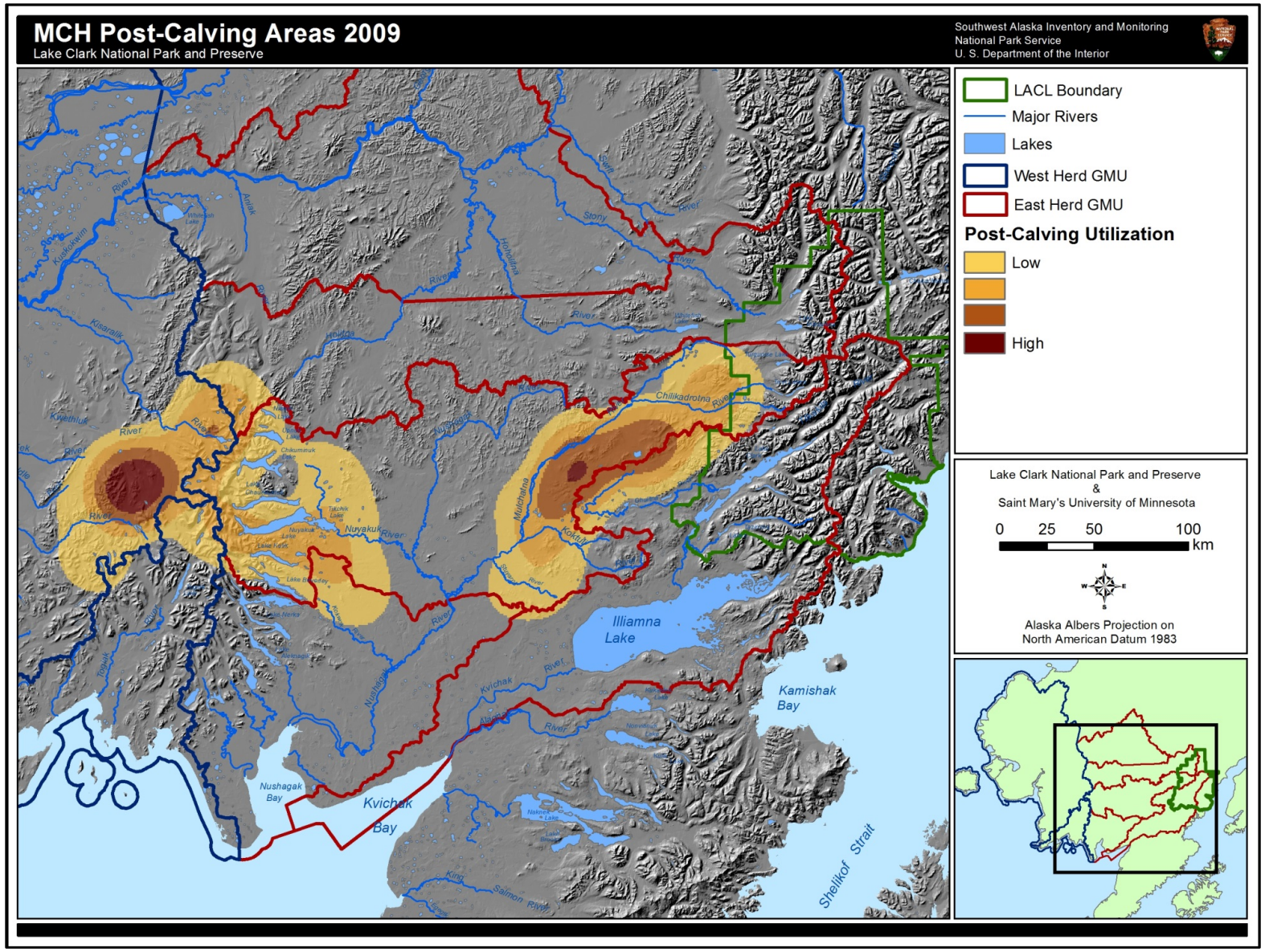


Plate 13. MCH post-calving areas.

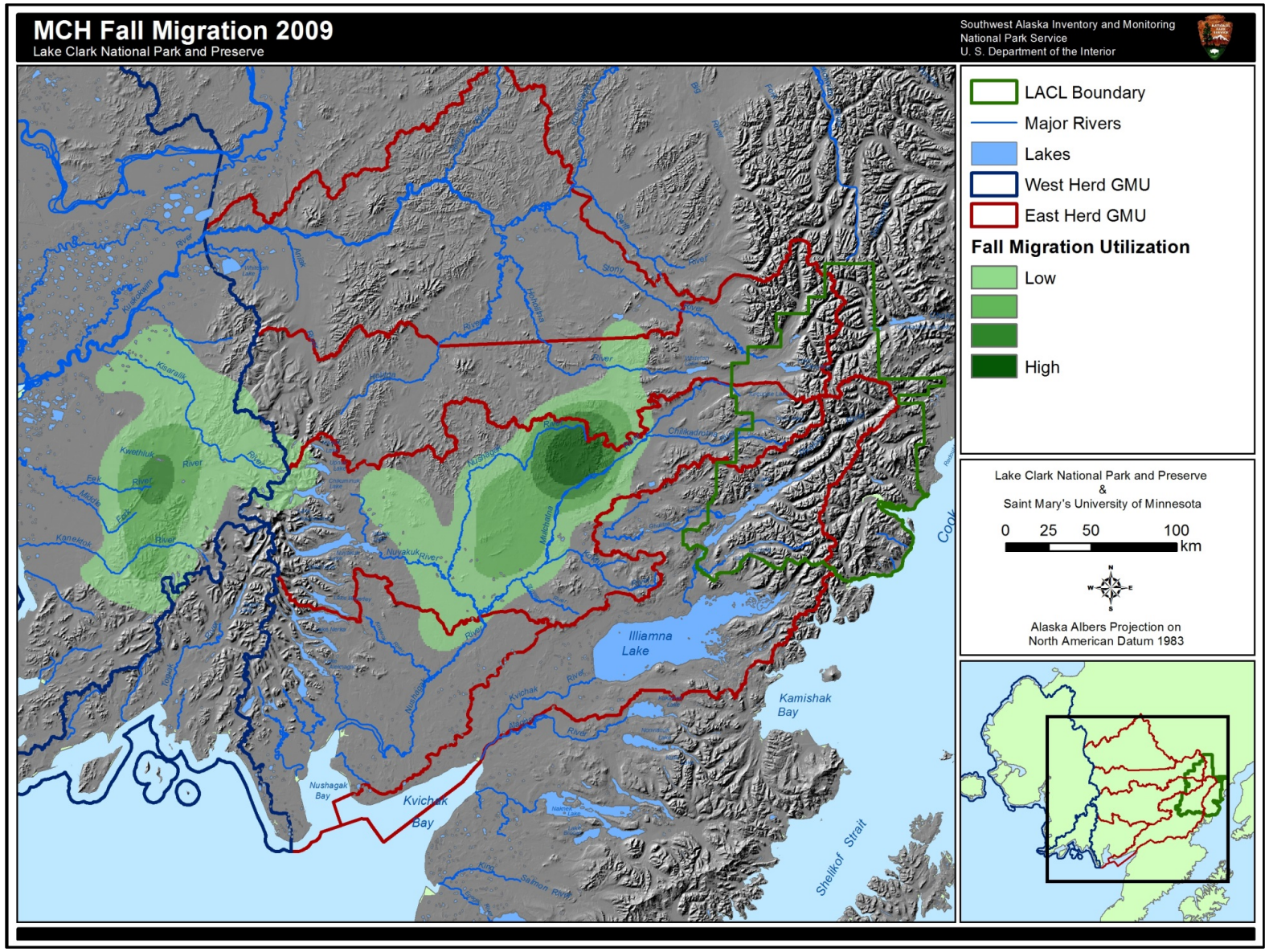


Plate 14. MCH fall migration ranges occurring between August and October.

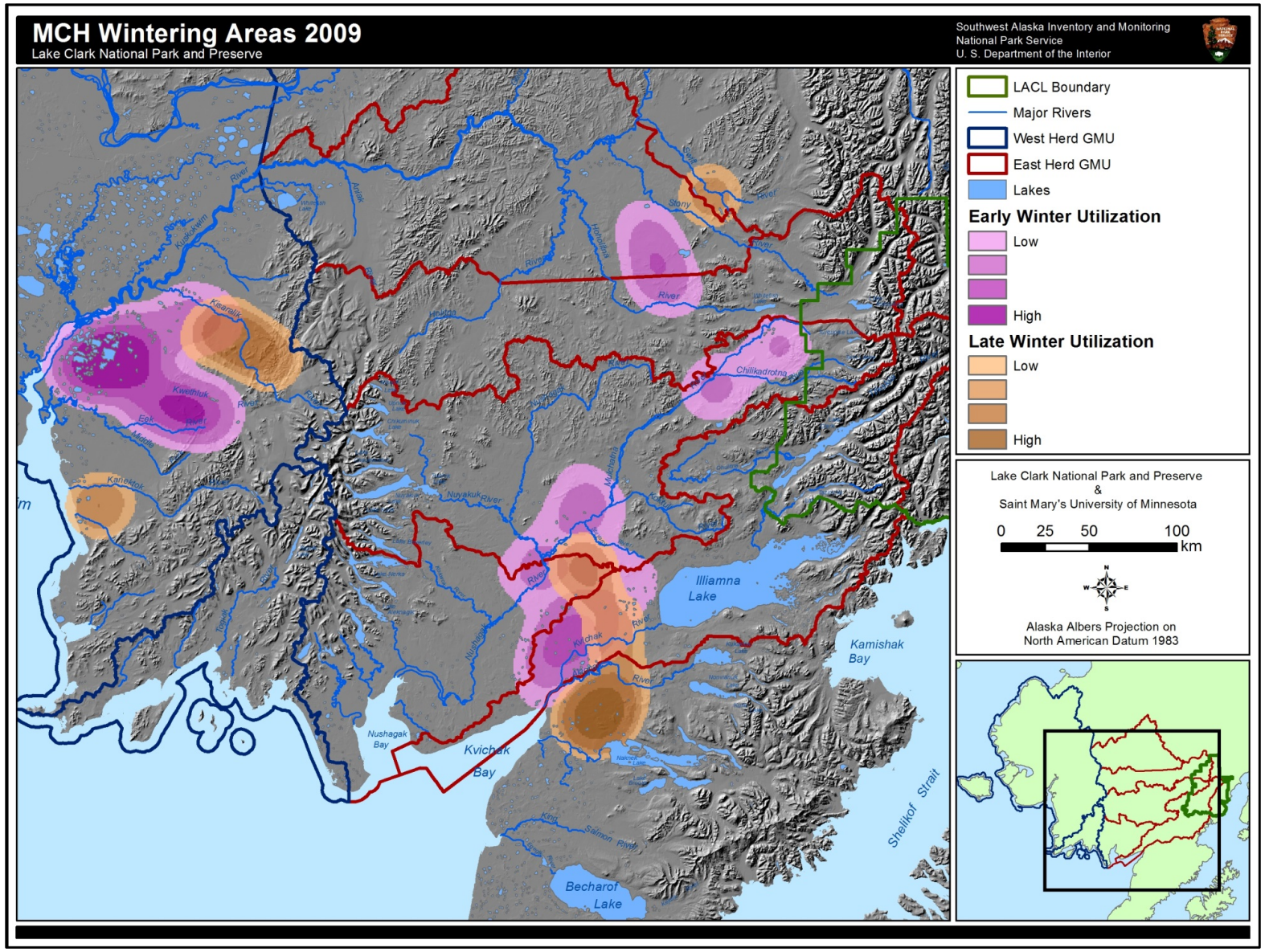


Plate 15. MCH early and late wintering areas occurring between November and February.

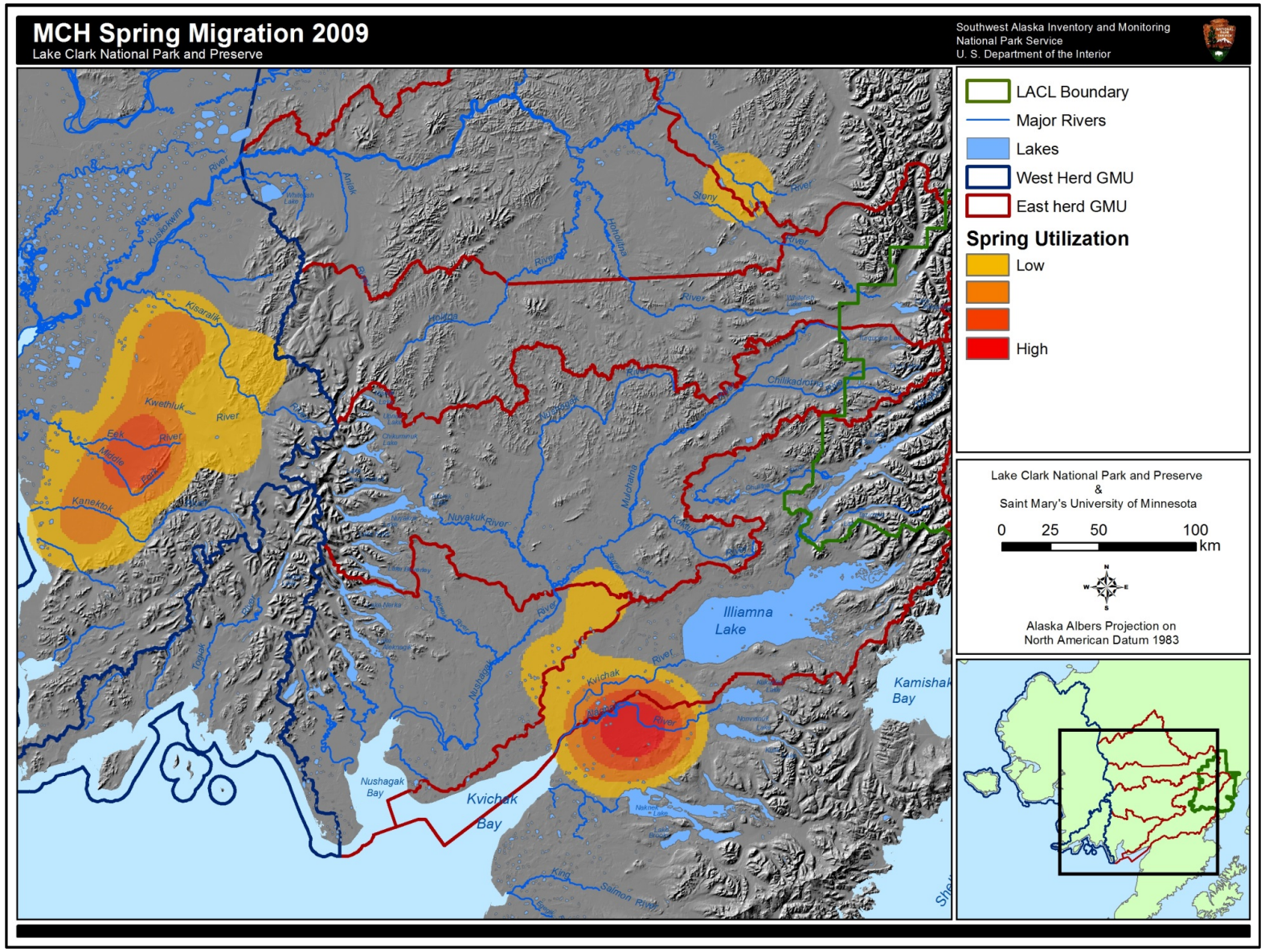


Plate 16. MCH spring migration ranges occurring between March and April.

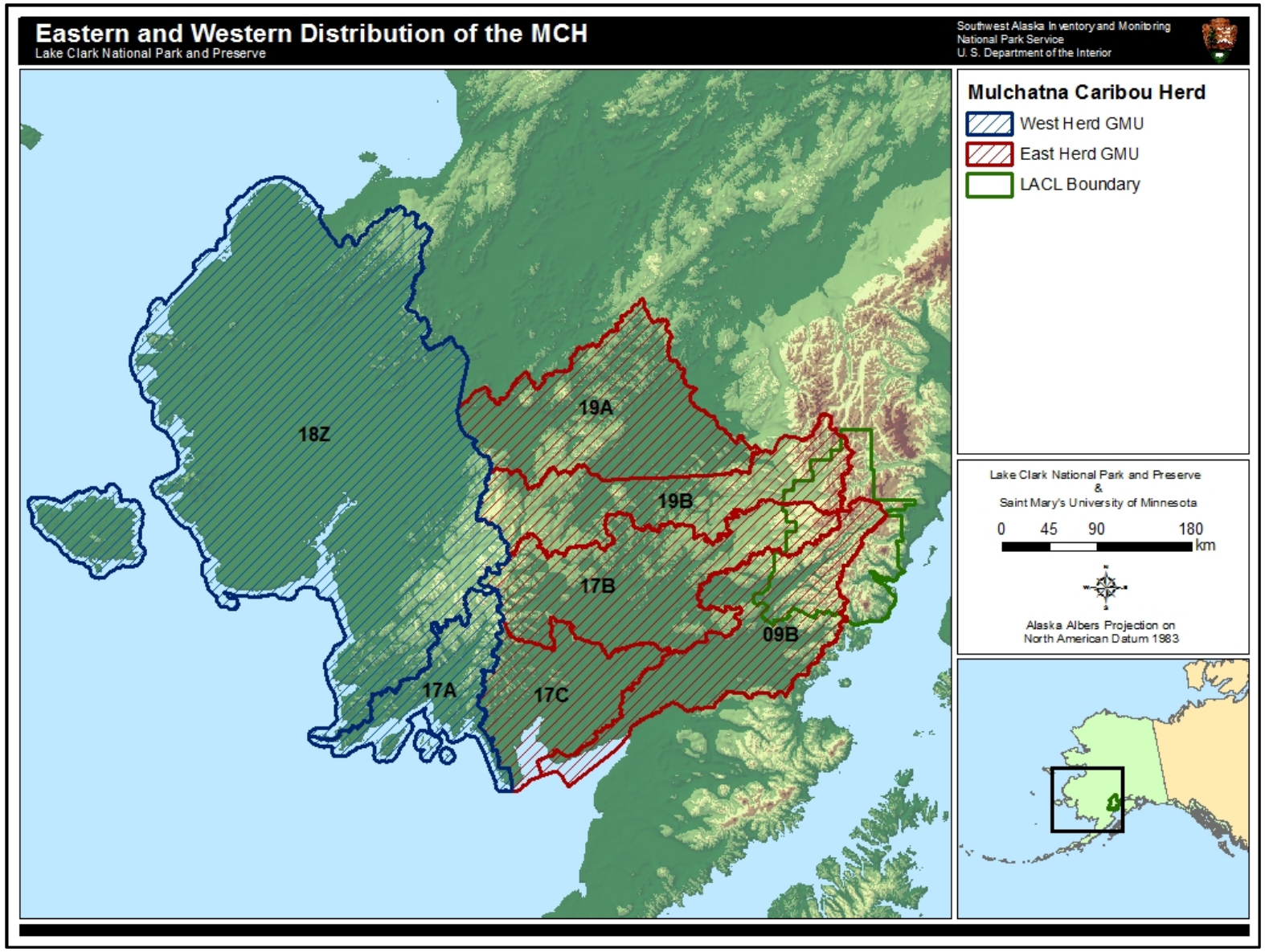


Plate 17. The GMUs that represent the eastern and western distribution of the MCH (NPS 2014).

4.3.4 Data and Methods

ADF&G caribou management reports (Woolington 2009b, 2011b) provide information on defined herd management goals. ADF&G conducts population size, age structure, and sex ratio surveys with the aid of radio telemetry, helicopters, and fixed winged aircraft within GMUs 9B, 17, 18 and 19B. ADF&G reports also outline sources of mortality; establish caribou population and composition objectives, and monitor temporal trends in population size and composition (Woolington 2009b, 2011b).

Photo censuses are conducted by ADF&G (Woolington 2004, 2006, 2008) to estimate caribou population size. Censuses take place in early July over post-calving concentrations of caribou. Wide angle 35-mm still photos are taken from aircraft over areas with large numbers of caribou and later counted in an effort to increase the accuracy of the population estimate. The population estimate includes the number of recaptured radio collared caribou, aerial photos taken by the aircraft camera, and the number of caribou counted from search planes (Woolington 2004, 2006, 2008).

ADF&G (Woolington 2004 – 2012) conducted composition counts for the MCH. Composition counts occur in October and determine recruitment (calf:100 cow) and sex ratios (bull:100 cow). Woolington (2004- 2012) splits the MCH into two sections, an east and west side of the herd's range. Plate 17 displays the GMUs that split the Mulchatna caribou herd range.

LACL provided 2008 – 2010 caribou radio location data for the MCH. However, the dataset does not contain three full years of data; the only year with 12 months of data was 2009, so 2008 and 2010 were not included in this analysis. Kernel density analysis was used to determine the overall and seasonal utilization distributions of the MCH. Kernel density calculates density by determining the probability that a neighboring point is around existing points within a search radius. A spatial autocorrelation tool was used to determine the search radius. The tool takes into account the location of points and count values to determine the most appropriate search radius of the data. The data were used to create several plates using ArcGIS software. The GMU plates were created using an Alaska GMU data layer provided by NPS Theme Manager. A MCH utilization map was created to represent the herd's range throughout a year. Seasonal plates depicting calving, post-calving, fall migration, wintering areas, and spring distribution were created.

4.3.5 Current Condition and Trend

Population Size

Woolington (2004 - 2012) presents a minimum estimate of the MCH for each year between 1974 and 2012. Between 1974 and 1980, the herd declined from 14,000 to 7,500 caribou. In 1981 the herd estimate was up to 20,600 caribou and continued to increase over the next 15 years. In 1991, an ADF&G survey, estimated the population size at 90,000 caribou (Woolington 2009b, 2011b). In 1992 and 1993, the herd was estimated at 115,000 and 150,000 caribou, respectively. The peak in population size occurred in 1996 with an estimated 200,000 caribou. According to Woolington (2004 – 2012), the next recorded population estimate occurred in 1999 displaying that the population size had decreased to 175,000 caribou. The caribou population continued to decline to 30,000 caribou in 2008. The 2008 estimate is the most current estimate for the herd. According to Woolington (2004, 2006, 2008), rain and poor light conditions are not conducive to yielding accurate counts of caribou

aggregations when utilizing aerial photography, and poor weather conditions during the 2008 survey are believed to be the cause of a reduction in caribou observed of nearly 20,000 from the previous census in 2006. Table 40 displays the population estimates and composition counts for the MCH between 1991 and 2009.

Table 40. Estimated population size and fall composition counts of the Mulchatna Caribou Herd 1991 – 2009 (reproduced from Woolington 2011b).

Calendar Year	Total bulls: 100 cows	Calves: 100 cows	Calves (%)	Cows (%)	Small bulls (% of bulls)	Medium bulls (% of bulls)	Large bulls (% of bulls)	Total bulls (%)	Composition sample size	Estimate of herd size
1991	--	--	--	--	--	--	--	--	--	90,000
1992	--	--	--	--	--	--	--	--	--	115,000
1993	42.1	44.1	23.7	53.7	--	--	--	22.6	5907	150,000
1994	--	--	--	--	--	--	--	--	--	180,000
1995	--	--	--	--	--	--	--	--	--	190,000
1996	42.4	34.4	19.5	56.6	49.8	28.5	21.7	24.0	1727	200,000
1997	--	--	--	--	--	--	--	--	--	--
1998	40.6	33.6	19.3	57.4	27.8	43.7	28.5	23.3	3086	--
1999	30.3	14.1	9.8	69.3	59.9	26.3	13.8	21.0	4731	175,000
2000	37.6	24.3	15.0	61.8	46.6	32.9	20.4	23.2	3894	--
2001	25.2	19.9	13.7	68.9	31.7	50.1	18.3	17.7	5728	--
2002	25.7	28.1	18.3	65.0	57.8	29.7	12.5	16.7	5734	147,000
2003	17.4	25.6	17.9	69.9	36.2	45.3	18.5	12.2	7821	--
2004	21.0	20.0	14.2	71.0	64.2	28.9	6.9	14.9	4608	85,000
2005	13.9	18.1	13.7	75.8	55.3	33.3	11.5	10.6	5211	--
2006	14.9	25.5	18.1	71.3	57.5	33.7	8.9	10.6	2971	45,000
2007	23.0	15.8	11.4	72.1	52.7	36.0	11.3	16.6	3943	--
2008	19.3	23.4	16.4	70.1	46.8	36.1	17.1	13.5	3728	30,000
2009	18.5	31.0	20.7	66.9	39.7	43.9	16.3	12.4	4595	--

(--) – Data were not included in Woolington (2011).

Recruitment

Calf recruitment is an important factor affecting population growth. A herd requires a recruitment ratio greater than 25 calves:100 cows to grow (Manning and Butler 2013). Woolington (2004-2012) documented recruitment ratios for the MCH dating back to 1974. Recruitment ratios were consistently high until 1999, which estimated 14.1 calves: 100 cows. In 2000 recruitment had increased to 24.3 calves per 100 cows; however, this estimate was still below management objectives. Recruitment estimates did not reach acceptable ratios until 2002. Recruitment has only been greater than 25 calves: 100 cows five times since 1999. According to Alaska Board of Game (ABG 2011), the MCH has had, on average, low calf recruitment (22 calves:100 cows) since 2005. Woolington (2009b, 2011b) believes the low calf recruitment in 1999 and 2005 may have been linked to an outbreak of foot rot and bacterial infection during both those years. Low recruitment may also be a result of low pregnancy percentages. The percent of pregnant radio collared cows (three years old and greater) has fluctuated between 2000 and 2012; the percent of pregnant cows dropped below 80 percent in nine of the 13 years observed (Appendix OO, Woolington 2012a). Table 41 displays the recruitment ratios and percentage of calves in the MCH since 1974. It should be noted that ratios were recorded irregularly from 1974 to 1998.

Table 41. MCH recruitment ratios and percentages of calves in the herd, taken from a composition counts survey between 1974 and 2012 (Woolington 2004 – 2012b).

Year	Calves: 100 cows	Calves(%)
1974	34.9	18.4
1978	64.5	27.6
1980	57.1	30.0
1981	45.1	22.8
1986	36.9	19.2
1987	60.1	26.3
1988	53.7	24.4
1993	44.1	23.7
1996	34.4	19.5
1998	33.6	19.3
1999	14.1	9.8
2000	24.3	15.0
2001	19.9	13.7
2002	28.1	18.3
2003	25.6	17.9
2004	20.0	14.2

Table 41 (continued). MCH recruitment ratios and percentages of calves in the herd, taken from a composition counts survey between 1974 and 2012 (Woolington 2004 – 2012b).

Year	Calves: 100 cows	Calves(%)
2005	18.1	13.7
2006	25.5	18.1
2007	15.8	11.4
2008	23.4	16.4
2009	31.0	20.7
2010	19.5	14.3
2011	19.0	13.5
2012	29.8	19.5

Woolington (2004 - 2012) also documented recruitment ratios for the east and west side of the MCH between 2004 and 2012. LACL falls in the "east side" of the MCH territory. Table 42 displays the calf:cow ratios for the east and west side of the herd as well as the combined ratio. The lowest combined recruitment rate occurred in 2007 at 15.8 calves to 100 cows, while the highest combined recruitment rate occurred in 2009 at 31.0 calves to 100 cows. According to Woolington, the combined ratios for 2009 and 2012 are the highest since 1999 (33.6 calves:100 cows).

Table 42. The east side, west side, and combined calf:cow ratios for MCH between 2004 and 2012 (Woolington 2004 – 2012). Note that LACL falls in the east side of the MCH territory.

Side	2004	2005	2006	2007	2008	2009	2010	2011	2012
East	23.6	22.7	25.2	14.4	17.1	25.7	16.9	14.3	22.2
West	17.5	13.5	26.0	19.4	26.6	36.6	23.4	28.1	37.5
Combined	20.0	18.1	25.5	15.8	23.4	31.0	19.5	19.0	29.8

Sex Ratios

The management goal for bull:cow ratios in the MCH is 35:100 (Woolington 2011a). Woolington (2004 – 2012) documented sex ratios for the MCH that date back to 1974. MCH sex ratios ranged from 30.3 to 68.2 between 1974 and 2000. The only ratios falling below management objectives occurred in 1980 and 1999 with estimates of 31.3 bulls to 100 cows and 30.3 bulls to 100 cows, respectively (Woolington 2004–2012). Historically, the herd's sex ratios met the management goals set by ADF&G; however, the herd has not met the criteria since 2000 (Woolington 2012b). Between 2000 and 2012, the herd has experienced sex ratios below 20 bulls: 100 cows for six years. According to ABG (2011), the low sex ratios of the MCH are caused by low calf recruitment, which has been observed within the herd since 2004. Table 40 displays the MCH sex ratios.

Female Survival

Demma (2011) presents adult cow (>2 years of age) survival data from 1993 to 2011, based on radio-collared animals. It should be noted that adult cow survival has experienced fluctuations throughout this time period. Cow survival rates were within an acceptable range (80 to 90 percent) between 1993 and 1996. Survival rates hit a low of 71 percent in 2001; however, survival rates began to increase before they peaked in 2003 at 96 percent. Survival rates dropped and remained below acceptable percentages between 2004 and 2009 (Nick Demma, ADF&G Wildlife Biologist, personal communication, 6 November 2013). Woolington (2011a) documented adult cow survival between 1996 and 2008. Mean annual survival was 90 percent during this subset of the data. Female survival dropped below 80 percent in over half of the years during the 13-year time period. While average annual survival of 90 percent would allow population maintenance or growth, annual rates below 80 percent could have caused a decline in the population. These lower survival rates may be due to several factors including predation, nutrition, and diseases (Woolington 2011a). Figure 24 displays MCH adult cow survival.

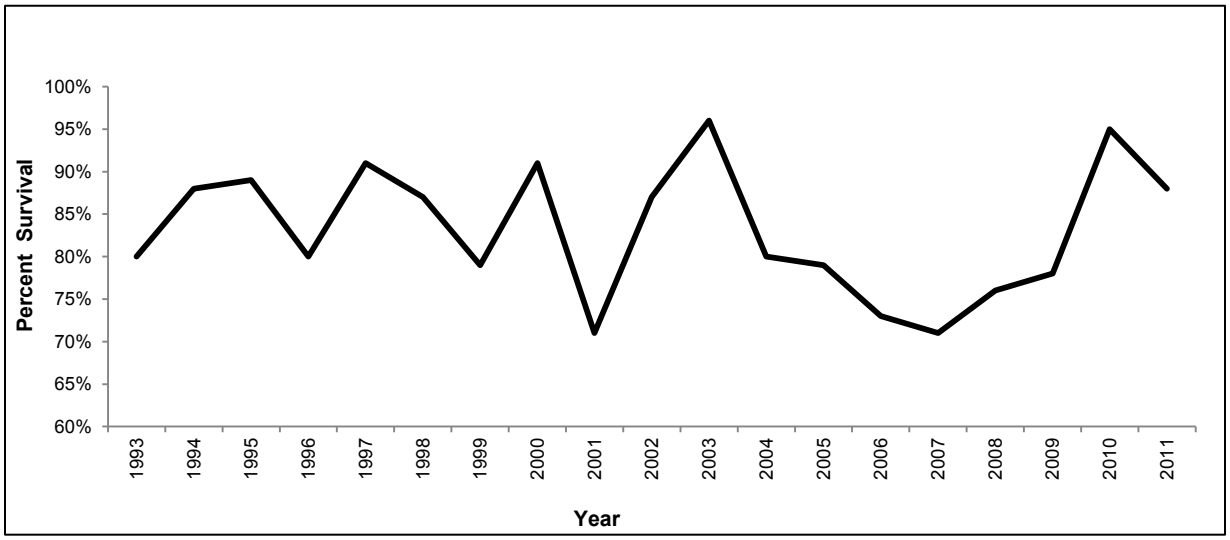


Figure 24. MCH adult cow survival, based on data from radio-collared caribou (Demma, personal communication, 6 November 2013).

Threats and Stressor Factors

LACL staff identified four threats to the MCH: disease, habitat condition, winter ice events and predation. Hoof rot is a disease caused by a soil-dwelling bacterium (*Spherophorous necrophorous*); the most common symptom is abscesses that grow above the hoof (ADF&G 2013). Hoof rot was observed in the MCH in the late 1990s (ADF&G 2013). Hoof rot is considered a direct and indirect threat because, if left untreated, it can result in death. It can also make infected caribou susceptible to predation if they begin to limp and lose mobility.

Poor habitat condition is another threat to caribou in and around LACL. Specifically, forage quality is a concern. Birth weights, survival, growth, and pregnancy rates can all be affected by the quality of forage (Joly and Klein 2012). Pregnancy rates of various age classes can be an indicator of forage

quality. Females can birth a calf by 16 months of age if they have been consuming high quality forage and are in good health. According to Woolington (2012a), pregnancy percentages were really low for the 2-year age class. Caribou that were five years and older had significantly higher pregnancy rates than those in the 2-year age class. Low forge quality may be a factor causing the low pregnancy rates in the two year old caribou. Appendix OO displays 13 years of MCH pregnancy rates by age class for 2000 through 2012.Forage quality can be diminished by over grazing/browsing and shifts in vegetation communities due to climate change (Mangipane, personal communication, 12 November 2013).

Winter ice events are a seasonal threat to caribou in LACL. If ground ice becomes too thick, it can reduce mobility and prevent caribou from foraging on the food source beneath it. This may result in lower winter survival rates because caribou may starve if they are unable to find an alternative food source (USFWS 2012).

Predation is another stressor that affects the MCH. Brown bear and wolf predation occurs within the herd (Woolington 2009b, 2011b). Predation is one reason for the herd's high level of calf mortality, which diminishes the population's ability to grow (Mangipane, personal communication, 12 November 2013).

Data Needs/Gaps

There is little information on recruitment by cohort and adult cow survival rates for the MCH. Continuation of the annual caribou surveys is needed to allow managers to evaluate long-term trends in population dynamics. Furthermore, continued yearly estimates of female survival based on radio-collared cows may help researchers and managers more accurately assess the current health of the population.

Overall Condition

Population Size

The project team defined the *Significance Level* for population size as a 2. Mulchatna Caribou Herd population estimates and observations within LACL and the surrounding region indicate that the population has been declining since 1998. According to Woolington (2012b), the most recent population estimate taken in 2008 was 30,000 caribou, which is at the lower end of the herd management goal assigned by ADF&G. The decline of the MCH could be attributed to several factors including poor weather conditions, low recruitment levels, cow survival, or predation. While the population size has declined over the years, it is possible that the herd size has stabilized or increased since 2008. As a result, this measure was assigned a *Condition Level* of 2, indicating that it is of moderate concern.

Recruitment (through cohorts)

The project team defined the *Significance Level* for recruitment as a 3. According to Woolington (2011b), calf recruitment has been poor since 2003. There are no data regarding recruitment by cohort. Because of these limitations, no *Condition Level* was assigned for this measure.

Sex Ratios

The project team defined the *Significance Level* for sex ratios as a 2. Woolington (2011b) documented sex ratios between 1991 and 2009 that display a significant drop, and ratios have not met ADF&G objectives since 2000 when the ratio was 37.6 bulls to 100 cows. According to USFWS (2009), the sex ratios may be below the management goal of 35:100, but they seem to be increasing. As a result, this measure was assigned a *Condition Level* of 2, indicating that it is of moderate concern.

Female Survival

The project team defined the *Significance Level* for female survival as a 3. Woolington (2011b) reported a mean cow survival of 90 percent between 1996 and 2008. However, seven of the thirteen years were below 80 percent survival. Female survival data from Demma (2011) was estimated from a graph, so it may not be entirely accurate. The mean survival between 1993 and 2010 was 84 percent. Seven out of 18 years had survival rates below 80 percent. As a result of the fluctuating survival rate, this measure was assigned a *Condition Level* of 2, or of moderate concern.

Weighted Condition Score

The *Weighted Condition Score* for caribou in LACL is 0.67, indicating that the condition of this component is of high concern. It should be noted that the WCS is toward the low end of the high concern range, meaning it is very close to being of moderate concern. Due to a lack of recent data regarding population size, a trend could not be determined for this component.

Caribou			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.67**
Population Size	2	2	
Recruitment	3	n/a	
Sex Ratios	2	2	
Female Survival	3	2	

4.3.6 Sources of Expertise

Nick Demma, ADF&G Wildlife Biologist

Buck Mangipane, LACL Wildlife Biologist

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4.4 Black Bear

4.4.1 Description



Photo 11. Black bear in LACL (NPS photo).

Black bear (*Ursus americanus*; Photo 11) utilize LACL resources year-round for foraging, reproduction, and denning. The species is widely dispersed throughout the forested areas of the park during much of the year and is considered to exist in natural populations largely free of human disturbance. However, concentrations near coastal, riverine, and lake ecosystems sometimes occur. During the summer and fall, black bears gravitate towards areas of the park with large concentrations of berries. Black bears also forage along the expansive 320-km (200-mi) LACL intertidal area and coastal shoreline (Bennett 1996). Black bears with access to salmon will likely feed on this resource as well to supplement their fat reserves for winter denning. As omnivores, black bears consume a wide variety of foods in their diet including sedges, berries, clams, colonial insects, salmon and a wide variety of other plant material. Caribou and moose are also consumed; neonatal members of both species are predominantly targeted (Franzman and Schwartz 1986).

Alaskan black bear males (boars) average 80 to 90 kg (180-200 lbs) with females being slightly smaller, averaging 45 to 60 kg (100-150 lbs) upon emergence from denning in spring (ADF&G 2008a). Black bears typically weigh 20 to 40% less upon den emergence in the spring compared to pre-denning weights in the fall. Mating generally occurs from June to July, and typically two cubs are born in the mid-winter months, though litters of three to four are not uncommon (Pelton 1982). When black bear cubs emerge from the den they typically weigh around 2.3 kg (5 lbs) (ADF&G 2008a). Litter intervals are typically every other year, and cubs remain with their mother for just over a year (Pelton 1982). Denning usually takes place from October to May, The condition of the bear, food availability, sex and age (females and juveniles typically den earlier), and local weather patterns for that year determine the time and duration of denning (Pelton 1982).

Black bears are hunted for both sport and subsistence within LACL. The ADF&G (Butler 2009) defines GMUs across Alaska in an effort to assess regional game populations and define hunting regulations. Portions of five individual GMUs extend over LACL, including units 09A, 09B, 16B, 17B, and 19B (Plate 18).

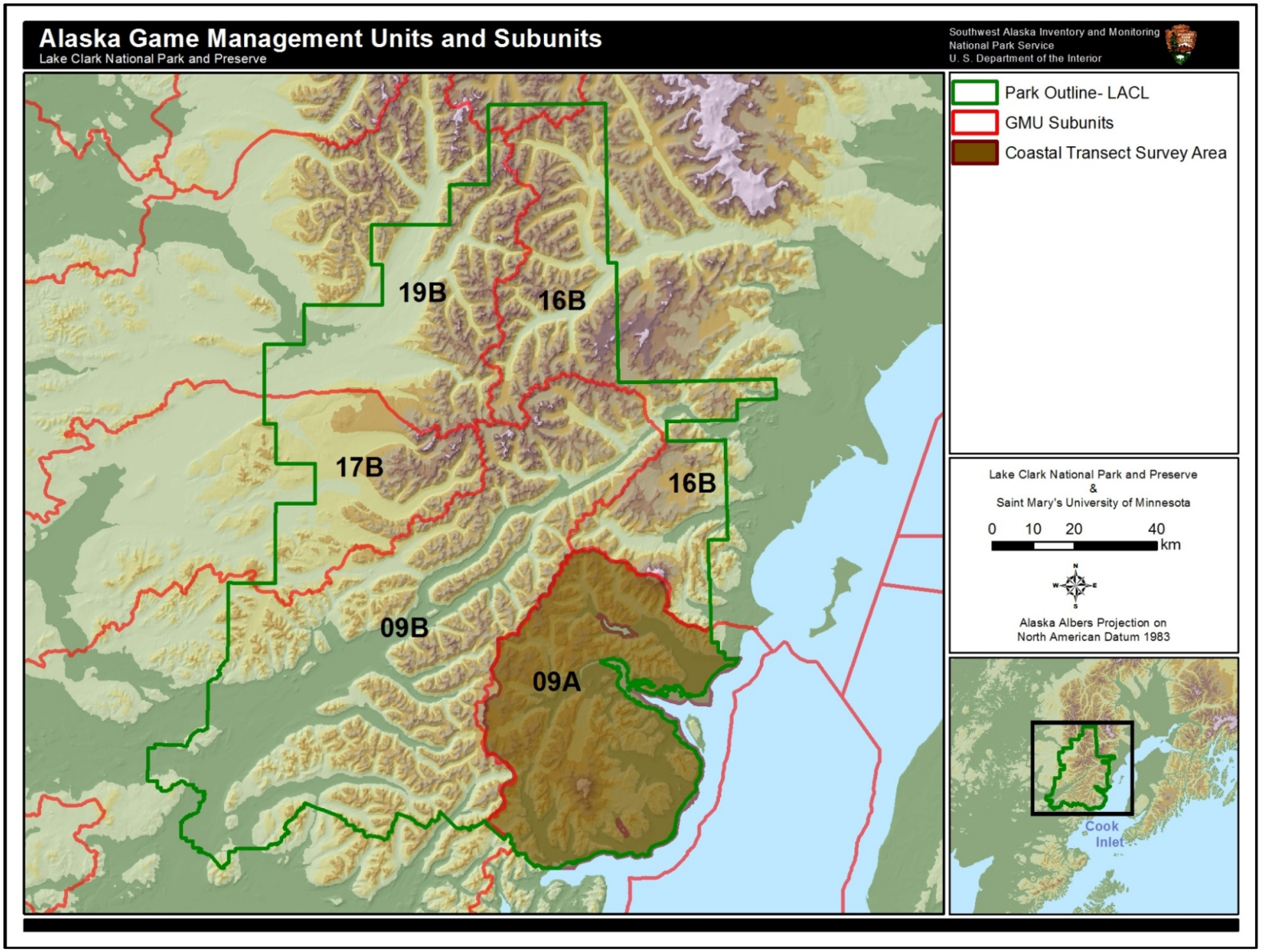


Plate 18. Game Management Unit boundaries and the black bear coastal transect survey area boundary.

4.4.2 Measures

- Population size and density
- Recruitment (through cohorts)
- Sex ratios
- Female survival

4.4.3 Reference Conditions/Values

There is insufficient information to determine reference conditions for black bear distribution and abundance in LACL at this time. While population abundance and distribution estimates are available for black bears within ADF&G management units 16B and 19B (ADF&G 2008b), which include portions of LACL, precise estimates do not exist for a park-wide, baseline reference condition. The general management objective for black bears in the park is to allow for the current natural and healthy population to persist free from human habituations and interference with existing quality habitat.

4.4.4 Data and Methods

NPS (2013) collected coastal bear trend count data along the intertidal, salt marsh, and tributary areas of the LACL coastline from 2004 to 2013 (2006 being omitted from the data set). NPS (2013) provides a data source to assess the park's black bear population (Plate 19), however, the survey primarily covered brown bear habitat from 2004 to 2007. Survey areas were expanded in 2008 to include more of the freshwater meadows and marshes in an effort to conduct a more thorough investigation of black bear populations within LACL. Surveys were conducted by fix winged aircraft for a majority of the months of June and July during the aforementioned survey years and utilized the line transect double count method. The ADF&G (2008b) black bear management report provides black bear population size and density estimations from a line transect survey taken in 2007. Transect surveys were conducted in GMU 16B and 19B; density estimates were derived from lands classified as quality black bear habitat areas. In GMU 16B, this only included land below 1,067 m (3,500 ft).

Olson and Putera (2007) conducted a survey in 2003-2004 which resulted in population and density estimates for black bears within the southeastern portion of LACL in GMU 9A. Data was collected by fix winged aircraft utilizing the line transect double count method.

A SWAN/LACL coastal data project in 2010 provided data for bears within LACL in 2010. Data was collected by fix winged aircraft utilizing the line transect double count method. The survey area covered the entire LACL coast, transects were generated from an elevation of 3000 feet on down to the coastline.

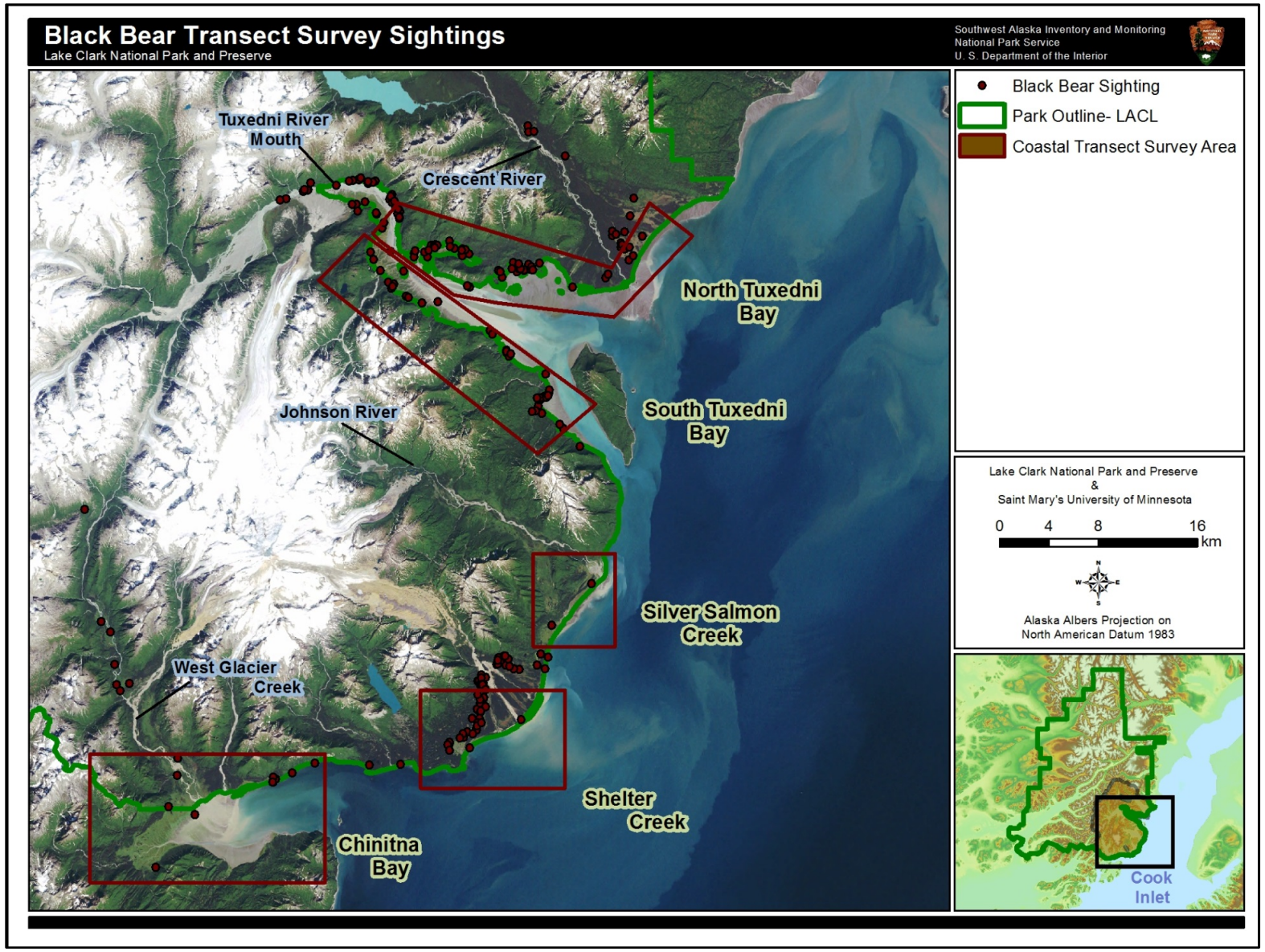


Plate 19. Black bear sightings during the LACL coastal transect survey from 2004 to 2013.

4.4.5 Current Condition and Trend

Population Size and Density

Minimal data exist regarding the population size and densities of black bears in the LACL region. Coastal minimal count survey data indicate an increase in black bear sightings beginning in July 2008 (45 bears) and peaking in July 2011 (51 bears) (NPS 2013, Table 43). This increase in black bear numbers is a reflection of the expanded survey area implemented in 2008; black bears were likely frequenting these areas in similar numbers prior to the survey expansion (Mangipane, personal communication, 30 July 2013). Olson and Putera (2007) estimated that between 302 and 132 black bears reside in the LACL portion of GMU 9A. Generally, more black bears are observed during the July survey than in the June survey. A 2010 survey within LACL observed 151 black bears; sexes could not be determined on a majority of the bears (110), as gender identification of black bears is much more difficult from a distance compared to brown bears (Table 44). Nearly 50% of the black bears observed during the LACL coastal transect survey were outside of the five designated salt marsh areas. Salt marsh areas support high brown bear densities; black bears avoid these areas, occupying the more forested and freshwater meadow/marsh areas of LACL, preferably near a lake or stream system. Black bears prefer these areas as they support more bountiful vegetation with higher nutritional values. Clusters of bear sightings away from salt marsh habitats included areas around West Glacier Creek, Crescent River, and the Tuxedni River mouth (NPS 2013, Plate 19).

Table 43. Total number of adult and subadult black bears counted within the LACL coastal survey area between 2004 and 2013 (NPS 2013).

Date	Total Bears	Date	Total Bears
06/21/04	1	07/15/09	6
07/12/04	1	06/23/10	18
06/15/05	4	06/23/11	24
06/23/05	3	07/13/11	51
07/13/05	5	06/21/12	7
07/20/05	2	07/20/12	45
06/18/07	7	06/12/13	10
06/27/08	9	06/25/13	22
07/10/08	45	07/09/13	17
06/24/09	28	--	--

Table 44. NPS aerial survey project 2010 LACL coastal black bear sightings during 2010 aerial surveys (NPS 2013).

Description	Total
Adult-sex unknown	110
Breeding Pair	1
Sow with cubs > yearling	2
Sow with COY	6
Sow with yearling cubs	20
Large male	12
Total	**151**

Olson and Putera (2007) estimated that between 60 and 136 black bears/1000 km^2 reside in the LACL portion of GMU 9A; densities on the higher end of this range being found near the coastal and waterway regions of the park. Black bear densities have also been estimated for GMU 16B and 19B at 125 bears/1000 km^2 and 106 bears/1000 km^2 respectively; both units comprise portions of LACL to the north and east (ADF&G 2008b). These densities provide a benchmark for comparison (if similar studies are conducted in LACL) and prediction of black bear densities within LACL over areas of quality bear habitat (Table 45, Plate 19).

Table 45. Percentage of observed black bears within the five main survey/marsh areas of the coastal transect survey region. The blank field represents a bear sighting outside of the five designated salt marsh areas.

Date	Chinitna Bay	North Tuxedni Bay	Shelter Creek	Silver Salmon Creek	South Tuxedni Bay	Blank
06/21/04	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
07/12/04	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
06/15/05	0.00%	75.00%	0.00%	0.00%	0.00%	25.00%
06/23/05	0.00%	66.67%	0.00%	0.00%	33.33%	0.00%
07/13/05	0.00%	60.00%	0.00%	0.00%	40.00%	0.00%
07/20/05	0.00%	50.00%	0.00%	0.00%	0.00%	50.00%
06/18/07	0.00%	28.57%	0.00%	0.00%	14.29%	57.14%
06/27/08	0.00%	50.00%	0.00%	0.00%	12.50%	37.50%
07/10/08	0.00%	27.50%	0.00%	0.00%	20.00%	52.50%

Table 45 (continued). Percentage of observed black bears within the five main survey/marsh areas of the coastal transect survey region. The blank field represents a bear sighting outside of the five designated salt marsh areas.

Date	Chinitna Bay	North Tuxedni Bay	Shelter Creek	Silver Salmon Creek	South Tuxedni Bay	Blank
06/24/09	0.00%	24.00%	0.00%	0.00%	8.00%	68.00%
07/15/09	0.00%	33.33%	0.00%	0.00%	50.00%	16.67%
06/23/10	0.00%	9.09%	36.36%	0.00%	18.18%	36.36%
06/23/11	0.00%	31.58%	0.00%	0.00%	10.53%	57.89%
07/13/11	8.16%	20.41%	8.16%	4.08%	8.16%	51.02%
06/21/12	0.00%	16.67%	0.00%	0.00%	33.33%	0.00%
07/20/12	5.00%	25.00%	15.00%	0.00%	15.00%	40.00%
06/12/13	0.00%	40.00%	0.00%	0.00%	10.00%	50.00%
06/25/13	0.00%	27.27%	4.55%	0.00%	13.64%	54.55%
07/09/13	0.00%	47.06%	0.00%	11.76%	5.88%	35.29%
Average	**0.69%**	**33.27%**	**3.37%**	**0.83%**	**15.41%**	**43.79%**

Recruitment (through cohorts)

The availability of food plays the most significant role in determining the age at which a female will produce her first litter, the number of cubs born, and cub survival to weaning stage (Miller 1994). Females are generally 3-5 years old before they produce a litter; however, due to nutritional stress or fitness, this value can range from a low of 2 years to a high of 7 years (Pelton 1982). Very minimal data exist regarding black bear recruitment within LACL, the 2010 survey (Table 44) allows for basic analysis. Cubs of various ages (COY, yearlings, and > yearlings) were observed, meaning successful reproduction to the weaning stage of black bear cubs occurs within the park; lack of data for previous years prevents further analysis.

Sex Ratios

Sex could not be determined for almost 73% (110 bears) of the black bears observed in the 2010 survey; 28 of the 40 bears identified to sex were females, a rate of 70% sows. However, sex determinations are largely based on cub presence and therefore do not accurately represent black bear sex ratios within LACL. Mark and recapture studies would be needed to accurately define this measure.

Female Survival

At the time of publication, there were no quantitative data regarding female black bear survival rates in LACL. The inclusion of female survival rates in the SWAN annual surveys and monitoring programs will allow this measure to be assessed in the future. Female survival data are helpful in indicating black bear condition in the park.

Threats and Stressor Factors

Sport and Subsistence Hunting/Defense of Life and Property Kills (DLP)

Sport and subsistence hunting within LACL are authorized in sections 201 and 203 of ANILCA (Haertel 1984). Only subsistence hunting for black bears is permitted within the park portion of LACL; however, both sport and subsistence harvest of bears is legal, subject to state and federal regulations, within the preserve portion of LACL (Haertel 1984). Black bear hunting is open year round with a bag limit of three bears per regulatory year (ADF&G 2013). The portion of LACL within GMU 9B receives a majority of the hunting pressure for caribou, moose and brown bears; harvest of black bears often occurs as the opportunity arises. A long season and generous bag limits have been contributors to a continued rise in black bear hunting participants (ADF&G 2008b). Harvest permits are not issued for black bears, therefore no reporting of a kill is necessary and little data regarding harvest within LACL has been compiled. However, some black bear harvests are reported for GMU's with a portion of their extents within LACL (Table 46, ADF&G 2008b). Generally only one DLP kill occurs annually within LACL; at least three have taken place over the past 5 years, the most recent being in August 2013 (Mangipane, personal communication, 30 July 2013). Undoubtedly, some bears killed in a DLP situation end up being reported as sport or subsistence harvest so exact numbers are unknown.

Table 46. 2001 to 2007 reported black bear harvests within GMU's 16 and 17 (ADF&G 2008b). The average boar and sow size field is recorded utilizing skull measurements.

Regulatory Year	GMU	Sow Harvest	Boar Harvest	Average Sow Size (in)	Average Boar Size (in)	Total Harvest
2001-2003	16	*		*	*	197
2004-2006	16	28%	72%	*	*	415
2006-2007	16B only	*	*	*	*	>225
1994-1995	17	7(54%)	6(46%)	*	*	13
1995-1996	17	5(38%)	13(62%)	*	*	18
1996-1997	17	6(23%)	19(77%)	*	*	25
1997-1998	17	6(33%)	12(77%)	*	*	18
1998-1999	17	12(41%)	17(69%)	*	*	29
1999-2000	17	4(20%)	16(80%)	*	*	20
2000-2001	17	2(20%)	8(80%)	*	*	10
2001-2002	17	1(11%)	8(89%)	*	*	9
2002-2003	17	4(50%)	4(50%)	*	*	8
2003-2004	17	6(46%)	7(54%)	*	*	13

Table 46 (continued). 2001 to 2007 reported black bear harvests within GMU's 16 and 17 (ADF&G 2008b). The average boar and sow size field is recorded utilizing skull measurements.

Regulatory Year	GMU	Sow Harvest	Boar Harvest	Average Sow Size (in)	Average Boar Size (in)	Total Harvest
2004-2005	17	8(38%)	13(62%)	*	*	21
2005-2006	17	1(14%)	6(86%)	18	18.3	7
2006-2007	17	5(36%)	9(64%)	17	18.6	14

Human Habituation

Human habituation may pose a problem to the safety and wellbeing of bears and humans alike. When a bear's overt reaction distance (ORD) decreases (the distance at which a bear will avoid or flee humans), the likelihood of bear-human interaction increases. Bears and people come into contact with each other most commonly within LACL during the activities of hiking, camping and fishing. These encounters between bears and humans have the potential to cause stress on individual bears.

Salmon Escapement

The coastal tributaries of LACL support strong salmon runs. However, when poor runs occur in some or many of these tributaries, black bears that rely on this resource to put on fat reserves before denning could become stressed. Slower reproductive rates can occur following poor salmon years, as nutritionally stressed females produce fewer and less fit cubs (Hilderbrand et al. 1999).

Data Needs/Gaps

Data gaps exist within the NPS (2013) coastal bear survey dataset, most notably the absence of bear counts for all of 2006, July 2007, and July 2010. Adverse weather conditions and lack of sufficient funding to perform the survey are the primary reasons for these gaps. Consistency regarding the coastal survey data could be beneficial in the assessment of population dynamics and overall health of LACL black bear populations and resources (Mangipane, personal communication, 30 July 2013).

Aerial surveys to estimate black bear population size are identified as an accurate measure of the resource, but are difficult to implement. The surveys must be conducted in the spring after bears emerge from their dens, but prior to vegetation leaf-out. This is a short period of time that varies temporally among years which makes planning difficult. Additionally, weather conditions must allow for safe low level flying to meet the requirements of the survey technique.

Overall Condition

Summary

Quantitative data defining population size and density, recruitment, sex-ratios, and female survival that would enable explicit conclusions regarding condition of these measures do not exist for this component; the *Significance Level* for all measures was 3. Lack of sufficient data regarding this resource prevent the ability to accurately assign *Condition Levels* to the preceding measures. However, the absence of literature expressing concern for the resource and anecdotal observations from park staff indicate that black bears are currently stable within LACL.

Black Bears			
Measures	**Significance Level**	**Condition Level**	**WCS = N/A**
Population Size/Density	3	n/a	
Recruitment through Cohorts	3	n/a	
Sex Ratios	3	n/a	
Female Survival	3	n/a	

4.4.6 Sources of Expertise

Buck Mangipane, LACL Wildlife Biologist

Jeff Shearer, LACL Chief of Natural Resources

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4.5 Dall's Sheep

4.5.1 Description

Dall's sheep (*Ovis dalli dalli*) inhabit mountain ranges farther north than all members of the closely related bighorn sheep (*Ovis canadensis*), and are a prominent mammal species in LACL. The protection of Dall's sheep and the unique habitat in which they reside was part of the grounds for the establishment of LACL: "… to protect habitats for and populations of fish and wildlife, including, but not limited to caribou, Dall's sheep, brown/grizzly bears, bald eagles, and peregrine falcons" (Haertel 1984, p. 2).



Photo 12. Members of a ram band in LACL (NPS photo).

Adult males (rams) rarely exceed 135 kg (300 lbs) and adult females (ewes) average 68 kg (150 lbs). Mature Dall's sheep rams have massive horns. Horn measurements of the top 25 trophy rams ever harvested average basal circumferences of 37.6 cm (14.4 in) and lengths of 112 cm (44 in) (Photo 12), which upon reaching a full curl or beyond, flare away from the cheeks, a characteristic unique to the species (Krausman and Bowyer 2003). Distinct annual rings are laid down across the horns each successive year of growth and can be used to approximate ram age. By the time rams reach 8 years of age, almost all have "full curl" horns. Ewes also grow horns, although they are much shorter and thinner in comparison (Krausman and Bowyer 2003).

Dall's sheep ewes reach sexual maturity around 18 months of age, although ewes rarely breed this early and are generally 3 years old before having their first lamb. Typically one lamb is born between May and early June each year. Rams are often 7 or 8 years old before participating in mating rituals including the chasing of a female in heat, the formation of a tending bond, and subsequent guarding and copulation of the tended female (Krausman and Bowyer 2003).

Contemporary Dall's sheep populations inhabit the same mountain ranges in Alaska, the Northwest Territories, the Yukon, and British Columbia where they were historically known to reside, unlike the bighorn sheep which has seen drastic changes from its historic range. Within LACL, Dall's sheep frequent open alpine areas, steep slopes with rugged "escape" terrain, and high meadows (Olson 2008). The entire population of Dall's sheep in LACL occurs on the western side of the mountain divide; coastal climate influence on the eastern slopes, primarily in the form of heavier winter snows, is the most likely cause for this distribution (Bennett and Terenzi 1997). Dall's sheep within LACL represent the southwestern-most population of sheep in Alaska. The diet of Dall's sheep in the summer months is extremely diverse, as food is abundant in the park. Typical items include meadow grasses and sedges, although forage varies greatly between populations and mountain ranges. Exposed sedges and meadow grasses are typically consumed in winter, although some populations persist on lichens and moss (Olson 2008). Dall's sheep reside year round in LACL, as they migrate between spring, summer, winter, and lambing areas (Olson 2008). Rams and ewes typically separate into groups occupying different seasonal ranges and only intermix at mineral sites and during the

breeding season (November through December). Young rams under 4 years of age are usually tolerated in ewe bands, and will often leave ewe bands to join ram bands when the two converge at mineral sites; movements of this nature are also observed to a lesser degree after winter (Mangipane, personal communication, 30 July 2013). Within LACL, sheep will travel extensively, often several kilometers (typically in the spring) to reach natural mineral licks. Ram home ranges within the park were determined to be larger at 156.5 ± 17.5 km^2 (60 ± 6.8 mi^2) but not significantly different than ewe home ranges of 121.3 ±22.5 km^2 (46.8 ± 8.7 mi^2) (NPS 2008).

4.5.2 Measures

- Population size
- Population density
- Lamb-ewe ratios
- Sex ratios
- Ram composition
- Survival data

4.5.3 Reference Conditions/Values

The defined lamb:ewe ratio to maintain a stable Dall's sheep population is 27 lambs:100 ewes, with a range of 20-34 lambs (Heimer and Watson 1986). This reference condition provides the benchmark for comparison regarding the health of the Dall's sheep population within LACL. Reference conditions for the remaining measures discussed in this document have not been determined.

4.5.4 Data and Methods

Troyer (1979) conducted the park's first Dall's sheep survey in 1978 and 1979, 2 years before LACL was designated as a National Park and Preserve (1980). These surveys utilized Citabria and Piper Supercub aircraft, and surveyed the extreme and rugged terrain in the LACL area; weather and terrain limited the success of these early surveys.

In 1981, Singer and Lovaas (1981) delineated six sheep survey units in an effort to more accurately determine the Dall's sheep population of LACL (Plate 20). From 1981-1990, the six sheep survey units were surveyed five times (Singer and Lovaas 1981, Adams 1986), although not all units were surveyed during each aerial survey (Putera and Mangipane 2004).

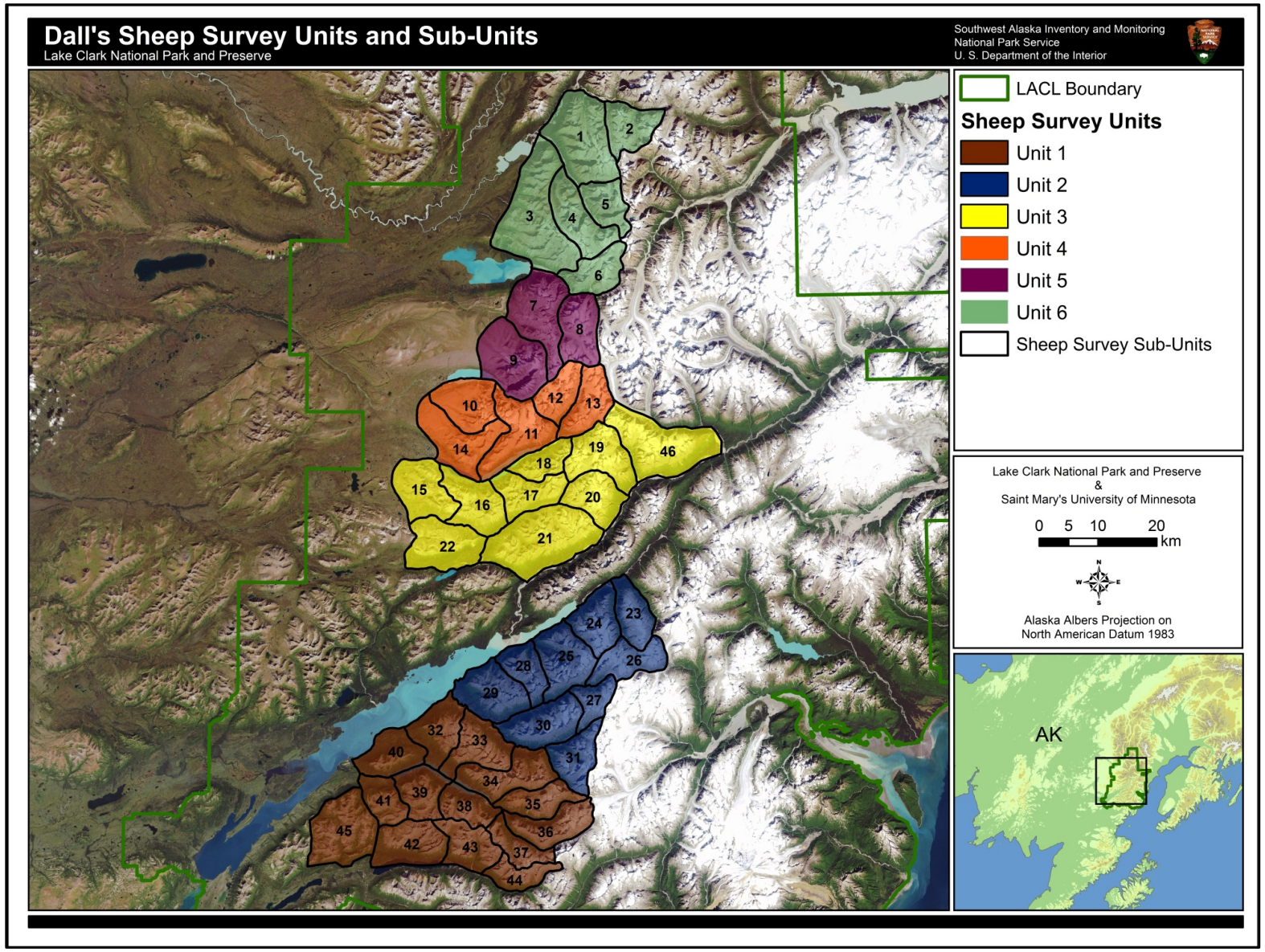


Plate 20. Dall's sheep survey units and sub-units (Bennett 1992).

Portions of the six individual survey units overlapped state-defined GMU's, and problems arose as sheep population data collected within these sheep survey units were used to define specific ADF&G GMU regulations. Data specific for each unit were required so that each GMU (often with variable regulations regarding harvest goals or legal ram size) could set harvest regulations to coincide with management goals (Bennett and Terenzi 1997). Bennett (1992) alleviated this problem by creating 44 survey subunits ranging from 32 to 145 km^2 (12.5 to 56.2mi^2) which do not intersect GMU boundaries. Bennett (1992, 1995) also estimated the LACL sheep population using stratified random sampling techniques; the 44 subunits were stratified based on density values obtained in previous surveys and a random sample of the subunits from each stratum were surveyed.

Putera and Mangipane (2004) report survey results from 2003 and 2004 regarding LACL Dall's sheep population dynamics, seasonal distribution, and sightability utilizing a double count method where the survey extent was first flown by fixed wing aircraft and then by helicopter. The helicopter counts determined sightability differences attributed to season, weather, observers, and aircraft.

NPS (2004) provides a summary of methods, surveyed sheep units, and results in Excel spreadsheet form regarding the survey of Dall's sheep within LACL for 13 survey years between 1978 and 2004 (Appendix WW). Beginning in 1997, ground surveys of three mineral lick sites, located in Sheep Canyon, Emerson Creek Valley, and Holey Mountain were conducted utilizing 8X binoculars and 15X60 spotting scopes. Mineral lick surveys were conducted at a distance of less than 100 m (320 ft) during the last two weeks of June. This survey data added to the integrity of the LACL sheep census by providing more precise data regarding the classification of lambs, ewes, rams, ram composition, and lamb:ewe ratios (Bennett and Terenzi 1997).

NPS (2008) provides a summary of home range and survival data on Dall sheep within LACL utilizing global positioning system (GPS) radio collars which provide an update on location every 5 to 7 hours. In total, 40 sheep were captured, radio collared, and released between 2005 and 2007.

4.5.5 Current Condition and Trend

Population Size

The entire population of Dall's sheep in LACL occurs on the western side of the mountain divide; coastal climate influence on the eastern slopes, primarily in the form of heavier winter snows, is the most likely cause for this distribution (Bennett and Terenzi 1997). Dall's sheep within LACL represent the southwestern-most population of sheep in Alaska. Generating an accurate population assessment of Dall's sheep is difficult due to natural annual fluctuations in numbers, volatile weather conditions over sheep ranges, and the steep, often in accessible mountainous terrain where sheep reside. Troyer (1979) regarded LACL as the most challenging terrain that the researchers had ever surveyed for Dall's sheep. Heimer (1995) explains that Dall's sheep population numbers can vary widely by 20-25% from year to year and that these variations can be independent of long-term population trend. Over time, annual composition counts document the range of annual variation in productivity and survival for sheep at LACL. Surveys to estimate sheep populations within LACL have been conducted intermittently from 1978 to 2012. However, only six of the 13 total survey years provide an estimate of the park-wide population by including the entire sheep range within

LACL (Table 47); other years include only portions of this range (Appendix WW, XX, YY, and ZZ). Sheep survey years including only a portion of the sheep's range are generally driven by specific management concerns and often include only survey units 1 and 2, as these are the units where subsistence hunting is allowed (Appendix YY and Appendix ZZ). Park-wide population estimates are displayed in Table 47, and although sporadic, provide a benchmark for comparison for future park-wide population explorations and also for the most recent park-wide survey in 2012.

Table 47. Dall's sheep population estimates for LACL (NPS 2013).

Year	Population Estimate
1978-79	521
1981	805
1987	1088
1992	520
1995	680
2012	1010
Average	771

Population estimates have ranged from a low of 521 in 1978-79 to a high of 1088 in 1987 (NPS 2013). This variation is likely due to the variability in survey effort rather than actual population fluctuations. The average population estimate across all survey years was calculated at 771 sheep, which may be considered a rough estimate of the park-wide Dall's sheep population (Table 47). The largest population estimate for an individual survey unit was 333 sheep, recorded in 1981 within unit 4. (Appendix XX). The most recent park-wide survey was conducted in 2012 and estimated 1,010 sheep, a value similar to the highest park-wide population estimate ever recorded.

Population Density

The most recent estimate of Dall's sheep density was calculated over the entire extent of the known range that Dall's sheep occupy in LACL and was estimated to be 0.22 sheep per mi^2 (NPS 2013). Prior to the NPS (2013) estimate, previous densities were calculated for various units during survey years 1978-79, 1981, 1984, 1985, 2003, and 2004 (Table 48). Along with reporting the highest estimated sheep population for an individual survey unit, unit 4 also reported the highest sheep densities (Table 48).

Table 48. Dall's sheep population density (sheep per mi^2) in LACL sheep survey units (NPS 2013).

Count Unit	Area (mi^2)	1978-79	1981	1984	1985	2003[A]	2004	2012
1	320	0.15	0.15	0.57	0.21	0.55	0.54	*
2	300	0.33	0.19	*	0.26	0.31	0.31	*
3	250	0.51	0.62	*	*	*	*	*
5	120	0.61	1.03	*	0.36	*	*	*
6	230	0.09	0.38	*	0.16	*	*	*
LACL Density	*	*	*	*	*	*	*	**0.22**

* Denotes that Dall's sheep densities are not available for that year.

A - Densities were computed using the average of the total population of the two surveys conducted in 2003.

Lamb-Ewe Ratios

Recruitment data provides the benchmark for analysis regarding the health of the Dall's sheep population, as well as the reference condition for this resource within LACL. The accepted ewe to lamb ratio in order to maintain a stable Dall's sheep population within LACL is 27 lambs:100 ewes, with a range of 20-34 lambs:100 ewes (Heimer and Watson 1986). Lamb to ewe ratios have never been estimated below 20 lambs:100 ewes (the low end of the range to maintain a stable population) during any sheep survey years from 1978 to 2012 (Table 49, Appendix XX -Appendix ZZ). However, the survey in 1990, 2003, and the most recent surveys in 2004 and 2012, all reported a ratio below the recommended 27 lambs:100 ewes (NPS 2013).

Dall's sheep observations conducted from the ground around known mineral lick sites within LACL (Sheep Canyon, Emerson Creek, and Fall Mountain/Twin Lakes) also provide data regarding recruitment (Table 50; Mangipane and Putera 2005). The ratio of lambs:100 ewes was well above the recommended threshold to maintain a stable Dall's sheep population for almost all survey years. The only exception was the 1999 survey in Sheep Canyon which recorded only 18 lambs:100 ewes (Appendix AAA). Mineral lick sites are particularly useful when analyzing recruitment, as ewes and lambs have a much higher affinity to natural mineral licks than rams (Mangipane and Putera 2005); total rams visiting a mineral lick site was never observed to be higher than total ewes (Appendix AAA).

Table 49. Dall's sheep aerial recruitment data within LACL (NPS 2013).

Year	Lambs:100 Ewes
1978-79[C]	47
1981[C]	45
1984[D]	53
1985[D]	37
1987[C]	58
1990[D]	26
1992[D]	55
1995[C]	27
2003[A D]	33
2003[B D]	24
2004[D]	22
2012[C]	24

A - Based on the fixed wing survey completed between 6/13/03-6/20/03

B - Based on the fixed wing survey completed between 8/02/03-8/04/03

C - Represents a park wide survey year, ratios are lambs:ewe-like sheep

D - Only portions of the park were surveyed

Table 50. Dall's sheep mineral lick observation data regarding recruitment within LACL (Mangipane and Putera 2005).

Year	Lambs	Yearlings	Ewes	Lamb:100 Ewe Ratio
1993	7	3	23	30
1994	12	3	22	55
1997	14	8	38	37
1999	3	5	12	25
2003*	42	15	70	60

* - Only portions of the park were surveyed

Sex Ratios

For the sake of comparison, sex ratios were averaged for surveys conducted both before and after 1990. An average of 55 rams:100 ewes were counted before 1990 compared to 54 rams:100 ewes after 1990 (Table 51).

Table 51. Dall's sheep sex ratios between 1981 and 2010 (NPS 2013).

Year	Rams:100 Ewes
1981[C]	51
1984[D]	38
1985[D]	90
1987[C]	62
1990[D]	35
Average 81-90	**55**
1992[D]	55
1995[C]	37
2003[A D]	45
2003[B D]	69
2004[D]	47
2012[C]	68
Average 92-2012	**54**

A - Based on the fixed wing survey completed between 6/13/03-6/20/03

B - Based on the fixed wing survey completed between 8/02/03-8/04/03

C - Represents a park wide survey year

D - Only portions of the park were surveyed

Ram Composition

Ram composition data is most notably utilized by ADF&G to set harvest regulations for sport hunting throughout GMUs, and to verify that the current regulations in place are not adversely affecting the ram composition of an area. Liberal hunting regulations can cause mature ram numbers (rams near or exceeding a full curl) to be dramatically smaller than other ram classes. Aerial surveys between 1981 and 2010 reported percent of rams at curl length and unclassified rams (Table 52; NPS 2013).

The percent of rams with a ¾ curl and full curl prior to 1990 was 33% and 32%, respectively. The percent of rams with a ¾ curl and full curl from 1992-2004 was noticeably lower at 20% and 25% of the total ram population, respectively (NPS 2013; Table 52). The most recent survey in 2012 only defined rams as having less than a full curl or a full curl or greater; these values were reported as 283 and 70, respectively (Mangipane, personal communication, 30 July 2013). A discrepancy in the distribution of rams between the park and preserve areas is apparent (Plate 21). Surveys during August 2003 and June 2004 reported 22 and 11 full curl rams within the park area, compared with two and four full curl rams in the preserve area (NPS 2013; Table 53, Table 54). However, these data, as with all data collected on Dall's sheep within LACL, are tough to compare and draw solid conclusions from as different extents were surveyed each year, some covering all of LACL while

others include only units of management concern. If a skewed distribution of rams does exist, as this disjointed data implies, the likely cause is that more preferred habitat is found within the park portion of LACL.

Table 52. Dall's sheep ram composition between 1981 and 2010 (NPS 2013).

Year	Rams 1/4 Curl (%)	Rams 1/2 Curl (%)	Rams 3/4 Curl (%)	Rams Full Curl (%)	Unclassified Rams
1981[D]	15	27	28	42	-
1984[E]	9	13	41	38	-
1985[E]	16	17	38	29	-
1987[D]	24	19	19	36	-
1990[E]	31	12	41	16	-
Average 81-90	**19.00**	**17.60**	**33.40**	**32.20**	**-**
1992[E]	21	26	23	30	-
1995[D]	19	25	21	34	-
2003[A C E]	6	20	24	21	0
2003[B C E]	8	14	22	24	22
2004[E]	5	19	13	15	8
Average 92-2004[C]	**13.00**	**21.75**	**20.00**	**25.40**	**-**

A - Based on the fixed wing survey completed between 6/13/03-6/20/03

B - Based on the fixed wing survey completed between 8/02/03-8/04/03

C - The two values from 2003 were averaged together, and that value was used to calculate the 1992-2004 average.

D- Represents a park-wide survey year

E - Only portions of the park were surveyed

Table 53. Ram distribution in the park area of LACL (NPS 2013).

Year	Area	Sheep Groups	Total Sheep	Total Rams	Total Full Curl Rams	% Full Curl Rams
June 2003	Park	38	221	57	18	32
August 2003	Park	55	219	79	22	28
June 2004	Park	48	182	55	11	20

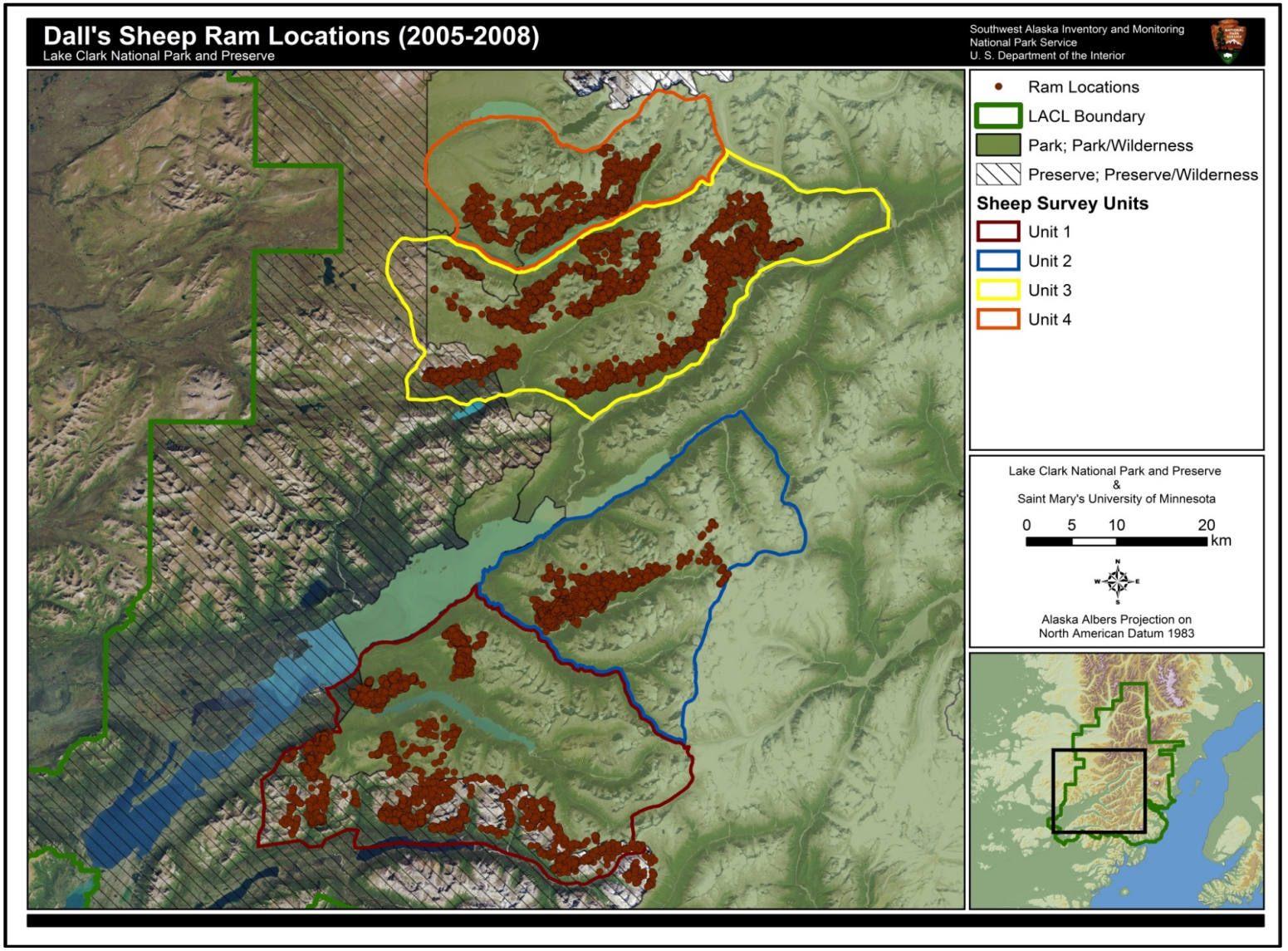


Plate 21. Ram locations within the park and preserve areas of LACL. Ram preference to the park and park/wilderness area is considered to be driven by prefered habitat and survey extent, not regulation or management differences between the two areas.

Table 54. Ram distribution in the preserve area of LACL (NPS 2013).

Year	Area	Sheep Groups	Total Sheep	Total Rams	Total Full Curl Rams	% Full Curl Rams
June 2003	Preserve	11	74	15	3	20
August 2003	Preserve	13	45	12	2	17
June 2004	Preserve	17	91	15	4	27

Survival Data

Forty Dall's sheep (26 ewes and 14 rams) were captured, radio collared (GPS radio collars returned sheep locations every 5 to 7 hours), and released between 2005 and 2007 in an effort to determine home ranges and survival within LACL (NPS 2008). Ewes captured and released averaged 6.4 years of age, while the average age of captured and released rams was 5.6 years (NPS 2008). During the study, 14 mortalities were observed with a spike of nine mortalities occurring in April and May (NPS 2008). Survival was calculated utilizing the Kaplan-Meier method where the total number of individuals surviving through the duration of the study is divided by the total number of individuals studied (NPS 2008). Ewe survival (± SE) from 2005-2006, 2006-2007, and 2007-2008 was 0.95 ± 0.04, 0.76 ± 0.08, and 0.85 ± 0.08, respectively. In the same time frame, ram survival was slightly lower at 0.83 ± 0.11, 0.74 ± 0.13, and 0.82 ± 0.12, respectively (NPS 2008). Differential survival rates favoring ewes are the norm for Dall's sheep populations, both hunted and non-hunted. The likely cause of this is related to the fact that rams expend more energy during the breeding season, although documentation regarding this matter is absent (Mangipane, personal communication, 30 July 2013).

Threats and Stressor Factors

Dall's Sheep Harvest

Subsistence hunting within the park and preserve portions of LACL and sport hunting within the preserve area are allowed in accordance with ADF&G regulations. Historic liberal hunting regulations across other Dall's sheep ranges allowed for the harvest of rams ¾ curl or larger. This historic regulation, coupled with too many harvest permits has severely impacted the natural composition of rams in a population to the point of almost complete extirpation of mature rams (Whitten 2001). Currently, rams within LACL must have horns with a full curl or larger, or be at least 8 years of age to be considered legal for harvest with a sport permit (Mangipane and Putera 2005). Rams with a 7/8 curl or larger are legal for harvest utilizing a subsistence permit; ewes are not permitted to be harvested (Mangipane and Putera 2005). Currently, five rams can be harvested in the summer/fall subsistence season and two rams during the winter subsistence season. Once these quotas are met, subsistence seasons are closed. Rule changes were proposed by the Lake Clark Subsistence Resource Commission (but not adopted by the Federal Subsistence Board) in the mid-2000s to allow for a quota of ewes and rams of any age to be harvested. If care is not taken to determine and adopt a sustainable quota for sheep harvest, the Dall's sheep population within LACL could decrease. Over 700 residents living within the boundary of LACL qualify for Dall's sheep

subsistence permits. However, the contemporary and historic reported harvest of Dall's sheep within LACL has been low between 1983 and 2011 (Table 55, NPS 2013).

Table 55. Total reported Dall's sheep harvest by sport and subsistence means within LACL (NPS 2013).

Year	Permits Issued	Total Sheep Harvest	Year	Permits Issued	Total Sheep Harvest
1983	--	3	1998	--	4
1984	--	2	1999	--	4
1985	--	0	2000	--	2
1986	--	3	2001	--	1
1987	--	3	2002	--	2
1988	--	2	2003	--	1
1989	--	4	2004	15	6
1990	--	1	2005	8	--
1991	--	2	2006	6	--
1992	--	1	2007	3	--
1993	--	0	2008	7	--
1994	--	3	2009	11	4
1995	--	3	2010	4	--
1996	--	5	2011	13	--
1997	--	5	--	--	--

Climate/Vegetation Change

Climatic changes have the potential to alter the vegetation communities across the higher elevations at which Dall's sheep reside. Pfeifer et al. (2012) reported a noticeable change in the diet of sheep in both Denali National Park and the Wood River area of Alaska between 2007 and 2008. During this time, consumption of sedges, shrubs, and rushes declined greatly. Temperature and precipitation changes are the most likely factors causing a change in the available browse items for Dall's sheep. Mangipane (pers. comm., 2013) indicates that NPS funding exists for an upcoming project which may answer some questions regarding the potential for Dall's sheep habitat to change in the future. The project will utilize existing GPS collar data to create a habitat use model; various climate change scenarios will then be applied in an effort to project how these preferred sheep habitat areas could change.

Data Needs/Gaps

NPS survey methods and goals indicate the desire to survey Dall's sheep within LACL every 3 to 4 years. Thirteen aerial Dall's sheep surveys have been conducted in the park between 1978 and 2012. However, sizable gaps exist within the dataset; there are several years where sheep surveys were not

conducted, most notably between 1995 and 2002. Furthermore, only six surveys from 1978-79 to 2012 covered the entire extent of the Dall's sheep range within LACL. All other surveys covered only portions of sheep ranges with management concerns (NPS 2004). Survey gaps can be attributed to many factors, including funding, availability of aerial survey equipment, and volatile weather creating difficult flying conditions (Bennett and Terenzi 1997). Efforts for each year are also inconsistent with regards to the number of units and total area covered during each sheep survey. These data gaps, coupled with the natural tendency of Dall's sheep populations to fluctuate widely, make statements regarding trends in population parameters difficult or impossible to make. To accurately define trends and current condition for the Dall's sheep population within LACL survey areas, survey techniques and temporal intervals between surveys should be consistent. LACL park staff is hopeful that the methodology of the most recent survey in 2012 will become the standard for future Dall's sheep surveys within LACL every three to five years (Mangipane, personal communication, 30 July 2013).

Overall Condition

Population Size

LACL staff assigned a *Significance Level* of 2 for this measure. Natural fluctuations (20-25%) in Dall's sheep numbers between subsequent years is not uncommon. These fluctuations make assessing the current condition of population size in LACL difficult. Annual surveys have not been completed in LACL, and data from the available surveys are of varying extents and methods. Park-wide population estimates were completed for six years between 1978-79 and 2012, reporting an average Dall's sheep population within LACL of 771 sheep during these survey years (Table 47). The most recent park-wide survey was conducted in 2012 and estimated 1,010 sheep, a value similar to the highest park-wide population estimation ever recorded. Even though limited population size data, especially contemporary data exist, the *Condition Level* for this measure is a 1, indicating low concern. This value was assigned based upon the most recent park-wide survey in 2012 and anecdotal observations from park staff.

Population Density

The *Significance Level* for the population density measure is 2. Data regarding sheep densities within LACL are minimal. Units 1 and 2 are categorized as having low sheep densities, while the highest sheep densities within LACL occur in unit 4, which has consistently recorded higher densities than any other survey unit. Even though limited population density data exist, especially contemporary data, the *Condition Level* for this measure is a 1. This value was assigned based upon the most recent park-wide survey in 2012 and anecdotal observations from park staff, which feel this measure likely tracks with the population size metric and is expected to be of similar condition.

Lamb-Ewe Ratios

The *Significance Level* for the lamb-ewe ratio measure is 2. Aerial survey data and observations from mineral lick locations are the most useful data sources when describing the recruitment of Dall's sheep within LACL. Mineral lick observations in 1999 recorded 18 lambs:100 ewes, representing the only survey to record a ratio below the threshold recommended to maintain a stable Dall's sheep population (27 lambs: 100 ewes, with a range of 20-34 lambs). Aerial survey data has never recorded

a lamb:100 ewe ratio that was below the threshold needed to support a stable Dall's sheep population. The ratio of lambs:100 ewes is above the reference condition of this measure for a majority of the survey years. The most recent park-wide estimate from 2012 of 24 lambs:100 ewes is slightly below the threshold, but within the range of the reference condition. A 2013 survey of the higher density areas within units one and two report a 29 lambs:100 ewes ratio, a ratio which falls in the upper range of the reference condition. Data, as well as anecdotal reference provided by park staff regarding the lamb:ewe ratio within LACL, suggests a stable population. Therefore, this measure is assigned a *Condition Level* of 1 (low concern).

Sex Ratios

The *Significance Level* for the sex ratios measure is 2. A decrease of 4 rams/100 ewes was observed between surveys completed before 1990 (average of 55 rams:100 ewes) and those completed after 1990 (average of 51 rams:100 ewes). Considering the difficulties of performing Dall's sheep surveys, these values are very similar and indicate that ram:100 ewe ratios have been fairly consistent across all survey years. Mangipane (personal communication, 30 July 2013) indicates that these ratios fall within accepted levels for population stability. *Condition Level* for this measure was assigned at 1.

Ram Composition

The *Significance Level* for the ram composition measure is 3. All ram classes, as well as the ratio of rams:100 ewes, showed a decrease when data before and after 1990 were compared. This decrease is of most concern regarding the class of ¾ and full curl rams, which decreased by 13% and 7%, respectively (NPS 2013). Full curl rams are an important resource for wildlife viewing, sport hunting, and subsistence hunting within LACL. Rams in general and rams of greater size are more likely to be found within the park area of LACL. This trend is also observed in the overall sheep population, and is most likely a product of preferred habitat within the park area and not regulation of activities. Since anecdotal information from park staff and survey data indicate that ram composition is stable within LACL, this measure is assigned a *Condition Level* of 1.

Survival Data

The *Significance Level* for the survival measure is 2. Rams have a lower survival rate and larger home ranges in comparison to ewes; home range differences between sexes were not significantly different and therefore do not explain the slightly higher mortality rate. Anecdotal information from park staff and survey data indicate that survival is stable within LACL. Therefore, this measure is assigned a *Condition Level* of 1.

Weighted Condition Score (WCS)

Sufficient quantitative data exist regarding population size, density, composition, and survival (coupled with anecdotal information from park staff) to assess current condition. The absence of literature expressing concern for the resource, survey data, and anecdotal information from park staff indicate that Dall's sheep are currently stable within LACL. The *WCS* for Dall's sheep is 0.33, indicating a low level of concern, only showing signs at this time of limited and isolated degradation. For a detailed explanation of the methodology used to calculate this score, see Chapter 3.

Dall's Sheep			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.33**
Population Size	2	1	
Population Density	2	1	
Lamb-Ewe Ratios	3	1	
Sex Ratios	2	1	
Ram Composition	3	1	
Survival Data	2	1	

4.5.6 Sources of Expertise

Buck Mangipane, LACL Wildlife Biologist

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4.6 Moose

4.6.1 Description



Photo 13. Bull moose (NPS photo).

Moose (*Alces alces*) (Photo 13) are found in the lowlands of LACL. They occupy boreal forests as well as areas of shrub/scrub near the rivers and lake riparian zones (Rausch et al. 2008). Moose are normally associated with northern forests and subarctic climates typical of southwestern Alaska. Moose are solitary mammals and rarely gather in groups except during the mating season. Moose can also be observed in loose aggregations along river corridors during the winter months (Jeff Shearer, LACL Chief of Natural Resources, written communication, 21 January 2014). Females weigh in excess of 363 kg (800 lbs), while males can weigh up to 725 kg (1,600 lbs) and exceed 1.83 m (6 ft) in height at the shoulder (Rausch et al. 2008). Antlers develop on males within the first year of life and grow larger each subsequent summer. Antlers typically develop in three to five months beginning in the spring, and are shed after the fall mating season. The average moose life span is 16 years, although 25-year-old individuals have been reported (Rausch et al. 2008).

Moose are herbivorous, feeding primarily on willow (*Salix* spp.), aspen (*Populus* spp.), aquatic vegetation, and a variety of grasses (Rausch et al. 2008). Moose are most often associated with open low or mixed shrub vegetation classifications near riparian zones. Sexual maturity and breeding occur at about 28 months. Calves are born in the spring, with females typically producing one calf per year. In productive populations, birth of twins can be common, occurring up to 60 percent of the time (Mangipane, written communication, 21 January 2014). During the mating season, sparring occurs between bulls in order to secure mates; injuries are common but rarely serious. Adult moose are generally calm and subdued, although aggressive behavior is displayed by cows with calves when startled, angered, or when offspring are threatened, as well as by bulls during the breeding period (Rausch et al. 2008).

Natural predators in LACL include wolves, black bears, and brown bears. Predation on yearlings or adults weakened by disease or injury is most common (Butler 2010). Subsistence hunting is legal within the national park and national preserve. Sport hunting is permitted within the national preserve (Plate 22) (NPS 2003a).

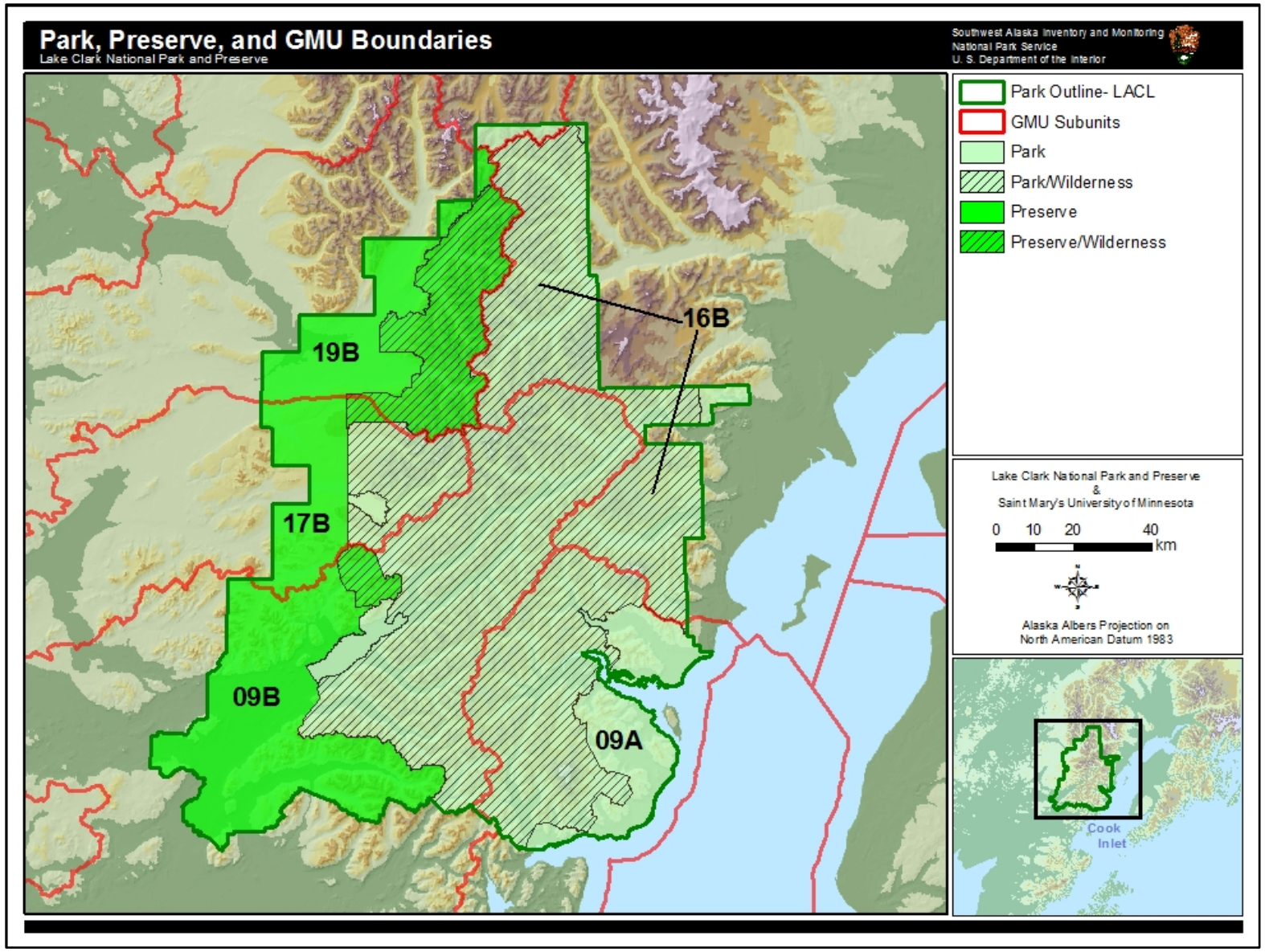


Plate 22. LACL park, preserve, and GMU boundaries.

4.6.2 Measures

- Population Size
- Population Density
- Sex Ratios
- Calf:Cow Ratios
- Bull Composition
- Female Survival

4.6.3 Reference Conditions/Values

According to the NPS's enabling legislation, LACL, like all other NPS managed lands, is to manage animal species in a manner consistent with maintaining a natural and healthy population. NPS policies that support the naturally occurring and healthy population are found in sections 4.4.1 and 4.4.3 of the NPS Management Policies (2006) which state that;

> *The NPS will maintain as parts of the natural ecosystem of parks all plants and animals native to park ecosystems…*
>
> *…preserving and restoring the natural abundances, diversities, dynamics, distributions, habitats, and behaviors of native plant and animal populations and the communities and ecosystems in which they occur…*
>
> *…minimizing human impacts on native plants, animals, populations, communities, and ecosystems, and the processes that sustain them.*
>
> *…the Service* (NPS) *does not engage in activities to reduce the numbers of native species for the purposes of increasing the numbers of harvested species (i.e., predator control), nor does the Service permit others to do so on lands managed by the National Park Service.*

Management of the moose population in LACL is intended to be implemented through the cooperative efforts of the NPS and the ADF&G. However, when the species in question is a harvested or game species, it should be noted that the NPS management policies may not be congruent with local or state wildlife management policies due to differing management objectives.

Currently, quantitative moose population metrics have not been established by the NPS that would define a set of moose population reference conditions (i.e., ranges of natural variability that embody natural and healthy populations). In lieu of NPS established moose population reference conditions, the following section reports population metrics according to ADF&G defined management goals. While the ADF&G defined management goals are discussed below, it is important to recognize that the NPS goals may differ and that management objectives of the ADF&G do not necessarily represent the management objectives of the NPS.

The reference condition utilized by this report for LACL's moose population will be defined by the ADF&G moose management report. ADF&G tracks parameters such as population density, population composition, habitat, and harvest for selected species in each GMU. ADF&G establishes individualized management objectives for moose in each GMU and in many cases for each subunit. ADF&G (2010) defines GMUs across Alaska in an effort to assess regional game populations and define hunting regulations. Portions of five individual GMUs extend over LACL, including units 09A, 09B, 16B south, 17B, and 19B (Plate 22). All five of these units have different moose population management goals and objectives. Table 56 displays the management objectives for each GMU within LACL.

Table 56. Moose management objectives for each GMU within the LACL boundary (ADF&G 2010).

GMU	Population Size	Population Density (moose / km^2 [moose/ mi^2])	Bull: 100 Cow Ratio	Calf: 100 Cow Ratio
09A,B	--	Maintain 0.19 – 0.58 moose/km^2 (0.5 – 1.5 moose/mi^2) and 0.58 – 0.97 moose/km^2 (1.5 – 2.5 moose/mi^2) in areas of moderate and high density, respectively.	25:100 in medium/high density areas	--
		Increase low density areas to 0.19 moose/km^2 (0.5 moose/mi^2)	40: 100 in low density areas	--
16B	6,500 – 7,000	--	20 – 25: 100	--
17B	4,900 – 6,000	0.39 moose/km^2 (1.0 moose/mi^2) in good habitat	--	--
19B	13,500 – 16,500	--	20 – 30:100	30 --40: 100

4.6.4 Data and Methods

Mangipane and Putera (2000) documented movements, survival, and productivity of moose in the Lake Clark Drainage, which is located in GMU 9B of LACL. Cows were radio collared to detect mortalities, estimate sightability during aerial surveys, determine productivity, calculate home ranges, identify and describe migration patterns, and determine survival rates.

NPS (1992 – 2003) estimated moose population parameters from data collected within the three moose survey units in LACL (Plate 23). Data were analyzed using the Gasaway method (Gasaway et al. 1986) for 1992, 1994, 1998, 1999, and 2003. The data were not collected annually from all of the units. Unit 1 data were collected in 1992, unit 2 and unit 3 north had data collected in 1994 and 1999, and unit 3 south data were collected in 1992, 1998, and 2003. The data analyzed included estimated population size, total number of calves, cows, and bulls, occasionally recording total large bulls.

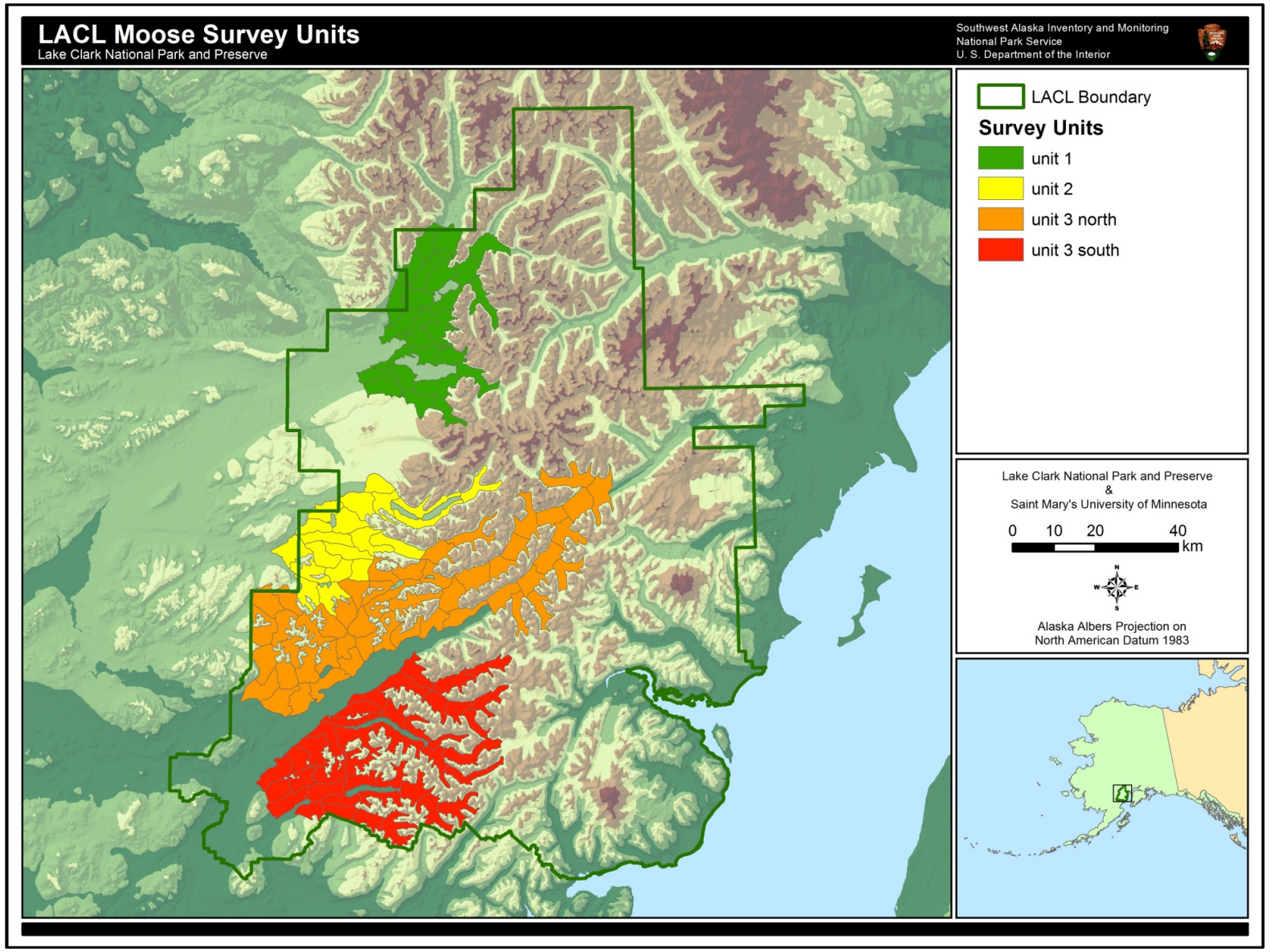


Plate 23. LACL Moose survey units (1, 2, 3 north, 3 south) (NPS 2012).

Beginning in 2003, moose populations were estimated using a LACL-specific sightability model (Putera and Drummer 2005). Unit 3 was split into two sections due to its size. Unit 1 was only surveyed in 2004, 2008, and 2013. Units 2 and 3 north were surveyed in 2005 and 2010, while unit 3 south was surveyed in 2003, 2007, and 2010-11. Several regions were sampled from each unit, and several subunits within those regions were sampled. That is the standard protocol, which gives LACL managers a spatial coverage from within the entire unit and also serves to create a stratified sample as the regions have somewhat different moose densities (Mangipane, written communication, 21 January 2014). Unit one had four regions sampled, including Telaquana River north, Upper Necons River, Trail Creek, and Stony River. There were four regions sampled from units 2 and 3 north. Those four regions were Kijik, Tlikakila, Twin Lakes, and Lachuna. There were five regions surveyed in unit 3 south, including Kontrashibuna, Currant, Upper Tazimina, Lower Lake Clark, and Tanalian – Tazimina. Plate 24 – Plate 26 display the regions within each survey unit.

ADF&G management reports (ADF&G 2008, 2010) provide information on defined population management objectives. These reports establish moose population and composition objectives, as well as monitor temporal trends in population size and composition. ADF&G conducts annual sex and age composition surveys from November through early December, assuming adequate snow cover, for all subunits within GMU 9 (Butler 2010) and GMU 17B (Woolington 2010). GMU 16B is split into three sections (north, middle, south) where various surveys are performed; however, 16B south is the only section that is located within LACL (Peltier 2010). The GMU 19 B report did not address the methods used for estimations (Seavoy 2010). Harvest rates and other sources of mortality are also reported (Butler 2010, Peltier 2010, Seavoy 2010, Woolington 2010).

4.6.5 Current Condition and Trend

Population Size

In the absence of quantitative moose population metrics from the NPS the following section reports population metrics according to ADF&G defined management goals. While the ADF&G defined management goals are discussed below, it is important to recognize that the NPS goals may differ and that management objectives of the ADF&G do not necessarily represent the management objectives of the NPS.

NPS (1992 –2003) found moose population sizes to vary throughout the three survey units within LACL. During this time period, there was only one survey completed in unit 1, two in unit 2/3 north, and three in unit 3 south. Unit 1 had one population estimate of 361 moose from 1992. Unit 2 /3 north were surveyed in 1994 and 1999 with population estimates of 342.5 and 596.6 moose, respectively. There was a decline in moose observations in unit 3 south. The population estimates were 241.3, 229.1, and 148.8 in 1992, 1998, and 2003, respectively. It is important to note that a trend would be difficult to determine with the lack of surveys performed per unit. Table 57 displays population estimates from LACL moose survey units 1, 2 / 3 north, and 3 south between 1992 and 2003.

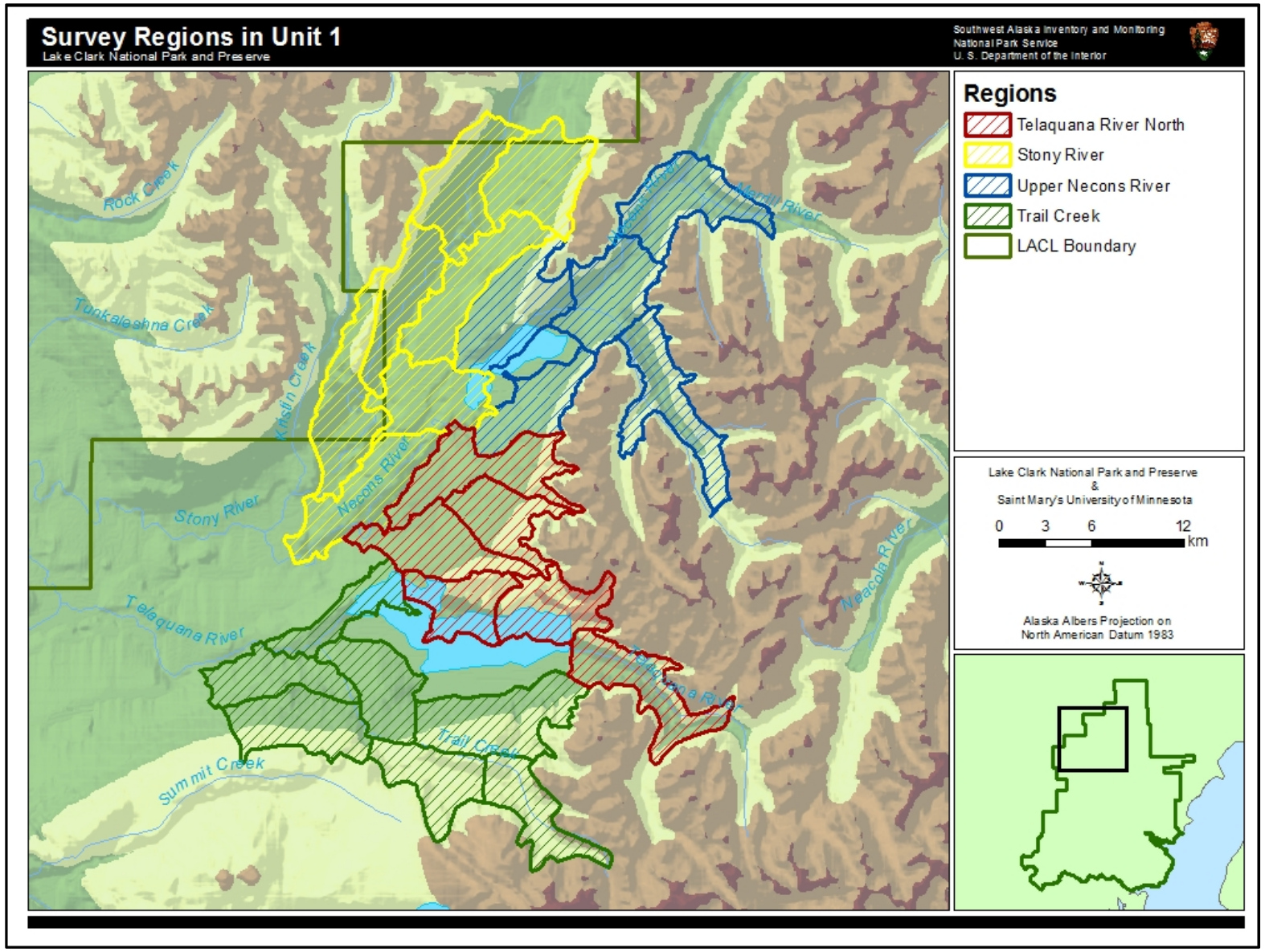


Plate 24. Moose survey unit 1, divided into regions surveyed (NPS 2003 – 2013).

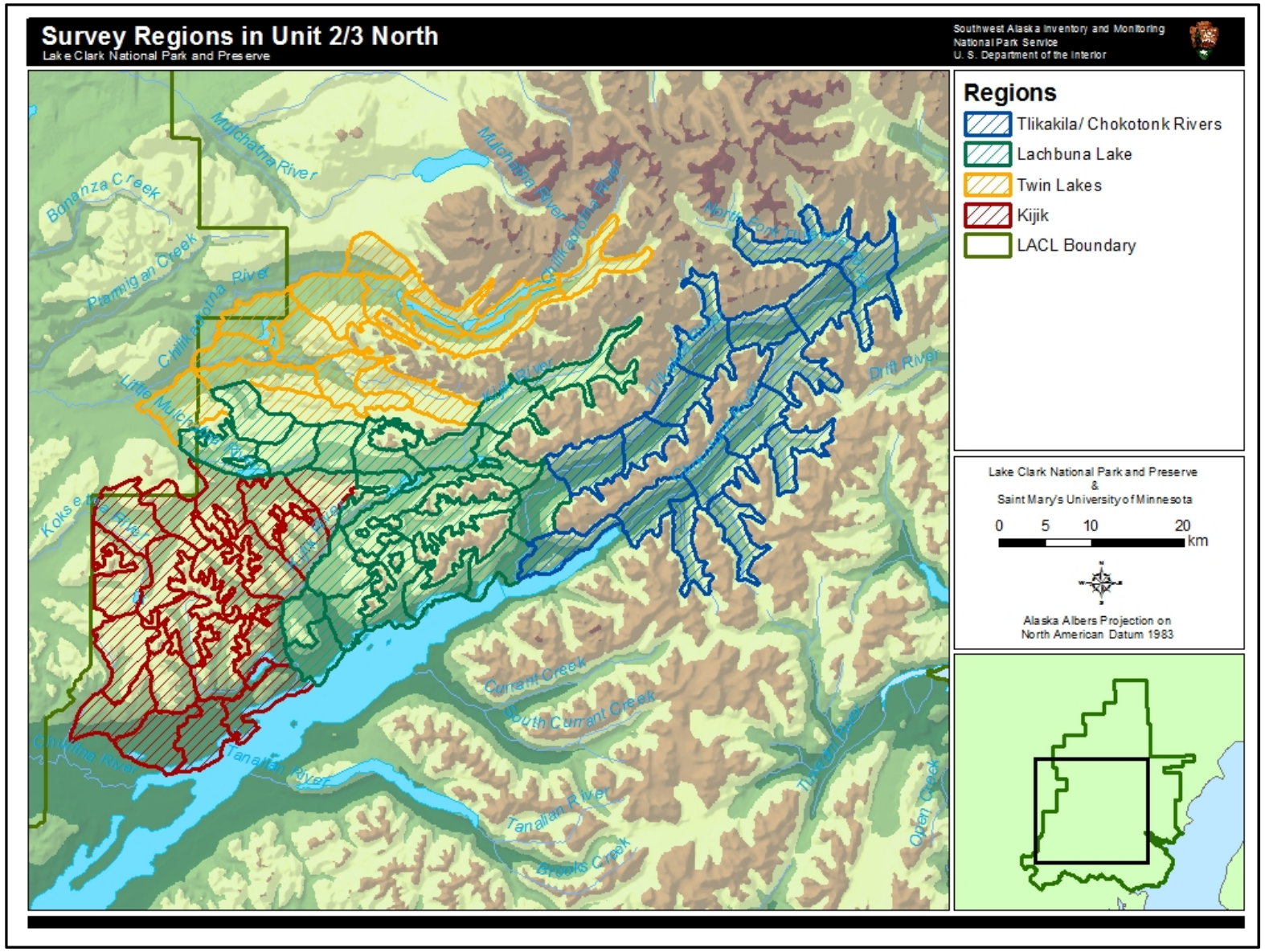


Plate 25. Moose survey units 2 and 3 north, divided into regions surveyed (NPS 2003 – 2013).

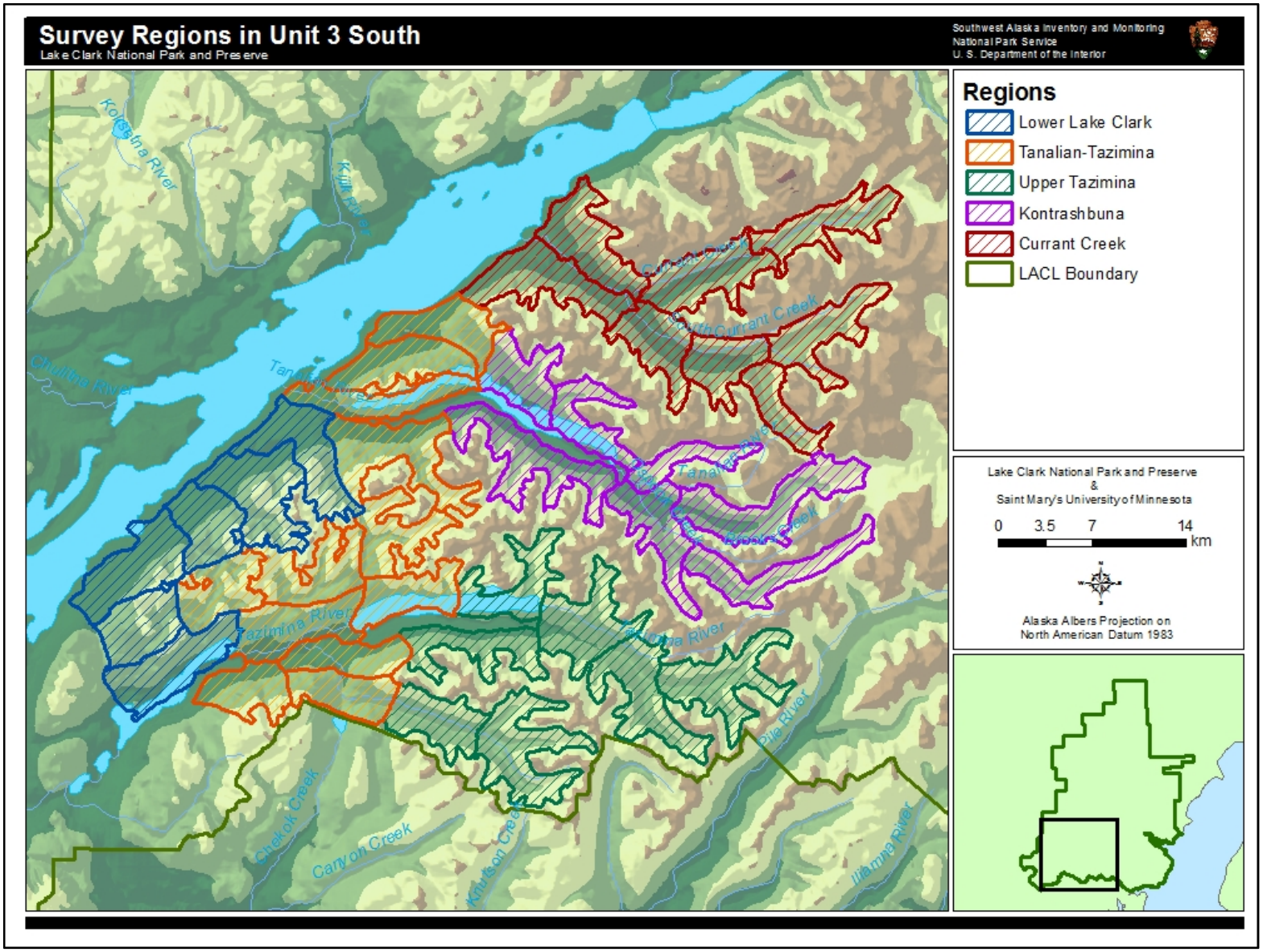


Plate 26. Moose survey unit 3 south, divided into regions surveyed (NPS 2003 – 2013).

Table 57. Moose population estimates taken from the three LACL moose survey units 1, 2/3 north, and 3 south (NPS 1992a,b, 1994a,b, 1998, 1999, 2003b).

Unit(s)	1992	1994	1998	1999	2003
Unit 1	361.0	--	--	--	--
Unit 2 / 3 north	--	342.5	--	596.6	--
Unit 3 south	241.3	--	229.1	--	148.8

NPS (2003 – 2013) recorded ten years of estimated moose totals in the moose survey units. During this study period, unit 1 was surveyed three times, unit 2 / 3 north was surveyed twice, and unit 3 south was surveyed three times. Unit 1 had estimates of 198.8, 133.5, and 145.6 moose in in 2004, 2008, and 2013, respectively. Unit 2/3 north displayed a decrease in moose totals from 2005 to 2010. In 2005, the moose totals were estimated at 383.2 moose then in 2010 the estimate was down to 262.4 moose. Unit 3 south was surveyed at fairly regular intervals. This unit was surveyed in 2003, 2007, and 2010-11. The total moose estimates for unit 3 south were 220, 165.4, and 166.3 moose, respectively. The decrease in moose totals may be a trend; however, it is difficult to assess a trend with data from three years or less. Table 58 displays population estimates from LACL moose survey units 1, 2/3 north, and 3 south between 2003 and 2013.

Table 58. Moose population estimates taken from the three LACL moose survey units 1, 2/3 north, and 3 south (NPS 2003c, 2004, 2005, 2006, 2007, 2008, 2009, 2011a,b, 2013).

Unit(s)	2003	2004	2005	2007	2008	2010-11	2013
Unit 1	--	198.8	--	--	133.5	--	145.6
Unit 2 / 3 north	--	--	383.2	--	--	262.4	--
Unit 3 south	220.0	--	--	165.4	--	166.3*	--

* - Survey conducted over two winters, November 2010 and November-December 2011.

According to ADF&G (Butler 2010), the moose population seems to be declining in parts of GMU 9B that are located in LACL. A population census, taken in 1983, estimated 2,000 moose in unit 9B. The census also made an estimate of 300 moose in unit 9A. A portion of unit 16B south is located in LACL. The most recent population survey for this unit was in 2006 and estimated 960 moose. As a whole, unit 16B had an estimated population of 3,794 – 4,852 moose in 2006 (Peltier 2010). The most recent surveys for unit 17B occurred in 2001, 2002, and 2006; the extrapolated estimates for those years were 1,202, 1,953, and 1,210, respectively. None of these population estimates for unit 17B met management objectives (Woolington 2010). While ADF&G did not document population estimates for unit 19B, Seavoy (2010) states that the moose population in unit 19B has been declining since the 1990s. None of the GMUs had a population estimate that met the management objectives (ADF&G 2010).

Population Density

In the absence of quantitative moose population metrics from the NPS the following section reports population metrics according to ADF&G defined management goals. While the ADF&G defined management goals are discussed below, it is important to recognize that the NPS goals may differ and that management objectives of the ADF&G do not necessarily represent the management objectives of the NPS. It is noted that in 2008, Young and Bortell reported that in lightly hunted and remote areas of Alaska 60-80 bulls: 100 cows were observed.

NPS (1992 – 2003) found moose density to vary throughout the three survey units within LACL. During this time period, there was only one survey completed in unit 1, one in unit 2/3 north, and two in unit 3 south. Unit 1 had a population density of 0.61 moose/km^2 in 1992. Unit 2 and 3 north were surveyed in 1999 with a population density of 0.33 moose/km^2. There was a slight decline observed in unit 3 south. The population densities were 0.24, 0.22, and 0.17 moose/km^2 in 1992, 1998, and 2003, respectively. It is important to note that a trend would be difficult to determine with the lack of surveys performed per unit. Table 59 displays population densities from LACL moose survey units 1, 2 / 3 north, and 3 south between 1992 and 2003.

Table 59. Moose population densities taken from the three LACL moose survey units 1, 2/3 north, and 3 south (NPS 1992a,b, 1994a,b, 1998, 1999, 2003b).

Unit(s)	1992	1994	1998	1999	2003
Unit 1	0.61	--	--	--	--
Unit 2 / 3 north	--	--	--	0.33	--
Unit 3 south	0.24	--	0.22	--	0.17

NPS (2003 – 2013) recorded 10 years of estimated moose densities in the moose survey units. During this study period, unit 1 was surveyed three times, unit 2 / 3 north was surveyed twice, and unit 3 south was surveyed three times. There were relatively low densities of 0.27, 0.18, and 0.20 moose/km^2 in unit 1 in 2004, 2008, and 2013, respectively. Unit 2/3 north displayed a decrease in moose density from 2005 to 2010-11. In 2005, moose density was estimated at 0.19 moose/km^2; then in 2010 the estimate was down to 0.13 moose/km^2. Unit 3 south was surveyed in 2003, 2007, and 2010-11. The total moose estimates for unit 3 south were 0.20, 0.15, and 0.15 moose/km^2, respectively. The decrease in moose densities may be a trend; however, it is difficult to determine a trend with data from three years or less. Table 60 displays density estimates from LACL moose survey units 1, 2/3 north, and 3 south between 2003 and 2013.

ADF&G (2010) only documented moose densities for east GMU 19A in 2005 and 2008, which is not in LACL; however, it mentions that the densities would be similar in GMU 19B. In 2005, the observable density was 0.11 moose/ km^2 (0.28 moose/mi^2). In 2008, there was an increase in density to 0.17 moose / km^2 (0.44 moose/mi^2). Even though GMU 19B did not have density objectives set, the densities from both years are below ADF&G management objectives from the other four GMUs.

Table 60. Moose population densities taken from the three LACL moose survey units 1, 2/3 north, and 3 south (NPS 2003c, 2004, 2005, 2006, 2007, 2008, 2009, 2011a,b, 2013).

Unit(s)	2003	2004	2005	2007	2008	2010-11	2013
Unit 1	--	0.27	--	--	0.18	--	0.20
Unit 2 / 3 north	--	--	0.19	--	--	0.13	--
Unit 3 south	0.20	--	--	0.15	--	0.15	--

Sex Ratios

NPS (1992 – 2003) recorded a large range in sex ratios among the GMUs within LACL. GMU 19B was only surveyed in 1992, and had the lowest recorded ratio of 21.4 bulls per 100 cows. GMU 9B had the highest sex ratio among the GMUs, which occurred in 1992 (73.6 bulls to 100 cows). The ratios in 9B declined significantly by 1994, then increased slightly in 2003. There was a slight decline in sex ratios in GMU 17B between 1994 and 1999. The sex ratios dropped from 37 bulls: 100 cows to 29 bulls: 100 cows, respectively. The sex ratio recorded in 19B was just within the management objective for GMU 19B. GMU 17B had no management objectives for sex ratio; however, the numbers do not seem to be of concern. Unit 9B has management objectives that vary depending on moose density. If the areas were considered low density the objective would be 40 bulls to 100 cows; however, if the areas were considered to have medium to high density, the objective would be 20 bulls: 100 cows. According to Mangipane (written communication, 21 January 2014), even in areas of LACL with high population levels there are low to moderate moose densities, so an objective of 40 bulls to 100 cows is more appropriate. This means the 9B ratios from 1992 and 2003 were the only years that met management objectives. Table 61 displays the sex ratios recorded in GMUs 9B, 17B, and 19B between 1992 and 2003.

Table 61. Sex ratios recorded in GMUs 9B, 17B, and 19B between 1992 and 2003 (NPS 1992a,b, 1994a,b, 1998, 1999, 2003b).

GMU	1992	1994	1998	1999	2003
9B	73.6	39.6	36.7	--	41.7
17B	--	37.0	--	29.0	--
19B	21.4	--	--	---	--

NPS (2003-2013) documented increasing ratios in two of the three moose survey units in LACL. Unit 1 was surveyed in 2004, 2008, and 2013; the ratios were 13.6, 25.9, and 87.2 bulls:100 cows, respectively. The ratios from 2008 and 2013 were within the ADF&G management objectives for unit 1's corresponding GMU (19B). GMU 17B, which corresponds to moose units 2 and 3 north, did not have an ADF&G objective for sex ratios, but Units 2 / 3 north had sex ratios recorded in 2005 and 2010 that were within and above other GMU management objectives. The ratios in this unit increased from 40.8 bulls to 52.7 bulls to 100 cows in 2005 and 2010, respectively. All of the sex

ratios documented in unit 3 south (GMU 9B) were well above ADF&G management objectives. The sex ratios ranged from 53.5 to 85.9 bulls per 100 cows. It seems to be a good sign that each survey unit had stable sex ratios. Table 62 displays the sex ratios documented for each moose survey unit in LACL between 2003 and 2013.

Table 62. Sex ratios documented in LACL moose survey units 1 , 2 / 3 north, and 3 south between 2003 and 2010 (NPS 2003c, 2004, 2005, 2006, 2007, 2008, 2009, 2011a,b, 2013).

Unit(s)	2003	2004	2005	2007	2008	2010	2013
Unit 1	--	13.6	--	--	25.9	--	87.2
Unit 2 / 3 north	--	--	40.8	--	--	52.7	--
Unit 3 south	53.5	--	--	52.9	--	85.9*	--

* - Survey conducted over two winters, November 2010 and November-December 2011.

According to Butler (2010), the bull: cow ratios in GMU 9B were above ADF&G management objectives in 2007. Between 2003 and 2007, the sex ratios increased from 14 bulls: 100 cows to 40 bulls: 100 cows. Sex ratios were also high in unit 16B south. The ratios ranged from 31 to 78 bulls: 100 cows between 1999 and 2008. This range comes from four non-consecutive years: 1999, 2001, 2003, and 2008 (Peltier 2010). GMU 17B did not have ADF&G management objectives for moose sex ratios, therefore there are no data recorded for this unit during this reporting period. In GMU 19B, the sex ratios were low between 2001 and 2005, with a consistent ratio of 18 bulls to 100 cows (Seavoy 2010). A jump in sex ratio occurred in 2007, and the ratio remained above ADF&G management objectives until 2009. Table 63 displays sex ratios for the four GMUs that occur inside LACL.

Table 63. Sex ratios for the GMUs located within the LACL boundary (ADF&G 2010).

	09 B		16 B south		17 B		19 B	
Year	Yearling Bulls:100 Cows	Bulls: 100 cows	Yearling Bulls:100 Cows	Bulls: 100 cows	Yearling Bulls:100 Cows	Bulls: 100 cows	Yearling Bulls:100 Cows	Bulls: 100 cows
1999	--	--	4	38	--	--	--	--
2001	--	--	3	31	--	--	16	18
2003	3.0	14	17	46	--	--	10	18
2005	5.5	23	--	--	--	--	18	18
2007	4.0	40	--	--	--	--	32	39
2008	--	--	13	78	--	--	28	33
2009	--	--	--	--	--	--	14	31

Calf:Cow Ratios

NPS (1992 – 2003) recorded low calf:cow ratios among the three GMUs within LACL. The ratios ranged from 0 to 22 calves:100 cows. The lowest ratio occurred in GMU 17B in 1994, and the highest ratio occurred in GMU 9B in 2003. The calf:cow ratios in GMU 9B increased between 1992 and 2003, with the exception of 1998 when the calf: cow ratio was 8.3 calves:100 cows. Ratios increased in GMU 17B as well but remained low. Population estimates were low in 17B, which may account for the extremely low calf: cow ratio. No trends could be assessed for GMU 19B because the unit was only surveyed in 1992. It should be noted that GMU 19B was the only GMU that had ADF&G management objectives for this measure (30-40 calves:100 cows). If all of the GMUs were to have similar objectives, then none of the ratios would be within management objectives. Table 64 displays calf:cow ratios from GMUs 9B, 17B, and 19B between 1992 and 2003.



Photo 14. Moose cow with two calves (NPS photo by Katie Thoresen).

Table 64. Calf: 100 cow ratios from GMUs 9B, 17B, 19B between 1992 and 2003 (NPS 1992a,b, 1994a,b, 1998, 1999, 2003b).

GMU	1992	1994	1998	1999	2003
9B	12.5	14.9	8.3	--	22.0
17B	--	0.0	--	13.8	--
19B	19.6	--	--	--	--

According to the NPS data (2003 – 2013), calf: cow ratios were low in LACL between 2003 and 2013. The calf:cow ratios ranged from 11.2 to 24.1 calves:100 cows. The lowest and highest ratios occurred in 2010 and 2013 in units 2 / 3 north and unit 1, respectively. Calf: cow ratios of 15.2, 15.7, and 24.1 calves to 100 cows were recorded in unit 1 in 2004, 2008, and 2013, respectively. According to ADF&G (2010), these were all below the management objective for GMU 19B, which contains unit 1. There was a slight increase in calf:cow ratio in unit 2 / 3 north from 2005 to 2010. This is a continued increase from the NPS (1992 – 2003) survey period for GMU 17B, which includes all of unit 2. The calf: cow ratio in unit 3 south has decreased since 2003. The ratio went from 19.7 calves: 100 cows in 2003 to 11.2 calves: 100 cows in 2010. If GMU 19B would be used as a reference for the entire LACL area, then all of the survey units would be well below management objectives. Table 65 displays the calf: 100 cow ratios for the LACL moose survey units 1, 2/3 north, 3 south.

Table 65. Calf: 100 cow ratios from the LACL moose survey units 1, 2/3 north, and 3 south between 2003 and 2013 (NPS 2003c, 2004, 2005, 2006, 2007, 2008, 2009, 2011a,b, 2013).

Unit(s)	2003	2004	2005	2007	2008	2010-11	2013
Unit 1	--	15.2	--	--	15.7	--	24.1
Unit 2 / 3 north	--	--	19.2	--	--	20.3	--
Unit 3 south	19.7	--	--	17.3	--	11.2*	--

* - Survey conducted over two winters, November 2010 and November-December 2011.

According to ADF&G (2010), calf: cow ratios were low in all the GMUs that documented the ratio, and was very low in 2007. The ratio in GMU 9B has averaged 21.5 calves to 100 cows over the last 25 years. There was a lower ratio in GMU 16B as well, with just 18 calves per 100 cows documented in 2007. GMUs 17B and 19B did not have specific calf: cow ratios documented. It has been thought that the low calf: cow ratios throughout the region have been due to higher levels of wolf and bear predation (ADF&G 2010).

Bull Composition

NPS (2003 – 2013) documented ten years of bull composition within the moose survey units. There were three nonconsecutive years (2004, 2008, and 2013) of bull composition data from unit 1. The total bull count increased slightly from 10 to 27 bulls; however, yearling bull counts decreased from two to one yearlings. The low numbers of yearling bulls may be a result of low calf:cow ratios; few male calves are surviving to be counted as yearlings. The survival rate of calves seems to increase after the calves reach yearling status since there are larger numbers of medium to large bulls (Mangipane, written communication, 21 January 2014). Table 66 displays the bull composition, including yearling bulls, medium bulls, large bulls and the total number of bulls observed in Unit 1 in 2004, 2008, and 2013.

Table 66. Bull composition including the number of yearling, medium, large, and total bulls found in unit 1 (NPS 2004, 2008, 2013).

Year	Total Yearling Bulls	Total Medium Bulls	Total Large Bulls	Total Bulls
2004	2	2	6	10
2008	0	5	8	13
2013	1	11	15	27

NPS (2003 – 2013) included two nonconsecutive years (2005, 2010) of bull composition data from unit 2 and unit 3 north. The total number of bulls remained the same between 2005 and 2010. However, there was an increase in total yearling bulls. There were two yearlings observed in 2005 and seven observed in 2010. Table 67 displays the bull composition in unit 2/ 3 north in 2005 and 2010.

Table 67. Bull composition including the number of yearling, medium, large, and total bulls found in unit 2/3 north (NPS 2005, 2011a,b).

Year	Total Yearling Bulls	Total Medium Bulls	Total Large Bulls	Total Bulls
2005	2	11	28	41
2010	7	6	28	41

NPS (2003 – 2013) documented three nonconsecutive years (2003, 2007, 2010-11) of bull composition data from unit 3 south. Table 68 displays the bull composition, in unit 3 south in 2003, 2007, and 2010.

Table 68. Bull composition including the number of yearling, medium, large, and total bulls found in unit 3 south (NPS 2003c, 2007, 2011a,b).

Year	Total Yearling Bulls	Total Medium Bulls	Total Large Bulls	Total Bulls
2003	5	4	22	31
2007	8	12	4	24
2010-11	4	13	20	37

There seems to be a larger number of large bulls throughout the survey units. Hunting can put pressure on bulls. Subsistence hunting allows any bull to be harvested while sport hunting only allows the harvest of bulls greater than 50." Large bulls are well represented which likely indicates that sport hunting/hunting is not the cause of the low population numbers (Mangipane, written communication, 21 January, 2014).

Female Survival

Mangipane and Putera (2000) recorded cow survival rates for four years between 1996 to 2000. Three of the four years had higher survival rates (equal to or greater than 90%). The survival rates ranged from 76% to 97%, with the lowest and highest percent occurring in the 4th and 3rd year studied, respectively. It was believed that cow age was a factor in survival; cows older than nine years of age had decreased survival rates (Mangipane and Putera 2000).



Photo 15. Moose being pursued by a pack of wolves (NPS photo).

Threats and Stressor Factors

Habitat Change and Succession

Habitat change and succession can cause stress to moose in LACL. According to Bangs et al. (1982), moose can over browse in wintering habitat during harsh winters. Moose numbers may also decline

as vegetation in burned areas matures. Fire seems to be an important ecological process because it allows for new vegetative growth, which results in better quality habitat for moose. Alder growth can cause indirect stress to moose populations. Alders are less preferred browse species compared to willow species. If alder increased dramatically, it could have a result of reducing carrying capacity of moose (Mangipane, written communication, 21 January 2014).

Predation

Predation is a common stressor to moose populations throughout Alaska. Bear and wolf are the key predators of moose throughout the GMUs that are located within the park (ADF&G 2010). According to Messier (1994), wolves usually prey on caribou in areas where they are present because of their higher numbers; however, moose can be targeted year round due to their non-gregarious and non-migratory nature. In GMU 9, bear are thought to reduce moose recruitment through neonatal predation (Butler 2010). According to Peltier (2010), there have been efforts to reduce wolf populations in unit 16B. However, bear densities are high in the unit, and they may be the primary predator for moose in 16B. Wolf populations are thought to be increasing in GMU 17, where bear populations are already relatively high (Woolington 2010). Wolf and bear predation in unit 19B also play a major role in moose mortality (Seavoy 2010). Predator control has been a part of moose management in several GMUs (although not within NPS boundaries) to promote moose population increases.

Sport Harvest

Aside from predation, sport hunting can be a threat for moose in LACL. ADF&G (2010) recorded hunter type and success data for the GMUs located in LACL (unit 9, 16B, 17, and 19B). While harvest can be a threat, legal harvest is currently not threatening moose populations in LACL (Mangipane, written communication, 21 January 2014). According to Woolington (2010), illegal harvest by residents has been thought to be a reason for low densities in unit 17. This may be a result of the units restricted bag limit. Table 69 displays the number of nonresident hunters with success and the total success (harvest) within each GMU within LACL.

Table 69. Sports hunter success and total success (harvest) from four GMUs (9, 16B, 17, 19B) that are located in LACL (ADF&G 2010).

	GMU 9		GMU 16B		GMU 17		GMU 19B	
Year	Sport	Total	Sport	Total	Sport	Total	Sport	Total
1999	--	--	40	168	99	146	--	--
2000	--	--	30	171	139	184	--	--
2001	89	175	--	--	125	169	--	--
2002	100	179	--	--	77	120	--	--
2003	102	177	1	99	97	141	--	--
2004	95	161	0	85	97	129	33	47

Table 69 (continued). Sports hunter success and total success (harvest) from four GMUs (9, 16B, 17, 19B) that are located in LACL (ADF&G 2010).

	GMU 9		GMU 16B		GMU 17		GMU 19B	
Year	Sport	Total	Sport	Total	Sport	Total	Sport	Total
2005	84	160	0	62	61	100	28	42
2006	73	125	--	--	38	76	20	28
2007	81	147	--	--	40	78	11	20
2008	53	106	--	--	24	51	15	25

Data Needs/Gaps

There are little available moose data after 2008. The NPS (1992 – 2013) has typically conducted surveys on three-year cycles; as a result, comparable data for survey units over time is limited. Current data for cow survival are not available. The most recent cow survival data are at least 10 years old (Mangipane and Putera 2000), and therefore may not be helpful in making an accurate assessment for the present moose population in LACL. ADF&G (2010) lacks the most current data. The data from the surveys are at least five years old, and are not consistent among the LACL GMUs. For example, the only population estimates in unit 9 were from a 1983 census and unit 19 B does not have a population estimate recorded. NPS (2011) contains current data; however, the survey only covers 45 percent of moose habitat in the park. This lack of data coverage makes it difficult to make an accurate assessment of current population dynamics.

Overall Condition

Population Size

The project team defined the *Significance Level* for population size as a 2. NPS (1992 – 2003) documented an increased moose population estimate from moose survey unit 2/3 north; however, the moose estimate in unit 3 south had decreased. Unit 1 was only surveyed once at the beginning of this surveying period. NPS (2003 – 2013) also documented estimates that seemed to decline. Units 1 and 3 south seemed to be stabilizing in the second and third year of this surveying period. Although units 1 and 3 south seem to be stabilizing, it does not mean the population size is healthy (Mangipane, written communication, 21 January 2014). ADF&G documented several population size estimates throughout the GMUs in the park; however, the data are outdated, with the most recent estimate coming from 2006. None of the population estimates were within the ADF&G management objectives. Although there is no reference condition for moose population sizes within LACL, there seems to be a decreasing trend in population estimates among all three survey units. As a result, this measure was assigned a *Condition Level* of 2, or moderate concern.

Population Density

The project team defined the *Significance Level* for population density as a 2. GMUs 9B and 17B are the only GMUs with ADF&G moose density objectives. NPS (1992 – 2003) documented a rather high density (0.61 moose/km^2) in moose survey unit 1 in 1992, but NPS (2003 – 2013) later

documented a significant drop to 0.18 and 0.20 moose/km^2 in 2008 and 2013, respectively. Densities in unit 2 and 3 north were below management objectives from 1992 to 2013. Unit 3 south was above the GMU objective from 1992 to 2003 (NPS 1992 – 2003), then dropped to 0.15 moose/km^2 in 2007 and 2010-11 (NPS 2003 – 2013). ADF&G (2010) only documented moose density for GMU 19, the only GMU within LACL to not have a management objective for density. Both density estimates for GMU 19 were under management objectives from the other GMUs within the park. According to Mangipane (written communication, 21 January 2014) densities are still low and have been for a while. As a result, this measure was assigned a *Condition Level* of 1, or low concern.

Sex Ratios

The project team defined the *Significance Level* for sex ratios as a 2. NPS (1992 – 2003) and NPS (2003 – 2013) documented an increasing trend in sex ratios between 1992 and 2013. Unit 1 (GMU 19B) increased from 21.4 bulls: 100 cows, which was within management objectives, to 87.2 bulls: 100 cows. Units 2 / 3 north sex ratios ranged from 29.0 to 52.7 bulls: 100 cows. Unit 3 south (GMU 9B) only met ADF&G management objectives twice between 1992 and 2003, but met objectives all three years the unit was surveyed between 2003 and 2010. NPS (2003 – 2013) documented a high sex ratio (87.2: 100) during a 2013 survey. All of the ratios from 2003 to 2013 were within ADF&G management objectives set by each corresponding GMU. ADF&G (2010) recorded bull ratios within or above management objectives from 2007 to 2009. The sex ratios do not seem to be under stress. As a result, this measure was assigned a *Condition Level* of 0, or no concern.

Calf:Cow Ratios

The project team defined the *Significance Level* for calf: cow ratios as a 3. Low calf: cow ratios were recorded throughout the reviewed reports and studies. GMU 19B was the only GMU with ADF&G management objectives for calf: cow ratios (30 – 40 calves: 100 cows); however, there were ratios recorded from all the GMUs within the park. NPS (1992 - 2003) documented ratios that ranged from 8.3 to 22 calves per 100 cows, with the highest ratio occurring in 2003. Unit 1 (GMU 19B) ratios seemed to decline after 1992, but showed signs of slight improvement in 2013. Unit 2 / 3 north (GMU 17B) ratios had increased from 0.0 calves: 100 cows in 1994 to 20.3 calves: cows in 2010. Unit 3 south (GMU 9B) had ratios that fluctuated between 1992 and 2010. The ratios for this unit seemed to increase between 1992 and 2003, but then decrease between 2003 and 2010-11 (NPS 1992 – 2003, NPS 2003 – 2013). Similar low ratios were recorded from ADF&G (2010). As a result, this measure was assigned a *Condition Level* of 3, or high concern.

Bull Composition

The project team defined the *Significance Level* for bull composition as a 2. According to Mangipane (written communication, 2014), the higher number of large bulls is a sign that hunting pressure is not overly taxing this segment of the population. Bull composition seems to be relatively stable throughout most of the surveying period. Bull compositions were stable in unit 1 all three years it was surveyed. Compositions were stable in unit 2 / 3 north when surveyed in 2005; however, in 2010 there were fewer medium bulls observed than yearling bulls. Unit 3 south had similar results in 2003. In 2007, there were a small number of large bulls in unit 3 south, which could have been a result of high hunting pressure. Bull composition stabilized by the time the unit was surveyed again in 2010-

11. The data suggest that the few bulls reaching yearling age are surviving at a fairly high rate, resulting in more bulls in the medium/large classes (Mangipane, written communication, 21 January 2014). As a result, this measure was assigned a *Condition Level* of 1, or low concern.

Female Survival
The project team defined the *Significance Level* for female survival as a 3. The report by Mangipane and Putera (2000) had the most current available data; however, the data were over 10 years old. Four years of cow survival percentages were recorded, ranging from 76 to 97 percent. Three of the four years had good cow survival rates (>90 %), but the last year (1999) had a concerning rate of 76 percent. It is difficult to assess a trend with outdated information, and as a result, a *Condition Level* was not assigned for this measure.

Weighted Condition Score
The *Weighted Condition Score* for moose in LACL is 0.47, indicating that the component is of moderate concern. Population size, density, and calf:cow ratio estimates have declined over the years; however, units 1 and 2 / 3 north seem to be stabilizing. This does not necessarily indicate good health; but a break in the previous declining trend. As a result, a stable trend has been assigned to the component.

Moose			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.47**
Population Size	2	2	
Population Density	2	1	
Sex Ratio	3	0	
Calf:Cow Ratio	3	3	
Bull Composition	2	1	
Female Survival	3	n/a	

4.6.6 Sources of Expertise
Buck Mangipane, LACL Wildlife Biologist

Jeff Shearer, LACL Chief of Natural Resources

4.6.7 Literature Cited

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4.7 Bald Eagle

4.7.1 Description

LACL is home to the northern subspecies of bald eagle (*Haliaeetus leucocephalus alascanus*) (Stalmaster 1987). This subspecies is slightly larger than the southern subspecies (*H. l. leucocephalus*), and is the only subspecies that has a breeding range in Alaska (Stalmaster 1987). Bald eagles are top-level predators and are excellent indicators of an ecosystem's (both terrestrial and aquatic) overall health (Hutto 1998, Morrison 1986, Stalmaster 1987, Bildstein 2001, Bennett et al. 2006, Thompson et al. 2009). In particular, bald eagles possess two characteristics that make them convenient species to survey: a large body size, and large, easily visible nests.

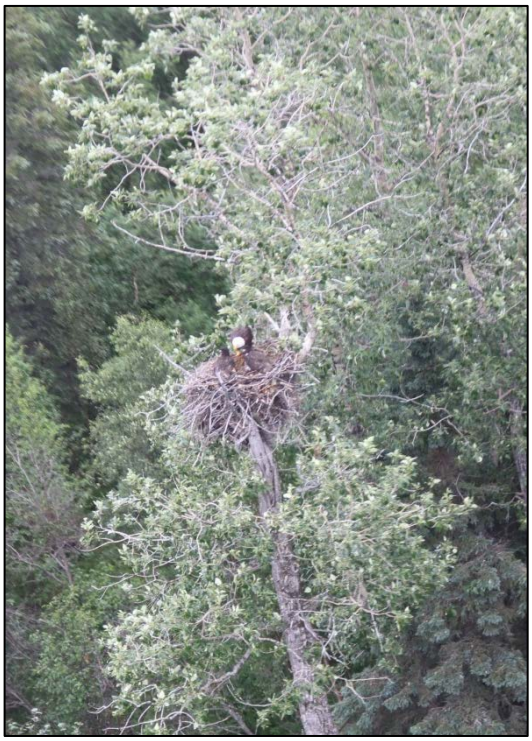


Photo 16. Adult bald eagle and two chicks in a cottonwood nest in LACL (Photo by Buck Mangipane, LACL).

On average, male bald eagles are approximately 84.3 cm (2.8 ft) from head to tail, weigh 4.3 kg (9.5 lbs), and have a wingspan of about 207.3 cm (6.8 ft) (Imler and Kalmbach 1955, Stalmaster 1987). Typical of raptor species, bald eagles exhibit reverse sexual size dimorphism; females are larger than the males, weighing approximately 5.3 kg (11.7 lbs) and with a wingspan of 221.1 cm (8 ft) (Imler and Kalmbach 1955, Stalmaster 1987). Juveniles exhibit an entirely brown/mottled brown plumage until they reach sexual maturity at around 5 years of age, at which time the characteristic white head and white tail appear on the bird (Stalmaster 1987).

Bald eagles construct very large nests, the largest nest of any North American bird species (Photo 16; Stalmaster 1987), and will return to the same nest/territory each year (Stalmaster 1987, Buehler 2000). Both the male and female eagles construct the nest, and they will often construct a second or third "alternate" nest in the territory to use if the other nest is damaged (Bowman et al. 1992). Sticks and other materials are added to the nest at the beginning of each breeding season, and eventually nests can be as large as 4 m (13 ft) deep, 2.5 m (8.2 ft) across, and weigh one metric ton (del Hoyo 1994). In LACL, cottonwood (*Populus deltoides*) and black spruce (*Picea* spp.) appear to be the favored nesting substrate, with rock and ground nests occurring far less frequently (Witter and Mangipane 2011).

While a large body size and large nest size make the bald eagle a good choice as an indicator species, those characteristics alone do not provide researchers with any indication of the ecosystem's health. As top-level predators, bald eagles are exposed to several threats and variables that can affect their reproductive success and occupancy rates (Tetreau 1991). These environmental variables and threats can be natural in occurrence, or they can have anthropogenic origins. Figure 25 is an adaptation from Stalmaster (1987), and represents the various factors that may influence bald eagle populations. A

change in bald eagle reproductive success can be indicative of a change in one or more of these variables (Stalmaster 1987).

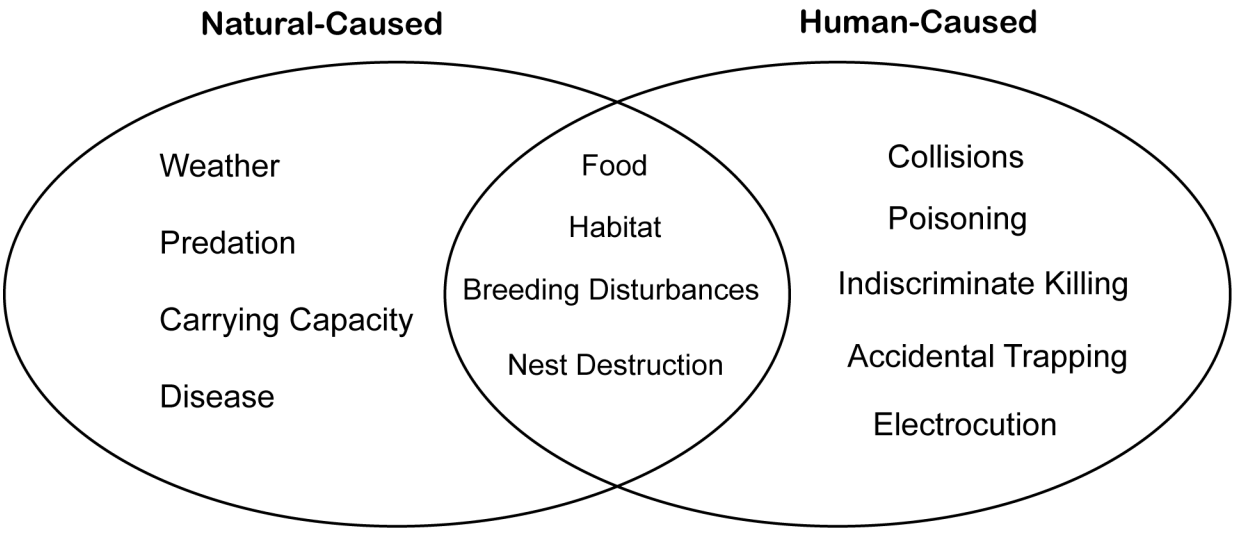


Figure 25. Various natural and human-caused factors that influence bald eagle populations. Modified from Stalmaster (1987) and Tetreau (1991).

The bald eagle's diet includes fish, birds, and mammals (Stalmaster 1987, Anthony et al. 1999, Armstrong 2008). Despite the broad spectrum of potential prey species, fish appear to be the primary prey item for bald eagles; Stalmaster (1987) summarized several bald eagle data sources from across the species' range and determined that fish made up approximately 56% of the species' diet. Imler and Kalmbach (1955) reported fish constituting 66% of bald eagle's diet in southeast Alaska, and Grubb and Hensel (1978) reported 62% of the bald eagle's diet consisted of fish on Kodiak Island, Alaska. The diet of bald eagles in LACL is poorly understood, although salmon and migratory waterfowl are thought to be important food sources (Witter and Mangipane 2011).

Bald eagle populations across the United States began declining in the early 1900s due to habitat fragmentation and direct human persecution (Sprunt and Ligas 1966, Buehler 2000). The use of toxic chemicals and pesticides, such as dichlorodiphenyltrichloroethane (DDT) and other organochlorides, exacerbated the decline (Brown et al. 2006). The use of DDT became widespread worldwide during the 1940s and 50s because it is an effective insecticide, thus reducing the transmission of insect-borne diseases to humans (Carson 1962). DDT and its derivatives are persistent organic pollutants that accumulate in the environment, and DDT concentrations are highest in high trophic-level predators due to the process of bioaccumulation (EPA 1975).

Bald eagle populations in Alaska remained stable during the time period that the continental U.S. populations of eagles declined. However, from the 1800s to 1953, Alaska offered a bounty on bald eagles because they were believed to prey on livestock (Laycock 1973, Hodges et al. 1979); between 1917 and 1952, a bounty was paid on 128,273 eagles (Laycock 1973). Despite the effects of the bounties, bald eagles in Alaska were never federally listed as endangered. However, all bald eagle populations (both continental and Alaskan) are protected under the Bald Eagle Protection Act of

1940. This Act provides for the protection of the bald eagle by prohibiting the taking, possession, and commerce of the species (USFWS 2011).

The ANILCA mandates that LACL be managed to "…protect habitat for and populations of fish and wildlife including, but not limited to, caribou, Dall sheep, brown/grizzly bears, bald eagles and peregrine falcons" (Public Law 96-487, Section 201[7a]). Furthermore, bald eagles are a "highly desirable" Vital Sign for all NPS units in SWAN (Thompson et al. 2009). SWAN will summarize data on nest occupancy and distribution every 1 to 5 years; they will also estimate trends every 5 years (Bennett et al. 2006). Bald eagles serve an important ecological role in freshwater and marine coastal ecosystems within SWAN, and monitoring of their populations across the region, including LACL, is important to understanding the overall ecological health of the area.

4.7.2 Measures

- Nest occupancy
- Productivity

4.7.3 Reference Conditions/Values

The unique geography of LACL isolates two specific regions of bald eagle nesting habitat: the interior of the park (shoreline habitat surrounding Lake Clark and the associated drainages), and the coastal region of the park (Cook Inlet coastline and the associated drainages). This component discusses these regions separately, as the two typically display unique yearly values and long-term trends in abundance and occupancy (Mangipane, written communication, 20 August 2013).

The reference condition for the occupancy measure is the 20-year historic occupancy average for the interior (20.15 active nests/year, and 56% of surveyed nests occupied) and coastal regions (24.2 active nests/year, and 56% of surveyed nests occupied) (NPS 2013a,b,c). The reference condition for the productivity measure is consistent with Sprunt et al. (1973)'s productivity threshold for a stable bald eagle population (50% of pairs are successful and 0.70 young per active nest).

4.7.4 Data and Methods

Sprunt et al. (1973) investigated the reproductive rates of six bald eagle populations in the United States (Alaska, Great Lakes shoreline, Wisconsin, Florida, Michigan, and Maine). The authors found that in any given population, at least 50% of nesting pairs must be successful in order to maintain stability. It was also determined that the population must produce an average of 0.70 young/active nest in order to maintain reproductive stability. These two values were used as the reference condition for the occupancy measures in this assessment.

As described in Bennett (1995), bald eagle nest data were collected in accordance with U. S. Fish and Wildlife Service (USFWS) guidelines beginning in 1992. The methodology of these surveys consisted of two aerial surveys conducted each year; surveys were flown on clear days with low winds and no precipitation, with two observers (pilot and passenger; Bennett 1995). The first survey was an occupancy survey that took place early in the bald eagle incubation period (late May-early June) when most eggs had been laid, but before nests would fail. The second survey took place later in the year (late July) and focused on observing the productivity of the active nests. Observers looked

for young that were large and dark enough to be visible; the young were typically two to three months old during the productivity survey.

In 1999, a survey protocol specific to LACL was implemented (Putera 1999). This protocol added an additional, intensive aerial survey early in the season that focused on locating any new nests and also checked the status of existing nests in three survey areas. The intensive surveys were to be rotated among the survey areas on a yearly basis (Putera 1999). The data collection and survey protocols followed the USFWS methodology with some park-specific modifications. While the USFWS dual observer method is being tested elsewhere in SWAN, LACL continues to use the 1999 method, although slightly modified. Beginning in 2012, LACL staff used GIS to delineate all potential bald eagle nesting habitat in the park. Surveys attempt to cover as much of this habitat as possible; in 2012 87% of the potential habitat was surveyed, and an additional 9% of this area was surveyed in 2013 (Mangipane, written communication, 13 May 2014).

During the 2013 occupancy survey, LACL researchers adjusted the Putera (1999) methodology and added an additional early occupancy survey. The adoption of an additional occupancy survey will likely help LACL staff obtain an accurate estimate of early and late nest initiations, as well as an estimate of early failure rates (Mangipane, written communication, 20 August 2013).

Witter and Mangipane (2011) summarized the nest occupancy and reproductive success of the LACL bald eagle population for the duration of the historic and contemporary surveys. Besides providing the summary statistics for occupancy and productivity, this report also provided the objectives of the ongoing eagle monitoring in LACL. These objectives are to:

> *... (1) obtain baseline data on population status, and (2) monitor long-term changes in reproductive rates. Additional objectives for the 2011 study were to summarize historic LACL bald eagle nesting data and tabulate data in a format that can easily be transitioned into a standardized SWAN bald eagle database* (Witter and Mangipane 2011, p. 1).

4.7.5 Current Condition and Trend

Nest Occupancy

Bald eagle occupancy surveys began in LACL in 1984, and continued with yearly surveys from 1987-1991. However, data obtained from the 1984-1991 surveys are difficult to analyze and summarize as no standard survey protocol was followed, nests were not assigned unique identifiers, and nest locations (interior/coastal) were not recorded (Witter and Mangipane 2011). Because of the discrepancies in these surveys, the data are only presented in Table 70 and were not used as a factor in an overall condition for this measure.

Table 70. Bald eagle nest occupancy in LACL from 1984-1991. Note that occupancy estimates here do not separate coastal and interior nests. Occupancy averages have been rounded to the nearest whole number (NPS 2013a,b,c).

Year	Occupancy (Occupied Nests/Total Nests)
1984	33/45 (73%)
1987	24/44 (55%)
1988	38/55 (69%)
1989	44/67 (66%)
1990	41/75 (55%)
1991	38/86 (44%)
Average	**60%**

From 1992 to 1997, occupancy surveys in LACL followed USFWS guidelines and protocols outlined by Bowman et al. (1992). Under the guidance of this protocol, aerial surveys were conducted on clear, calm days sometime during late May or early June (Bennett 1995). 1992 marked the first survey that separated the interior and coastal nesting data, allowing for separate analyses of occupancy trends for both regions (Table 71).

Table 71. Occupancy data for LACL from 1992-2013.

	Occupancy[C] (# Active Nests/# Total Nests)	
Year	**Interior**	**Coast**
1992[A]	16/30 (53%)	21/30 (70%)
1993[A]	24/33 (72%)	32/40 (80%)
1994[A]	18/37 (49%)	21/40 (51%)
1995[A]	15/27 (56%)	31/45 (69%)
1996[A]	14/24 (58%)	20/44 (45%)
1997[A]	17/25 (68%)	31/41 (76%)
1998[A]	N/A	N/A
1999[B]	15/27 (56%)	24/46 (52%)
2000[B]	26/38 (68%)	25/46 (54%)
2001[B]	18/40 (45%)	37/49 (76%)

Table 71 (continued). Occupancy data for LACL from 1992-2013.

	Occupancy[C] (# Active Nests/# Total Nests)	
Year	**Interior**	**Coast**
2002[B]	N/A	N/A
2003[B]	8/20 (40%)	3/19 (16%)
2006[B]	25/40 (63%)	19/40 (48%)
2007[B]	22/40 (55%)	17/40 (43%)
2008[B]	22/39 (56%)	22/41 (54%)
2010[B]	21/43 (49%)	29/42 (69%)
2011[B]	25/40 (63%)	27/42 (64%)
2012[B]	20/52 (39%)	26/59 (44%)
2013[B]	22/52 (42%)	36/63 (57%)
Average ('92-'97)	**59%**	**65%**
Average ('99-'13)	**54%**	**52%**
Average (All)	**56%**	**56%**

A - Indicate surveys that followed the Bowman (1992) protocol.

B- Indicate surveys completed using the Putera (1999) protocol.

C- Occupancy averages and percentages have been rounded to the nearest whole number (NPS 2013a,b,c).

For the duration of the standardized surveys in the park (1992-2013), the average number of active nests per year was highest in the coastal habitat (24.2 active nests/year ± 1.77 SE) when compared to the interior (20.15 active nests/year ± 1.16 SE). The number of active nests in the interior ranged from eight (2003) to 31 (2005; Figure 26), while the coast ranged from three (2003) to 37 (2001; Figure 27, Figure 28). The average annual occupancy rate for both the interior and coast was 56%. Occupancy rates ranged from 39% (2012) to 74% (2005; Figure 29) in the interior, and from 16% (2003) to 80% on the coast (1993; Figure 30, Figure 31).

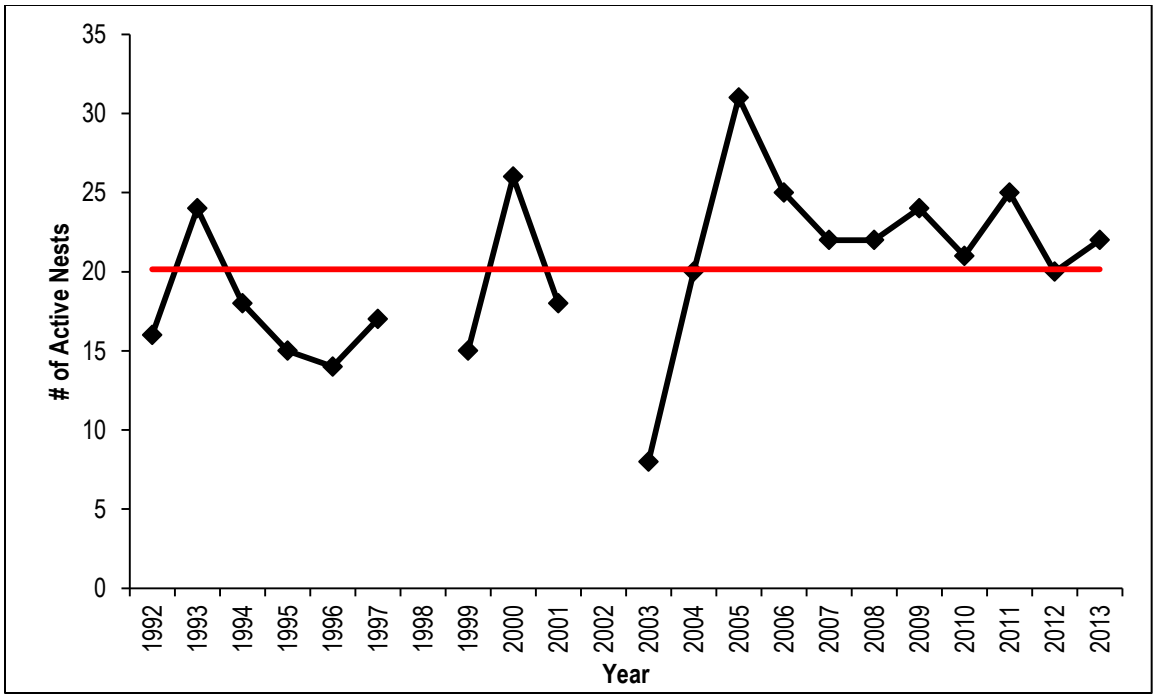


Figure 26. Total number of active nests in the interior breeding region of LACL from 1992-2013 (NPS 2013a,b,c). Red line indicates 20-year historic average for this region (20.15 active nests/year).

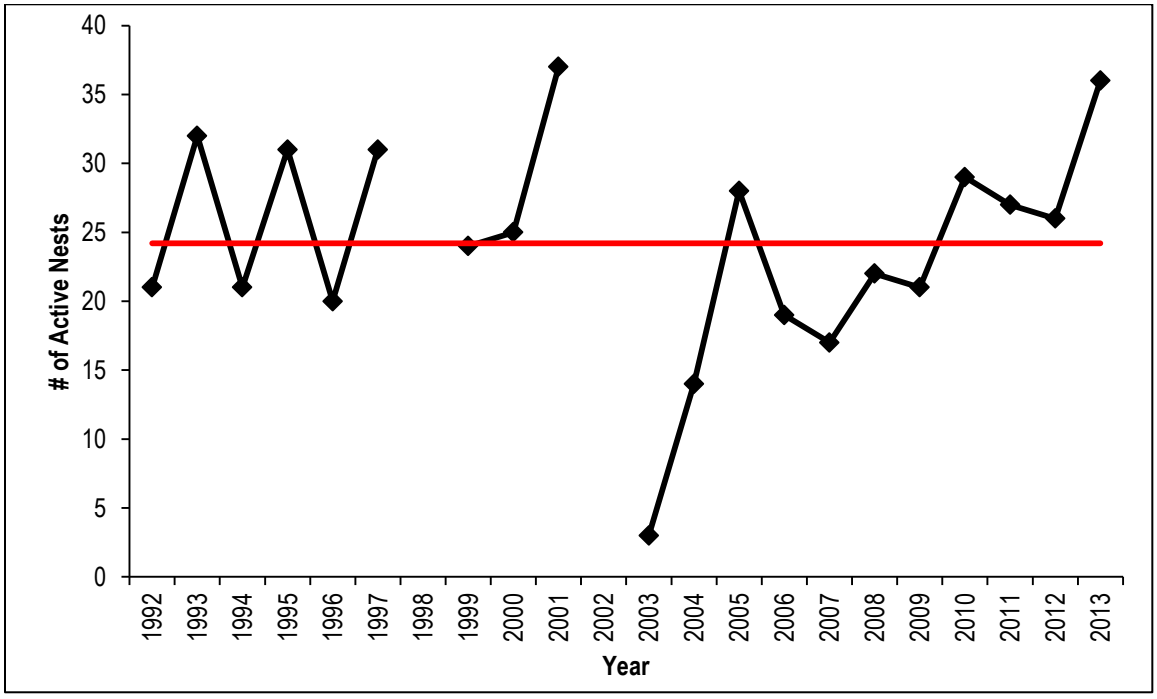


Figure 27. Total number of active nests in the coastal breeding region of LACL from 1992-2013 (NPS 2013a,b,c). Red line indicates 20-year historic average for this region (24.20 active nests/year).

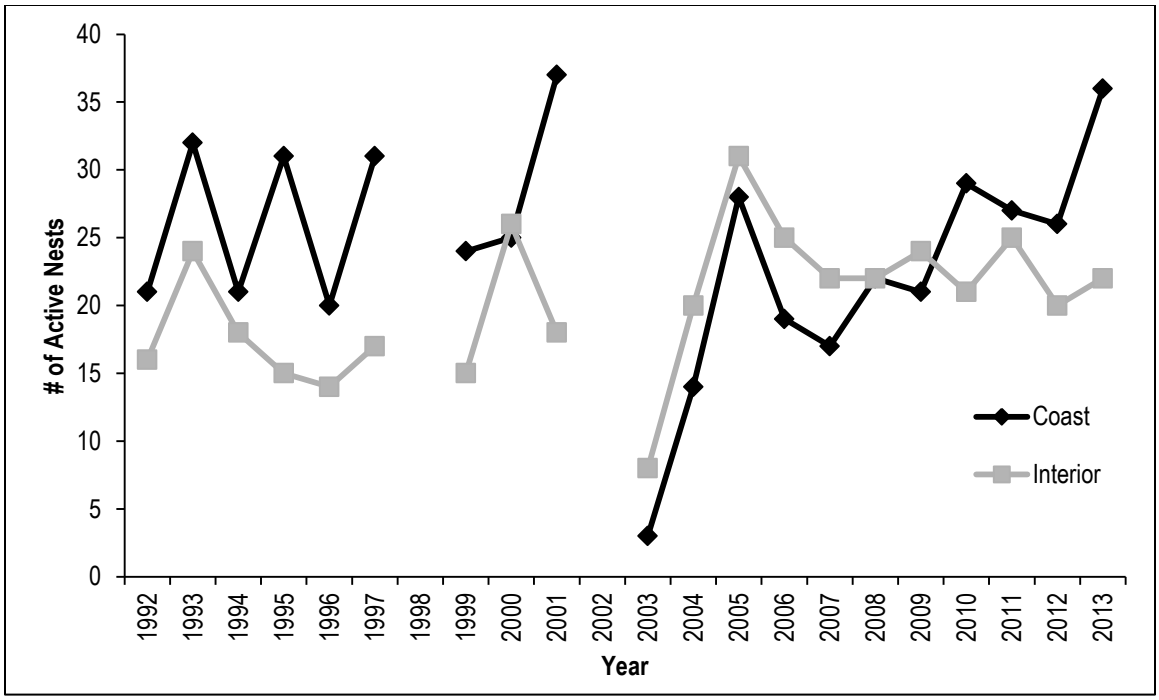


Figure 28. Number of active nests in both the interior (gray) and coastal (black) regions of LACL from 1992-2013 (NPS 2013a,b,c)

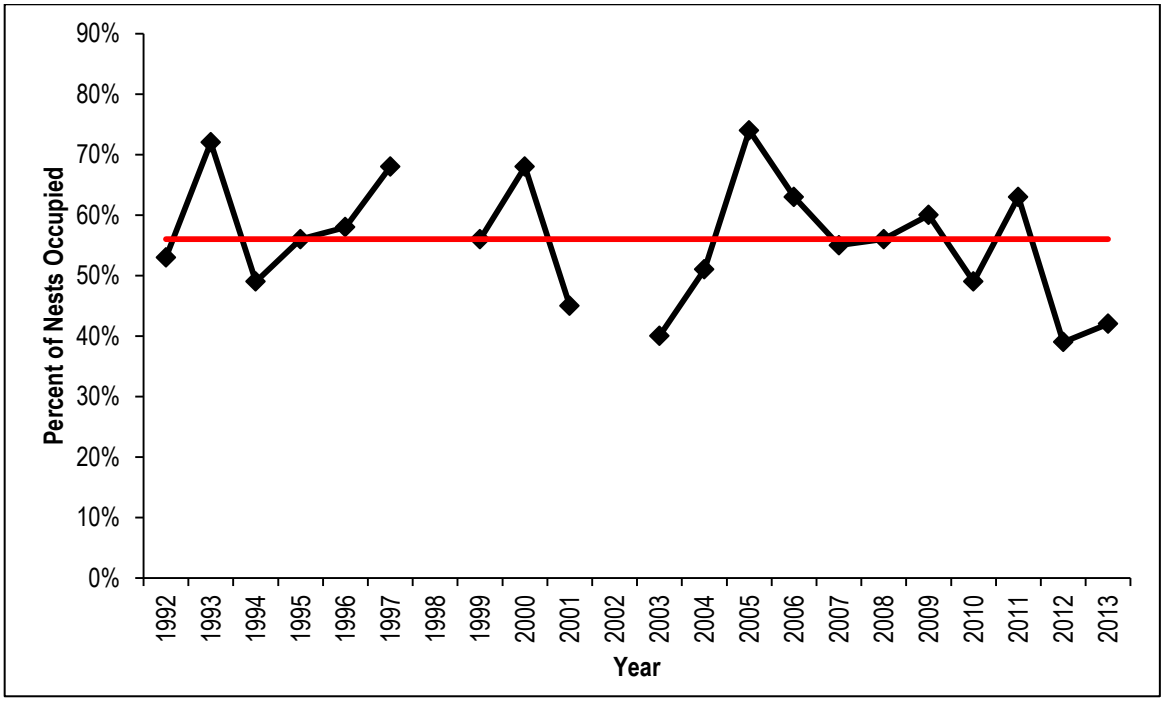


Figure 29. Annual occupancy rates in the interior region of LACL from 1992-2013. The solid red line indicates the reference condition, which is 56% (NPS 2013a,b,c).

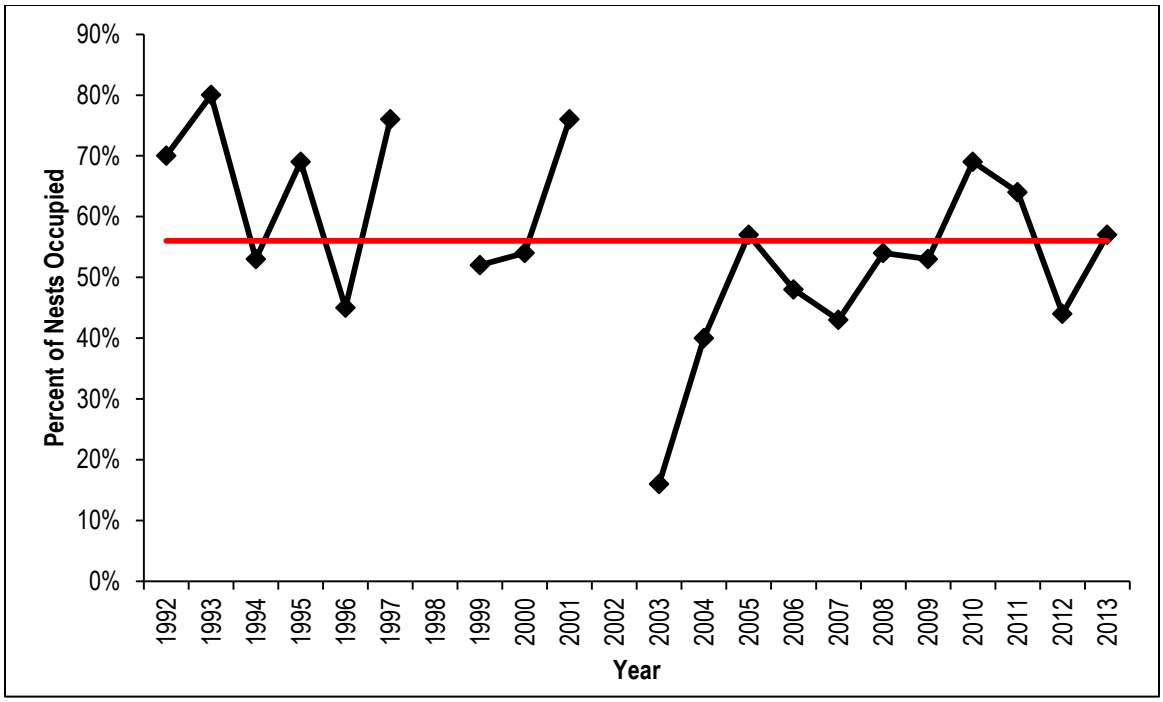


Figure 30. Annual occupancy rates in the coastal region of LACL from 1992-2013. The solid red line indicates the reference condition, which is 56% (NPS 2013a,b,c).

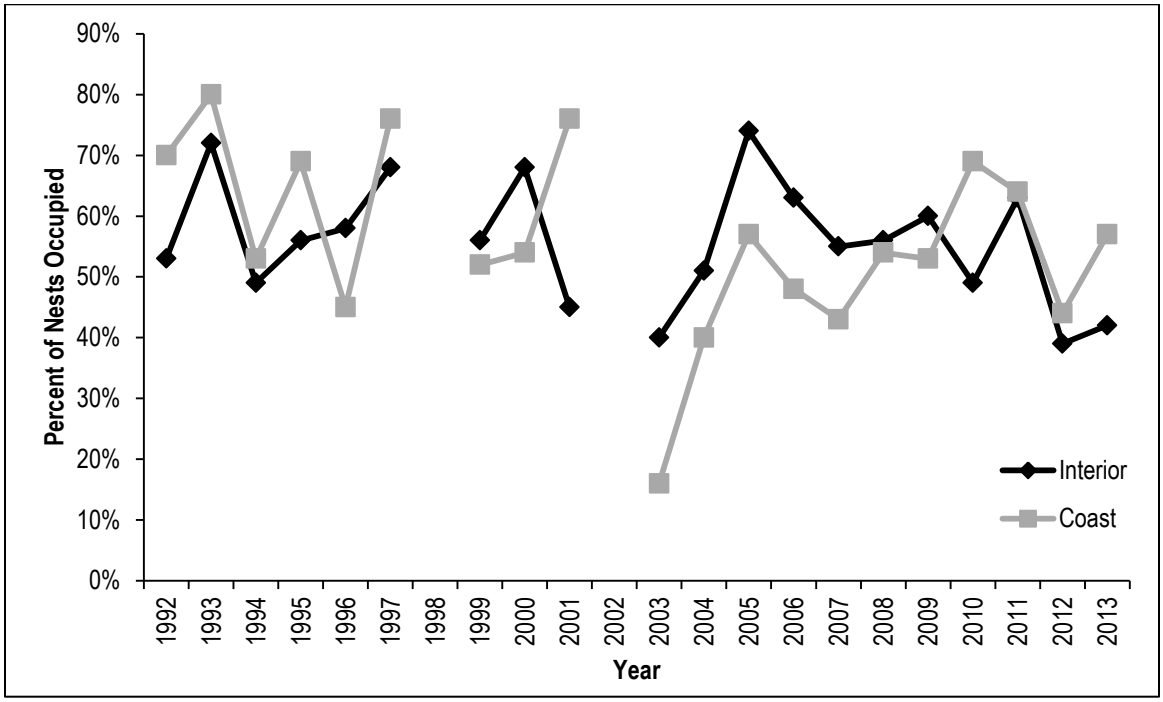


Figure 31. Annual occupancy rates for both the coastal and interior regions of LACL from 1992-2013 (NPS 2013a,b,c).

Both regions of the park had a higher than average number of active nests in 2013. Twenty-two active nests were observed in the interior during the 2013 surveys, which was slightly above the 20-

year average for the interior (20.15 ± 1.16 SE). The coastal region had 36 active nests, which was well above the 20-year historic average (24.2 ± 1.77 SE). Occupancy rates varied in 2013, as the occupancy rate for the interior was 42%, well below the 20-year average for the interior (56%), while the occupancy rate for the coast was 57%, only slightly above the historic average for this region (56%). The variations observed in occupancy rates in 2012 and 2013 (for both regions of the park) can likely be attributed to the expanded search efforts of LACL staff during annual surveys. Surveys expanded to investigate all potential bald eagle habitat, and some of these areas provided less than ideal habitat but still contained unoccupied nests. Additionally, new nests in existing territories where alternate nests occur appear to be inflating the nest number with no corresponding increase in active nests (Mangipane, written communication, 13 May 2014). The average occupancy rate for the survey period is likely a stronger indicator of overall health and condition for this measure because of these caveats.

Productivity

During aerial productivity surveys, a nest was classified as productive (i.e., successful) if at least one young was observed in the nest (Photo 17). LACL typically reports two metrics of productivity: 1) the average number of young per active nest (i.e., an active nest is a nest that has eggs, young, or an adult in an incubating posture), and 2) the average number of young per successful nest. Another valuable metric of productivity that is often reported is the percent of active nests that are successful each year.



Photo 17. A bald eagle nest observed in LACL during annual monitoring. Pictured are one adult bald eagle and two chicks (photo by Buck Mangipane, LACL).

Percent of Active Nests Successful

The annual percentage of active nests that were successful fluctuated in the interior of LACL from 1992 – 2013, averaging 55% and ranging from 33% (1992) to 73% (1999 and 2000; Figure 32). Sprunt et al. (1973) defines the minimum percentage of successful nests in a stable population as 50% (i.e., 50% of active nests have at least one young observed in the nest); the interior nesting population fell below the minimum percentage required for stability in seven of the 19 years that the area was surveyed (Figure 32).

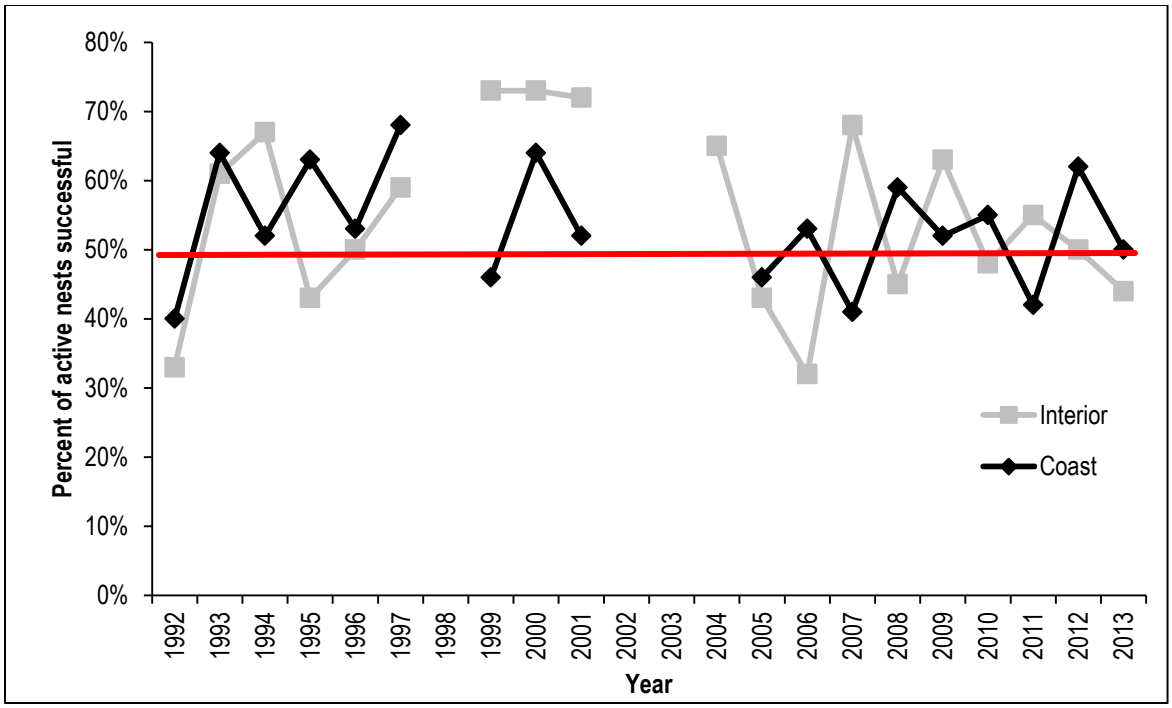


Figure 32. Percent of active nests that were successful for both the coastal and interior bald eagle nests in LACL, 1992-2013 (NPS 2013a,b,c). Solid red line represents the minimum productivity threshold of 50% as defined by Sprunt et al. (1973).

The productivity of the coastal bald eagle population in LACL has also been highly variable. The annual percentage of active nests that were successful has fluctuated from 40% (1992) to 68% (1997; Figure 32), and the average percent of coastal nests that were successful from 1992-2013 was 54%. The coastal population fell below the minimum percentage required for stability (as defined in Sprunt et al. 1973) in five of the 18 years that the area was surveyed (Figure 32).In 2013, 50% of the active nests in the interior were successful while the coastal population had only 44% of active nests that were successful, indicating that the area was below the threshold for stability (Figure 32).

From 1992-2013, the annual nest success for both regions of the park was highly variable; few trends are evident in the data for these regions, and the park has a limited understanding of the factors that may influence these annual fluctuations (Witter and Mangipane 2011). Analyzing data from 1992-2011, Witter and Mangipane (2011) found no significant correlation between historical nest success and spring/summer temps or wind speeds. However, there was a significant negative correlation between coastal nest success and total June-July precipitation levels (r_s = -0.76, p = 0.0012; Witter and Mangipane 2011).

Number of Young/Active Nest

According to Sprunt et al. (1973), 0.70 young/active nest is the minimum productivity required to maintain a stable bald eagle population. In the interior of LACL, the number of young/active nest has fallen below this threshold in nine of the 19 years where data are available (Figure 33). Nest productivity has ranged from 0.40 young/active nest (2006) to 1.27 young/active nest (2007; Figure 33); the average productivity for the interior from 1992-2013 was 0.78 young/active nest.

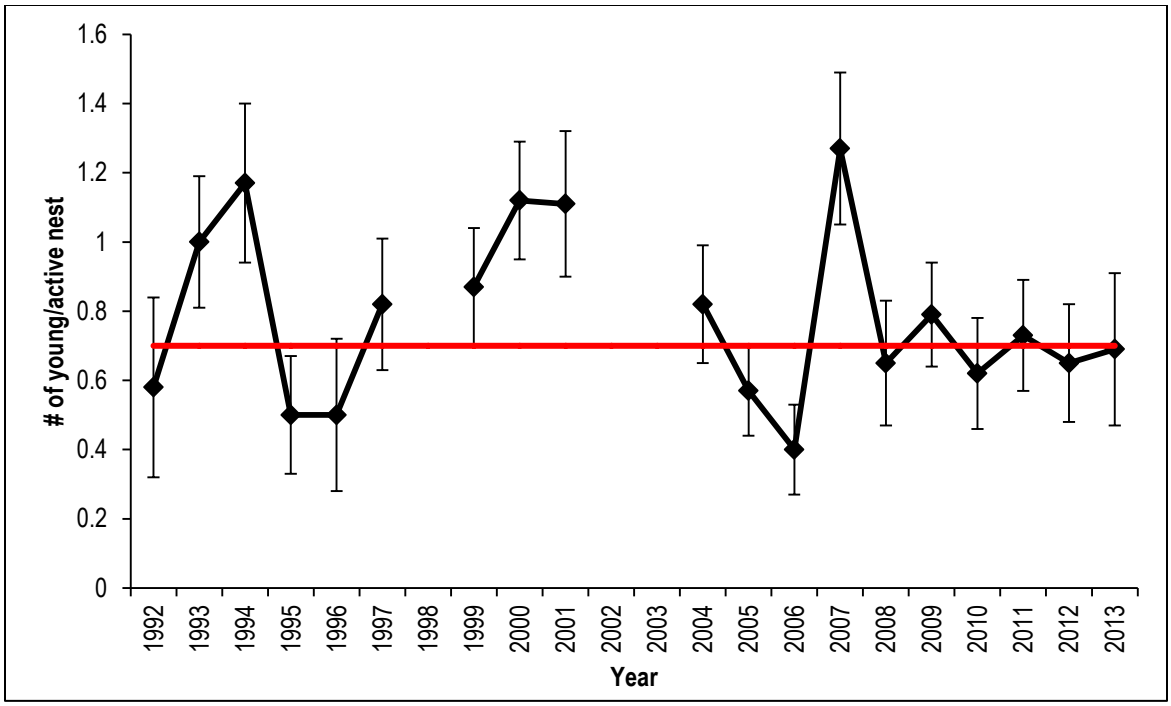


Figure 33. Number of young per active nest from 1992-2013 in the interior region of LACL (NPS 2013a,b,c). The solid red line indicates the reference condition of 0.70 young/active nest (Sprunt et al. 1973).

The coastal bald eagle population of LACL has fallen below the Sprunt et al. (1973) productivity threshold in six of the 18 years that have data available (Figure 34). Nest productivity has ranged from 0.54 young/active nest (2005) to 0.90 young/active nest (1997; Figure 34). The average productivity for the coast from 1992-2013 was 0.74 young/active nest. Interestingly, one of the lowest productivity values (0.54 young/active nest) and one of the highest productivity values for this region (0.89 young/active nest) occurred in consecutive years (2005-2006). A year later, a similar trend was observed in the interior, as productivity in 2006 was at its lowest (0.40 young/active nest), only to rebound to its highest levels in 2007 (1.27 young/active nest).

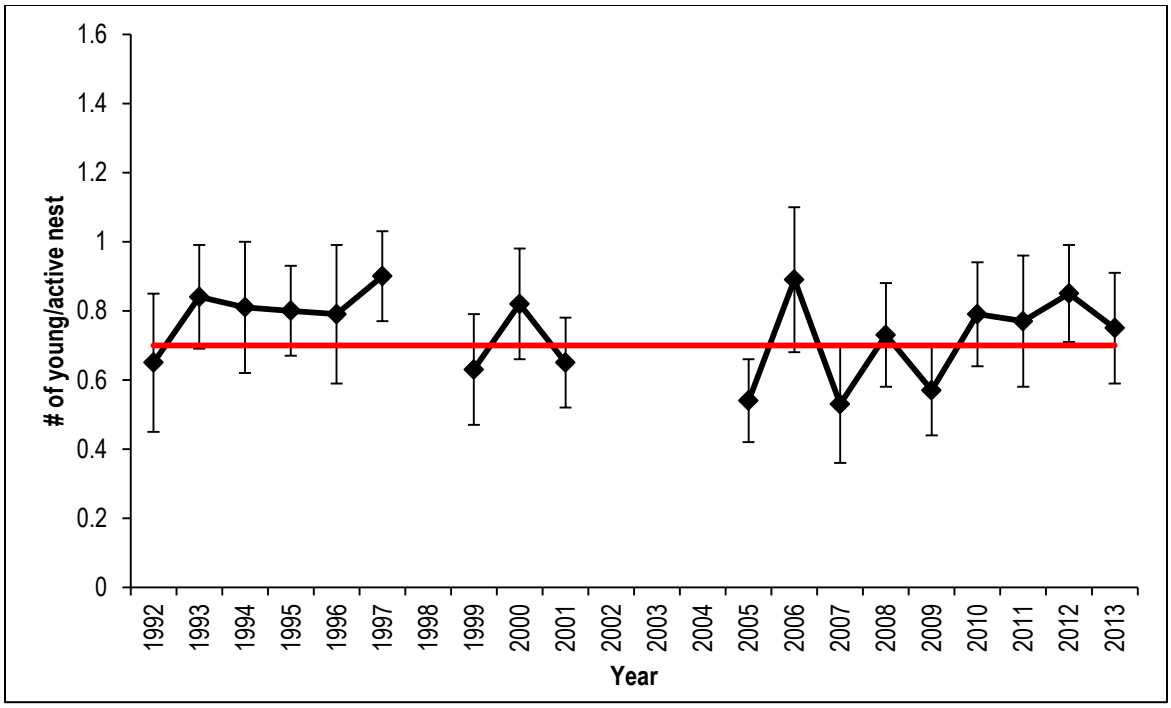


Figure 34. Number of young per active nest from 1992-2013 in the coastal region of LACL (NPS 2013a,b,c). The solid red line indicates the reference condition of 0.70 young/active nest (Sprunt et al. 1973).

In 2013, the number of young/active nest in the interior was 0.69 (Figure 33). This value is higher than 2012 (0.65 young/active nest), and is likely not a cause for concern to park managers. However, the region should continue to be monitored yearly in order to detect any potential long-term deviations from the reference condition. The number of young/active nest in the coastal region was 0.75 (Figure 34). Similar to the interior region, however, this area will need continued monitoring, as the 2013 value (despite being above the region's annual average) is the lowest productivity value the area has experienced since 2009 (0.57 young/active nest, which is the lowest value on record for the coast).

Yearly young/active nest values in the interior and coastal regions of the park do not appear to be closely linked. There were only two instances where the productivity of the interior and coast dropped below the threshold for stability (0.70 young/active nest) in the same year (1992, 2005). During other years, productivity varied greatly between regions. For example, in 2006, the productivity in the coastal region of LACL was 0.89 young/active nest (the second highest value recorded for this region), while the productivity in the interior of the park was the lowest in recorded history (0.4 young/active nest). Even more puzzling, the very next year (2007) productivity trends completely reversed and the interior region experienced the most productive season to date (1.27 young/active nest), while the coastal region experienced the lowest productivity in recorded history (0.53 young/active nest).

For both regions, instances where young/active nest values fell below the reference condition (0.70 young/active nest) corresponded to years where nest success also fell below (or was very near) the

reference condition (50% of pairs successful). Similarly, almost all years that had chick production values in excess of the reference condition also had nest success values above the reference condition (the exception being the coast in 2011, when productivity was 0.77 young/active nest but nest success was only 42%).

Number of Young/Successful Nest

Unlike nesting success and the number of young/active nest, a reference condition for the number of young/successful nest has not been established. For this assessment, the historic average for both the interior and coastal regions of LACL was used as a basis of comparison. The historic average for the interior of LACL is 1.40 (± 0.05 SE) young/successful nests, while the average for the coastal region of LACL is 1.38 (± 0.04 SE) young/successful nests.

The interior region of LACL has been below the historic average for 10 of the 19 years that have survey data available (Figure 35). Productivity in successful nests has ranged from 1.00 chick/successful nest (1996) to 1.87 chicks/successful nest (2007; Figure 35). The number of young/successful nest in 2013 was 1.58, which was the first time since 2008 that the region was above the historic average.

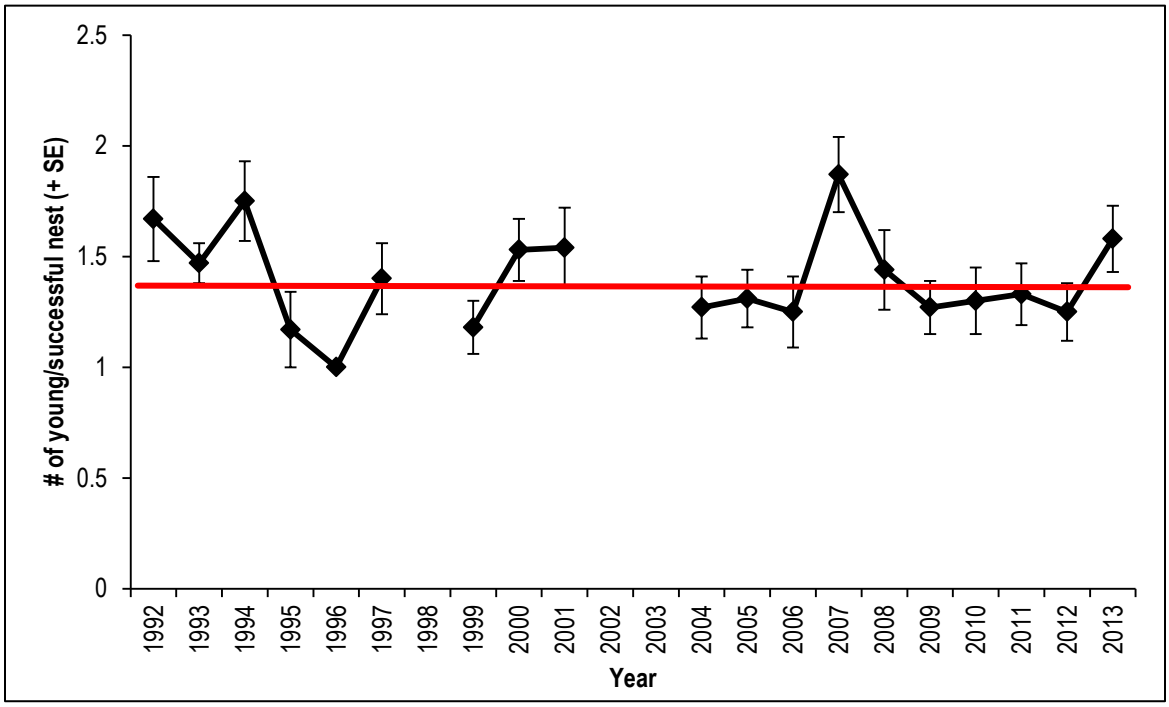


Figure 35. Number of young per successful nest from 1992-2013 in the interior region of LACL. The solid red line indicates the reference condition of 1.40 young/successful nest (NPS 2013a,b,c).

The coastal region of LACL has been below the historic average for 11 of the 18 years that have survey data available (Figure 36). Productivity in successful nests has ranged from 1.09 chicks/successful nest (2009) to 1.81 chicks/successful nest (2011). The number of young/successful nest in 2013 was 1.39, which is slightly above the historic average.

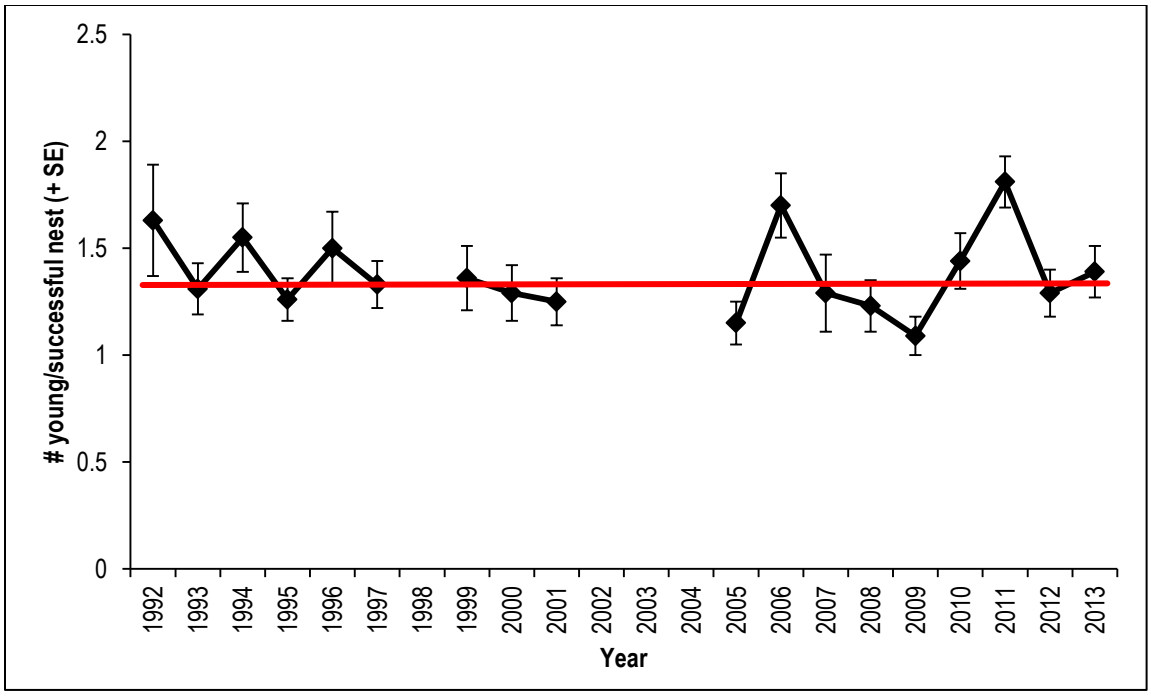


Figure 36. Number of young per successful nest from 1992-2013 in the coastal region of LACL. The solid red line indicates the reference condition of 1.38 young/successful nest (NPS 2013a,b,c).

Threats and Stressor Factors

Bald eagle populations face many threats from human-related activities: ecotourism; fishing (sport and commercial); timber harvest; and potential oil spills or other accidents along marine coastlines (Buehler 2000). In LACL, nesting bald eagles may experience stress from visitor use of the park; visitor activities that occur along the shoreline of the lakes and the coastline (e.g., boating, fishing, bear observation) could negatively impact the nesting population, as the majority of nests are located along LACL's shores.

Bald eagles are heavily dependent upon fish for their diet (Stalmaster 1987). In Alaska, salmon (Salmonidae family) often comprises a large portion of the eagle's diet (Grub and Hensel 1978, Stalmaster 1987), and a change in the abundance of these prey items could affect the mortality rates of the eagles in the park. Poor foraging conditions and scarcity of food forces adults to leave the vulnerable nestlings exposed for longer periods, thus increasing their chances of becoming hypothermic (Stalmaster 1987).

The introduction of contaminants into the food web (e.g., heavy metals, organochlorides, and other pesticides) could result in nesting failure, as observed in the continental U.S. population of bald eagles from the 1940s-1970s (Sprunt and Ligas 1966, Anthony et al. 1999, Buehler 2000). While Alaska was thought to have been less affected by the use of organochlorides, Anthony et al. (1999) found elevated levels of Dichlorodiphenyldichloroethylene (DDE;a metabolite of DDT), other organochlorides, and mercury in bald eagles of the Aleutian Islands. The bald eagles that had the highest concentration of these toxins had diets that were dominated by avian species, and lived in areas that were occupied by the military during World War II. More recently, Eagles-Smith et al.

(2014) found that mercury concentrations in Lake Clark exceeded the benchmarks for reproductive impairment in piscivorous birds. Furthermore, Flanagan-Pritz et al. (2014) found the presence of semi-volatile organic compounds (SOCS) (including pesticides, PCBs, and polycyclic aromatic hydrocarbons [PAHs]) in LACL fish. The concentration of these contaminants varied, and chlordanes were found in some samples to exceed health thresholds for piscivorous wildlife (specifically kingfishers) (Flanagan-Pritz et al. 2014).

DDT is still widely used in Japan and Russia as a pesticide (Anthony et al. 1999), and is present in Alaskan ecosystems. Anthony et al. (1999)'s suggestion that an avian diet may increase the risk of DDE in bald eagles may indicate the need for a prey base analysis in LACL. An analysis of the contaminant levels in LACL's bald eagle population may help to better understand the distribution of these chemicals across Alaska. Such a study would also help managers better gauge the health of the LACL bald eagle population.

According to Stalmaster (1987, p. 64), "cold, wet weather could directly influence the nesting pair by delaying the production of eggs until the weather improves." Analyzing data from 1992-2011, Witter and Mangipane (2011) found that the measures of productivity and nest success exhibited negative correlations in regards to both April-May and June-July precipitation in the park. Continued monitoring of this potential relationship is needed to examine the overall effect that precipitation levels have on bald eagle nesting success.

Other climate-related threats, such as temperature changes and the frequency of strong storms, may also alter the productivity and occupancy of bald eagles in LACL. Temperature changes can have dramatic effects on bird populations; timing of courtship, egg laying, and foraging are all closely tied to specific temperature ranges (Crick 2004). Temperature changes can also impact breeding success through, for example, chilling or starvation of young (Newton 1998, Crick 2004). Extreme weather shifts in the area (e.g., prolonged frozen spells, droughts) could have catastrophic effects on bald eagle nesting success (Crick 2004).

Data Needs/Gaps

The park has established an excellent survey protocol and has a wealth of nesting information for almost 30 years. However, there are still several areas in need of additional research in order to fully understand the bald eagle population of the park. Many of the data gaps that exist are related to current or potential threats that face the bald eagle population in the park. Because of the well-publicized plight of bald eagles in the lower 48 states, the most discussed threats to the species are DDT and other contaminants. In LACL, no contaminant analysis has been conducted on the eagle population.

Survey data from the interior and coastal populations show considerable annual variations in productivity. The cause of these variations, whether natural fluctuations, broad-scale threats, or an unknown factor, should be investigated in order to understand the dynamics of these birds in the park.

There has been no study related to the diet of bald eagles in the park, specifically in regards to any potential differences in diet between the coastal and interior populations. Prey base fluctuations may correspond with eagle productivity fluctuations, although this is only speculatory. While salmon is likely a critical component of the eagle's diet (Grubb and Hensel 1978, Stalmaster 1987), migratory waterfowl, carrion, and other mammalian species may make up a portion of the species' diet as well. Annual variations in salmon population size or escapement may contribute to fluctuations in eagle nesting success (Anthony 2001), and the shifts in the phenology of migratory waterfowl may also be contributing to the variability in eagle productivity.

While changes in migratory waterfowl phenology may be a threat, migratory patterns and initiation periods for bald eagles are often heavily influenced by climate (USGS 2011). Some climatic variables have been investigated in the park, namely the correlation between wind, precipitation, and temperature to bald eagle productivity. Expanded research on climatic variation and bald eagle nesting success would be beneficial to park researchers, and may provide vital information regarding annual variation and its link to bald eagle productivity.

Overall Condition

While the park has data related to the specified measures spanning 1984-2013, only data obtained after 1991 were used when considering the current condition and trend of the bald eagles in the park. Data from the 1984-1991 surveys are difficult to analyze and summarize as no standard survey protocol was followed, nests were not assigned unique identifiers, and nest locations (interior/coastal) were not recorded (Witter and Mangipane 2011).

Nest Occupancy

LACL staff assigned nest occupancy a *Significance Level* of 3, and analysis of the available data resulted in the designation of a *Condition Level* of 1. In 2013, the number of active nests in both regions of LACL were above average (22 active nests in interior [20.15 avg.]; 36 active nests on coast [24.2 avg.]); however, the occupancy rate of the interior was only 42% (below the historic average of 56%), while the coastal region was slightly above average at 57% (historic average of 56%).

There has been no apparent pattern between the occupancy rates in the two regions of the park; both of these regions have been highly variable from year to year, and a year or two below average in regards to this measure has not necessarily indicated a declining trend. Continued monitoring and analysis may help managers to identify long-term trends as they develop.

Productivity

The productivity measure was assigned a *Significance Level* of 3 during LACL scoping meetings. Productivity in LACL is analyzed looking at three metrics: percent of active nests successful, number of young per active nest, and number of young per successful nest. For this assessment, each of these productivity metrics was looked at individually for both the interior and coastal regions of the park, SMUMN GSS then used this information to assign an overall *Condition Level* for the measure.

The percent of active nests successful in LACL was highly variable in both regions of the park. The interior region fell below the 50% reference condition in seven of the 19 years for which data were available, and the average number of active nests successful in a year was 55% (above the reference condition). In 2013, the average number of active nests successful in the interior was 50%, which falls directly in line with the established reference condition. The coastal region fell below the 50% reference condition in only five of the 18 years for which data were available. The average number of active nests successful in a year was 54% (slightly lower than the interior's average, but still above the reference condition). In 2013, the coastal region of the park had 44% of the active nests successful, which is below the established reference condition.

Similarly, the number of young per active nest was also highly variable in both regions of LACL. The interior region of the park fell below the 0.70 young/active nest reference condition in nine of the 19 years for which data are available, while the coastal region fell below the reference condition in six of 18 years. The average number of young per active nest in each region from 1992-2013 was above the established reference condition of 0.70 (Interior: 0.78; Coast: 0.74). In 2013, the average number of young per active nest in the interior was 0.69, which is just below the reference condition. The coastal region's average was 0.75, which is above the established reference condition. There did not appear to be a pattern between the two regions in regards to this measure; however, statistical analysis is needed to better understand any potential relationship.

The reference condition for the number of young per successful nest was the historic average for the interior and coastal regions of LACL. In the interior region, the reference condition was 1.40 young/successful nest, and the population fell below the reference condition in 10 of the 19 years where survey data were available. In 2013, the number of young per successful nest was 1.58, which is above the reference condition for this region. In the coastal region, the reference condition was 1.38 young/successful nest, and the population fell below the reference condition in 11 of 18 years. In 2013, the coastal region had 1.39 young/successful nest, which is slightly above the historic average/reference condition.

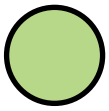
The two regions of the park are highly variable, and no clear pattern or relationship was visible when looking at the data. It appears that the populations are self-sustaining and are meeting all reference conditions, but with yearly fluctuations it is difficult to ascertain current trends accurately. A *Condition Level* of 1 was assigned to the productivity measure.

Weighted Condition Score (WCS)

The *Weighted Condition Score* for bald eagles is 0.33, indicating a component of Good Condition, and this WCS is assigned with high confidence. This WCS is at the upper limit of the good condition designation (nearing moderate concern), and the component should continue to be monitored annually to observe any potential trends or signs of degradation.

A trend arrow was not assigned to this measure, not because of a lack of data, but rather because of the highly variable data that exist for both measures. Fluctuations above and below the reference condition for these two measures happened extremely frequently, sometimes on a yearly basis.

Furthermore, the two distinct regions of nesting eagles make assigning a single trend graphic difficult.

Bald Eagles			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.33**
Nest Occupancy	3	1	
Productivity	3	1	

4.7.6 Sources of Expertise

Buck Mangipane, LACL Wildlife Biologist

4.7.7 Literature Cited

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4.8 Salmon

4.8.1 Description



Photo 18. Sockeye salmon preparing to spawn (NPS photo).

Five species of salmon are found within LACL waters: pink salmon (*Oncorhynchus gorbuscha*), chum salmon (*O. keta*), silver salmon (*O.kisutch*), sockeye salmon (*O. nerka*) (Photo 18), and king salmon (*O. tshawytscha*) (NPS 2015). Sockeye salmon are the primary species for both sport and subsistence fishing in and around LACL (Deschu 2003). LACL was specifically established by ANILCA "to protect the watershed necessary for perpetuation of the [sockeye] salmon fishery in Bristol Bay" (NPS 2011, p. 1). Sockeye salmon are the second most abundant (with pink salmon being the most abundant) species of salmon in North America (McNeil and Bailey 1975).

The salmon component for this NRCA was not finished prior to the publication of this document. This component will be published at a later date as an addendum to this document.

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4.9 Resident Fish

4.9.1 Description



Photo 19. Arctic grayling from an Alaskan lake (photo by Jacob Zanon, SMUMN GSS, 2011).

NPS (2014) identifies 46 native fish species as being present or probably present in LACL. Resident fish (i.e., non-migratory) are easily sampled and can provide insight into the environmental contaminants, changes in the food chain, and ecological health for the water bodies they inhabit (NPS 2012). Native fish are highly sought after by anglers and provide economic stimulation to the Southwest Alaskan Peninsula (NPS 2012). Native fish, including the Arctic grayling (*T hymallus arcticus*), rainbow trout (*Oncorhynchus mykiss*), Dolly Varden (*Salvelinus malma*), and lake trout (*Salvelinus namaycush*) are commonly targeted by sport fishing anglers (Photo 19).

The resident fish component for this NRCA was not finished prior to the publication of this document. This component will be published at a later date as an addendum to this document.

4.9.2 Literature Cited

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4.10 Air Quality

4.10.1 Description



Photo 20. Clear day in LACL (Photo by Andy Nadeau, SMUMN GSS 2013).

Air pollution can significantly affect natural resources and their associated ecological processes, and the health of park visitors. Consequently, air quality in parks and wilderness areas is protected and regulated through the 1916 Organic Act and the Clean Air Act of 1977 (CAA) and the CAA's subsequent amendments. The CAA defines two distinct categories of protection for natural areas, Class I and Class II airsheds. Class I airsheds receive the highest level of air quality protection as offered through the CAA; only a small amount of additional air pollution is permitted in the airshed above baseline levels. For Class II airsheds, the increment ceilings for additional air pollution above baseline levels are slightly greater than for Class I areas and allows for moderate development (EPA 2013). LACL is classified as Class II air quality area (Bennett et al. 2006).

Parks designated as Class I and II airsheds typically use the EPA's National Ambient Air Quality Standards (NAAQS) for criteria air pollutants as the ceiling standards for allowable levels of air pollution. The EPA believes these standards, if not exceeded, protect human health and the health of natural resources (EPA 2013). The CAA also establishes that current visibility impairment in these areas must be remedied and future impairment prevented (EPA 2013). However, the EPA acknowledges that the current NAAQS are not necessarily protective of ecosystems and is currently developing secondary NAAQS for ozone, nitrogen, and sulfur compounds to protect sensitive plants, lakes, streams, and soils (EPA 2010, 2011). To comply with CAA and NPS Organic Act mandates, the NPS established a monitoring program that measures air quality trends in many park units for key air quality indicators, including atmospheric deposition, ozone, and visibility (NPS 2008).

During initial project scoping, project stakeholders identified air quality as a placeholder component. These components are recognized in the assessment as an important resource for the park and preserve, but little or no data exist to examine its current condition. Available data will be summarized; however, condition will not be assessed. A description of the component, available data, and potential threats and stressors are provided for the primary purpose of inclusion in a future assessment when appropriate data are available.

4.10.2 Reference Conditions/Values

The NPS Air Resources Division (ARD) developed an approach for rating air quality conditions in national parks based on the current NAAQS, ecosystem thresholds, and visibility improvement goals (Table 72) (NPS 2010). Assessment of current condition of nitrogen and sulfur atmospheric deposition is based on wet (rain and snow) deposition. Ozone condition is based on the NAAQS standard of 75 parts per billion (ppb) (an annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years). Visibility conditions are assessed in terms of a Haze Index, a measure of

visibility (termed deciviews) that is derived from calculated light extinction and represents the minimal perceptible change in visibility to the human eye (NPS 2010). Finally, NPS ARD recommends the following values for determining air quality condition (Table 72). The "good condition" metrics may be considered the reference condition for LACL.

Table 72. National Park Service Air Resources Division air quality index values (NPS 2010).

Condition	Ozone concentration (ppb)	Wet Deposition of N or S (kg/ha/yr)	Visibility (dv*)
Significant Concern	≥76	>3	>8
Moderate Condition	61-75	1-3	2-8
Good Condition	≤60	<1	<2

*a unit of visibility proportional to the logarithm of the atmospheric extinction; one deciview represents the minimal perceptible change in visibility to the human eye.

4.10.3 Data and Methods

Monitoring in the Park

The Visibility Information Exchange Web System (VIEWS) database provided average annual visibility monitoring data (in deciviews [dv]) and trend graphics for LACL at Silver Salmon Creek from 2002 through 2008 (VIEWS 2010). Figure 37 displays the locations of air quality stations in and around LACL.

An IMPROVE particulate sampler was installed at Silver Salmon Creek in LACL in 2002 and still operates today, providing data for assessment of long-term trends in visibility and for establishing baseline conditions and tracking progress in improving visibility under the regional haze program (Figure 37). The sampler began collecting 25 particulate matter parameters, but more than doubled the number of parameters sampled by 2002 (IMPROVE 2014). There are 46 parameters sampled in most years up to the present date.

NPS Data Resources

Although data on air quality parameters are not actively collected within park boundaries, data collected at a regional monitoring station for various parameters can be used to estimate air quality conditions in LACL. NPS ARD provides estimates of ozone, wet deposition of nitrogen and sulfur, and visibility that are based on data interpolations from all air quality monitoring stations operated by the NPS, the EPA, various states and other entities, averaged over the most recent five years (e.g., 2008-2012). These estimates are available from the Explore Air website (NPS 2014) and are used to evaluate air quality conditions. On-site or nearby data are needed for a statistically valid trends analysis, while a 5-year average interpolated estimate is preferred for the condition assessment. It should be noted that ozone and wet deposition of nitrogen and sulfur were not estimated for LACL.

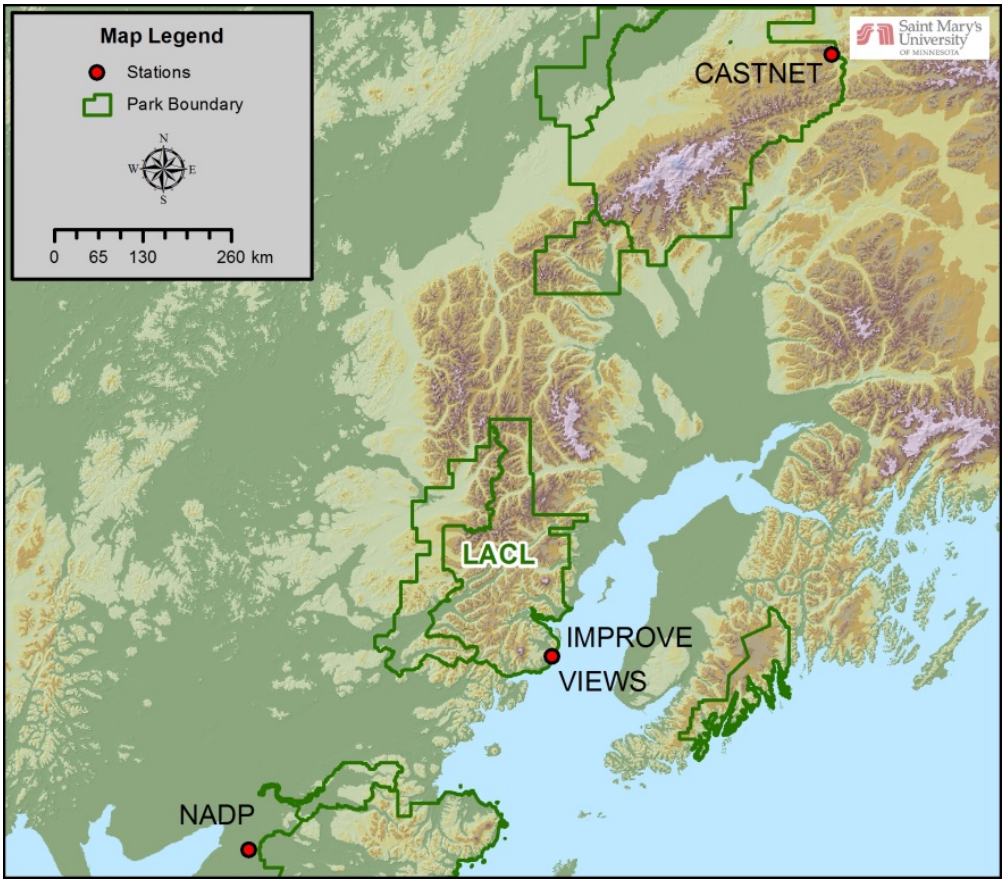


Figure 37. Air quality stations in and around LACL.

Other Air Quality Data Resources

The National Atmospheric Deposition Program (NADP) database provides annual average summary data for nitrogen and sulfur concentration and deposition across Alaska. NADP is a cooperative effort between many governmental and non-governmental agencies, educational institutions, and private companies to monitor precipitation chemistry (NADP 2014). 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). The nearest NADP monitoring site is located at King Salmon, Alaska (site ID: AK97), which is over 80 km (50 mi) south of LACL. Results from monitors located within 16 km (10 mi) from parks are generally considered to be representative of park conditions (Ellen Porter, NPS Air Resources Division Air Quality Specialist, phone communication, 25 October 2012). Data recorded at monitors beyond this distance from parks may represent regional conditions, but may not be representative of actual park conditions. There are no NADP network sites located within LACL or within a relevant distance for the condition assessment (Figure 37).

The Clean Air Status and Trends Network (CASTNET) provide summaries of the composition of nitrogen and sulfur deposition in various regions around the U.S. CASTNET began in 1991 under the CAA Amendments, and it provides long-term regional environmental monitoring (EPA 2007). Each sampler collects data for one-week from 10 m (33 ft) above ground. There have been four sites in

Alaska, but only the Denali site is still active (Figure 37). No CASTNET data have been collected in LACL. The distance and the variations in terrain make it difficult to extrapolate data accurately; thus, data from these monitoring stations were not considered in this assessment.

Special Air Quality Studies

Walton et al. (2011) conducted an airborne contaminants monitoring survey in SWAN using the common moss *Hylocomium splendens*. Moss samples were taking opportunistically and at long-term vegetation monitoring plots between 2008 and 2009. Monitoring sites in LACL were sampled in 2008 (Figure 38). Plastic lined containers and powderless latex gloves were used to collect 1-2 liters (0.26 ga) of moss, and samples were sent to the University of Minnesota Research Analytical Laboratory to be analyzed. Standard combustion methods were used to determine the concentrations of total sulfur, total nitrogen and nitrate. Emission spectrometry was used to detect other elements (Al, B, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, Zn).

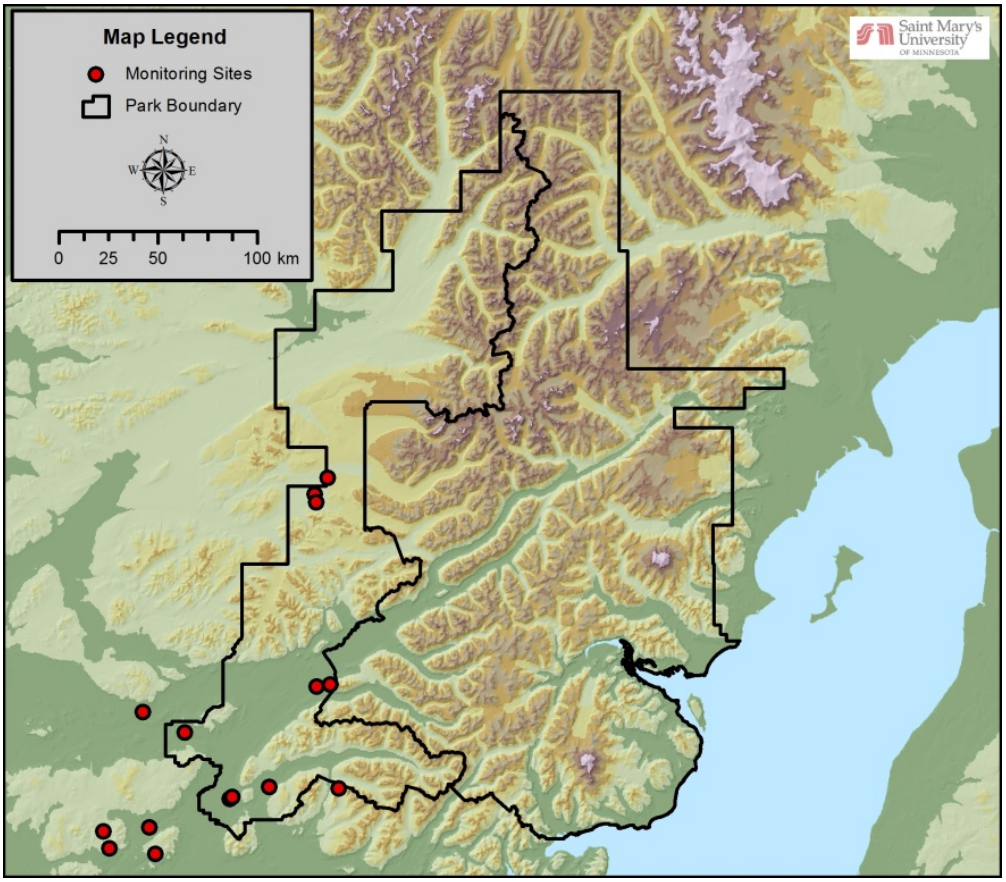


Figure 38. Airborne contaminant monitoring sites in LACL sampled in 2008 (Walton et al. 2011).

Moss and lichen studies are important and should be considered when assessing air quality. Lichen and moss are considered ecological indicators of environmental health due to their sensitivity to air pollution and habitat degradation (APIS 2014). Some lichen species are specifically sensitive to certain high concentrations of pollutants such as sulfur, nitrogen, acidity, halogens, heavy metals, and even ozone (APIS 2014). The presence of tolerant lichen species could also be an indicator of poor

air quality. If air quality is very poor, there would be an absence of lichen. According to APIS (2014), *Lobaria*, *Ramalina*, and *Usnea* spp. may be particularly sensitive to high sulfur dioxide concentrations, while *Bryoria*, *Parmeliopsis*, *Pseudevernia*, and *Rinodina* spp. are more tolerant. Acid rain and ammonium in precipitation cause declines in *Bryoria capillaris*, *B. fuscenscens*, *Imshaugia aleurites*, *Chaenotheca ferruginea*, and *Lobarion* spp., but species such as *Lecanora pulicaris* may thrive in higher acidities (APIS 2014). There are also nitrogen sensitive and tolerant moss species. More tolerant moss species include *Eurynchium praelongum* and *Brachythecium rutabulum*, while more sensitive species include *Pleurozium schreberi* (APIS 2014).

4.10.4 Summary of Past Study

VIEWS (2010)

In addition to providing average annual visibility monitoring data, VIEWS also examines the clearest and haziest 20% of days each year (NPS 2009). Conditions measured near 0 dv are clear and provide excellent visibility, and as dv measurements increase, visibility conditions become hazier. Figure 39 depicts visibility data (in dv) collected in LACL at Silver Salmon Creek for the 20% best (clearest) and 20% worst (haziest) days, as well as the default natural conditions for both (VIEWS 2010). Trend analysis of data from 2002-2008 indicate visibility to be of moderate condition on the clearest days and of significant concern on the haziest days.

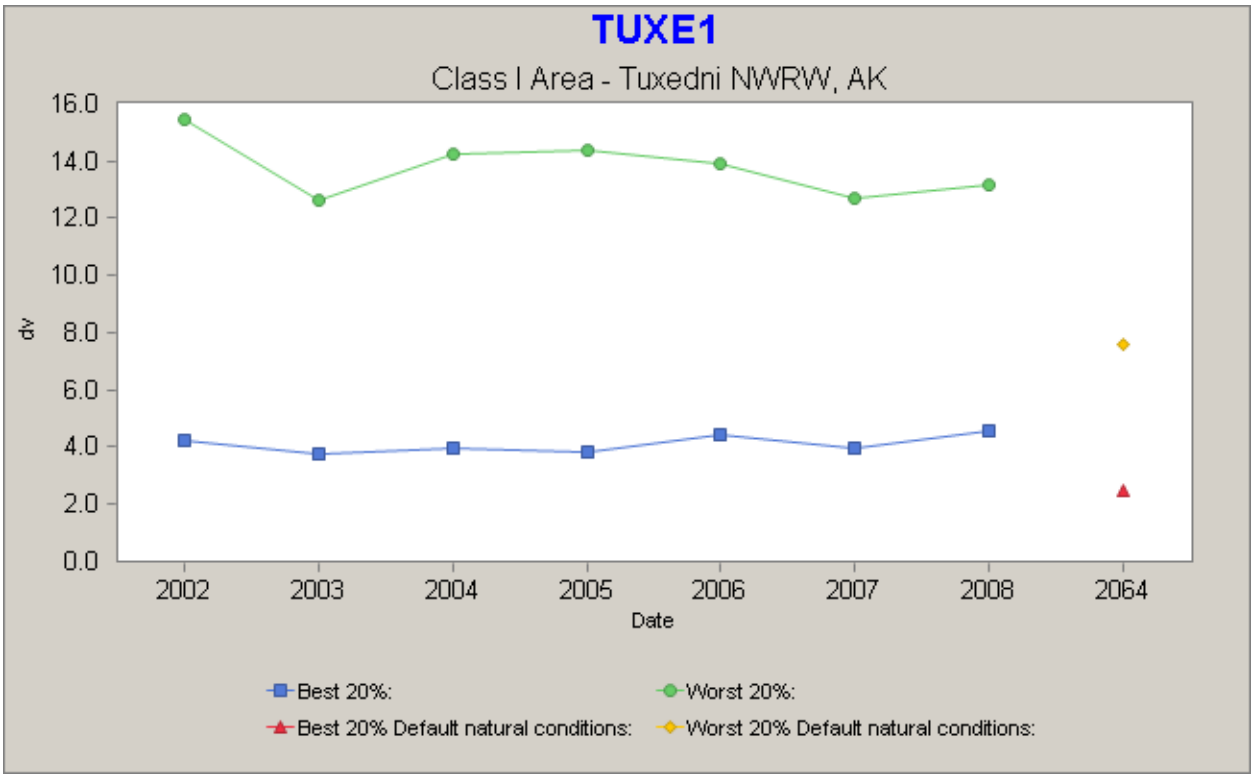


Figure 39. Annual visibility at Tuxedni, 2002-2008 (Tuxedni is located near the Southeast border of LACL) (VIEWS 2010). Values at 2064 are the natural background visibility conditions, set by EPA Regional Haze Rule.

Walton et al. (2011)

Walton et al. (2011) collected preliminary dry weight concentrations of six trace elements found in *H. splendens* in LACL in 2008. According to Walton et al. (2011), the concentrations for each element were considered background levels, or typical levels, found within other studies in Alaska and Europe. Percent total nitrogen ranged from 0.75 to 1.34%, and percent total sulfur ranged from 0.05 to 0.11%. Mercury concentrations ranged from 20.0 ng/g to 60 ng/g at LACL sites. Cadmium concentrations ranged from less than 0.13 mg/kg to 0.32 mg/kg. Copper was lower in LACL than other SWAN parks, ranging from 2.0 mg/kg to 5.0 mg/kg. Lead concentrations were also lower in LACL with concentrations less than 0.68 mg/kg. Figure 40 displays the preliminary baseline concentration of each trace element found in *H. splendens* at the SWAN monitoring sites.

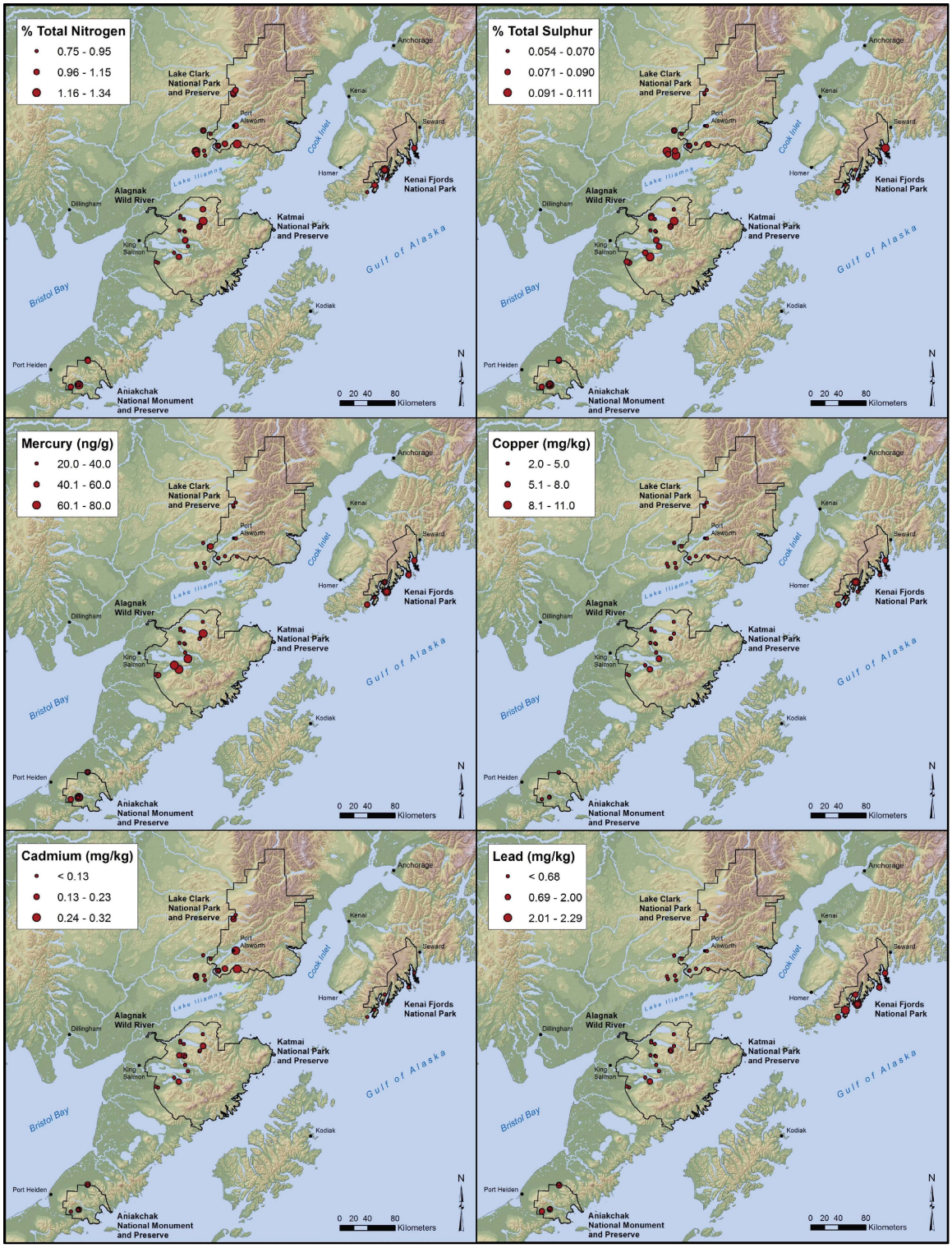


Figure 40. Preliminary baseline concentration of each trace element found in *H. splendens* at the SWAN monitoring sites (recreated from Walton et al. 2011).

NPS (2014)

The most current 5-year average (2008-2012) estimates average visibility in LACL to be 7.1 dv above average natural visibility conditions (NPS 2013, 2014). This falls into the *Moderate Condition* category for NPS air quality condition assessment (NPS 2013). It should be noted that these data were collected from a representative monitor near the park but were used for this report due to the lack of a monitor in LACL.

The clearest and haziest 20% of days each year are also examined for parks (NPS 2012), as these are the measures used by states and the EPA to assess progress towards meeting the national visibility goal. Conditions measured near 0 dv are clear and provide excellent visibility, and as dv measurements increase, visibility conditions become hazier. The most current 5-year average (2008-2012) estimates visibility at LACL at 4.0 dv on the 20% clearest days and 12.3 dv on the 20% haziest days (NPS 2014). On the 20% clearest days, visibility falls into the *Moderate Condition* category.

IMPROVE (2014)

Data on average particulate matter concentrations in LACL are available from 2002 through 2013, and are summarized as an annual average concentration and average concentrations on the 20% haziest and 20% clearest days in the park (IMPROVE 2014). Overall, average annual $PM_{2.5}$ concentrations in LACL have been decreasing since 2006 (Figure 41). $PM_{2.5}$ is the main cause of haze; as concentrations of fine particulate matter increase, haze also increases. The NAAQS human health-based standard for $PM_{2.5}$ is a weighted annual mean of 15.0 µg/m^3 or 35 µg/m^3 in a 24-hour period over an average of 3 years (EPA 2014a). Although $PM_{2.5}$ concentrations in LACL are well within the EPA standards for levels that are protective of human health, concentrations on the haziest days contribute significantly to impaired visibility in the park.

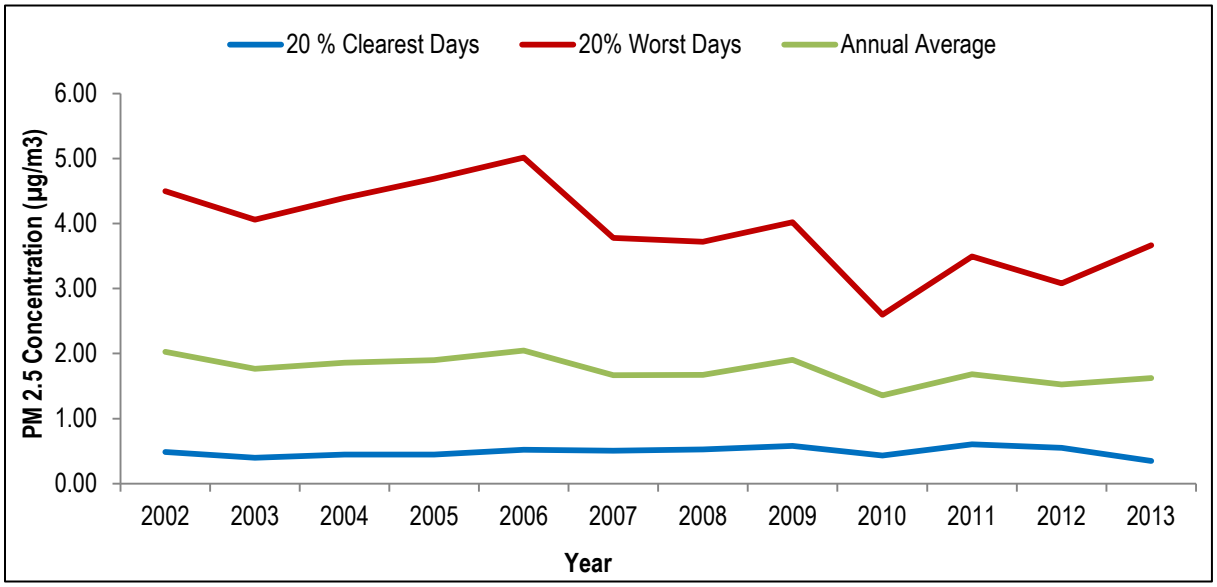


Figure 41. Particulate matter ($PM_{2.5}$) concentration in LACL, 2002 - 2013 (Source: IMPROVE 2014).

Threats and Stressor Factors

Potential threats to the air quality in LACL include anthropogenic fugitive dust from resource development, the release of natural gases and coal dust into the air, oil and gas development, and the long-range transport of air pollutants as well as particulates from natural sources such as wildfire smoke, pollen, and airborne glacial silt.

Fugitive dust is a type of particulate matter created from open air operations and is not filtered. Sources of fugitive dust include unpaved roads/runways, mining, transportation of uncovered mineral materials, blasting, gravel operations, and construction operations (ADEQ 2011). Port Alsworth has two unpaved runways that may contribute fugitive dust in the park (Figure 42).

According to Exponent (2001), controlling the amount of fugitive dust has been of high priority in Alaska. Additional measures have had to be taken due to the presence of this dust and emissions found on moss (ecological indicator) near Red Dog Mine and the Delong Mountain Transportation System in Northwestern Alaska. An increase in fugitive dust emissions reduces visibility and increased sulfur and nitrogen in the atmosphere resulting in diminished air quality (NPCA 2009).

Oil and gas operations and development near LACL also pose a threat to the park's air quality. According to USFWS (2012), operations in Cook Inlet pose a threat to the air quality in Alaska Maritime National Wildlife Refuge. Volatile organic compounds are released from natural gas production and emissions. These compounds result in smog which decreases visibility and, as a result of that, degrades air quality (EPA 2014b). Oil and gas activity is expected to increase in Cook Inlet with lease sales planned in the near future.

Long-range transport of air pollutants is another threat to air quality in LACL. Prevailing winds are what carry emissions such a great distance. Some of the emissions may fall into the Pacific Ocean, but large amounts of contaminants stay in the atmosphere (Kirby 2011). According to Jaffe et al. (1999), air quality in North America (e.g., North Pacific Region) is greatly impacted by emissions created in the East Asian Region. Sulfur dioxide, carbon dioxide, and nitrogen oxides are examples of emissions that have been increasing in East Asia (Elliot et al. 1997, Van Aardenne et al. 1999; as cited by Jaffe et al. 1999). Between the 1970s and 1990s, there has been an average increase of approximately 4% per year in nitrogen oxide and sulfur dioxide emissions (Jaffe et al. 1999). Long-range transport of emissions has been known to only take approximately six days to cross the Pacific Ocean and reach the western coast of North America (Jaffe et al. 1999).

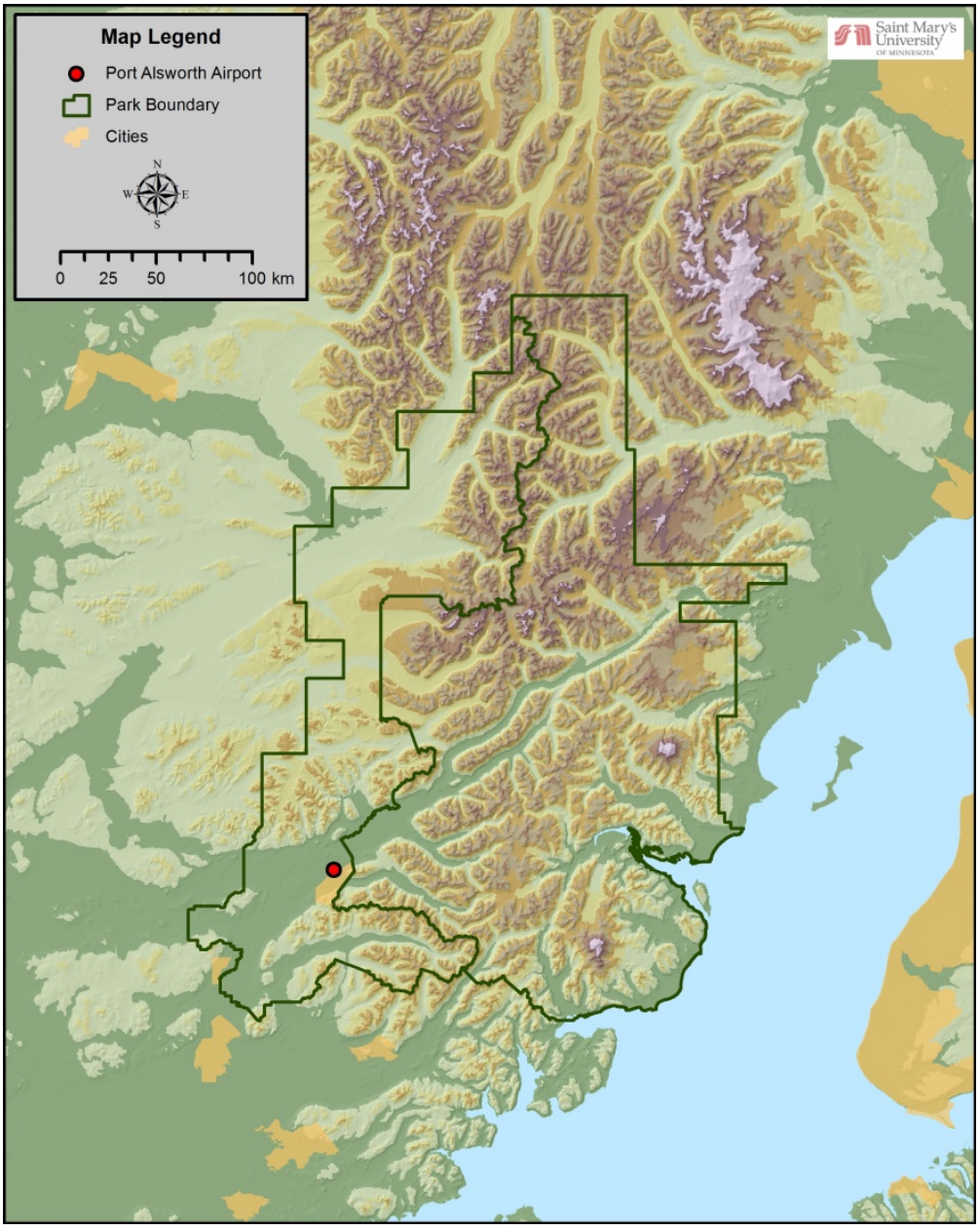


Figure 42. Port Alsworth airport, located in LACL.

Data Needs/Gaps

Wet and dry deposition and ozone monitoring programs are needed in order to more confidently report on the condition of air quality within the park. As a high precipitation region, it is more susceptible to wet deposition. More information regarding visibility from the Silver Salmon Creek IMPROVE station would be useful. Silver Salmon Creek reported lower concentrations of particulate matter compared to the EPA standards for human health. The IMPROVE dataset is the longest air quality dataset for LACL and could provide useful baseline air quality information for comparison to future monitoring results.

4.10.5 Sources of Expertise

Paul Burger, NPS Alaska Regional Air Quality specialist

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4.11 Water Quality

4.11.1 Description

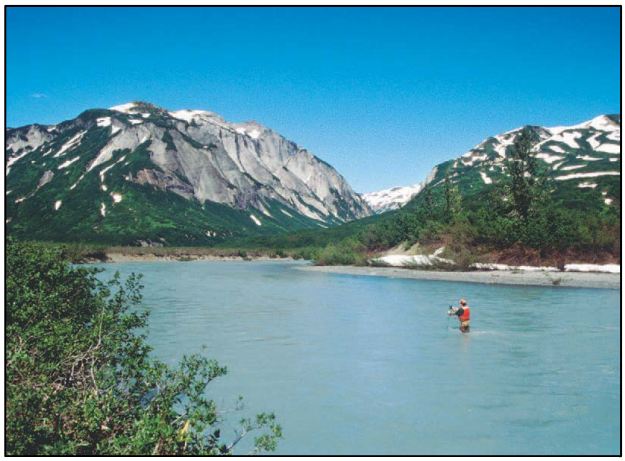


Photo 21. Data collection within the Johnson River, LACL. (USGS Photo).

Aquatic systems within SWAN parks are remote and pristine, providing researchers with an opportunity to examine the effects of climate change and atmospheric pollutants on intact systems. LACL is considered to have one of the most diverse collections of water resources of any SWAN park. LACL includes over 9,656 km (6,000 mi) of rivers and streams that flow through a variety of environments including glacial, volcanic, coastal, and freshwater ecosystems (Weeks 2003). Diversity of this nature causes water quantity and quality parameters of individual water bodies to be drastically different, even if relatively close geographically (Weeks 2003). Water quality analysis of physical and chemical characteristics can be important in understanding the aquatic community of a water body (NPS 2012, 2014). Researchers may use water quality analysis to explain the absence or extirpation of fish communities in habitats that appear suitable to sustain productive fish communities.

Currently, most water quality data for SWAN NPS units are limited to waters of specific management concern. A long term monitoring plan is in place to provide a broader spatial and temporal assessment of NPS waters (Shearer and Bartz 2015a). Specifically, SWAN intends to examine lake water quality parameters, both physical and chemical, along with data regarding other Vital Signs (e.g., surface hydrology, lake ice phenology, and glacial extent) to develop a more complete understanding of watershed dynamics (NPS 2012, 2014). The aforementioned parameters will be paired with other physical (temperature, turbidity, dissolved oxygen, etc.) and water chemistry (pH, specific conductivity, etc.) characteristics to gain a more in-depth understanding of how these dynamics influence water body productivity or fish reproductive success in LACL (NPS 2012, 2014).

During initial project scoping, project stakeholders identified water quality as a placeholder component. These components are recognized in the assessment as an important resource for the park and preserve, but data are often insufficient to determine current conditions or trends. Available data will be summarized; however, condition will not be assessed. A description of the component, available data, and potential threats and stressors are provided for the primary purpose of inclusion in a future assessment when appropriate data are available.

4.11.2 Data and Methods

Chamberlain (1988) conducted a study on the physical and biological characteristics of Lake Clark and nine other lakes within LACL from 1985 - 1987 (Figure 43).

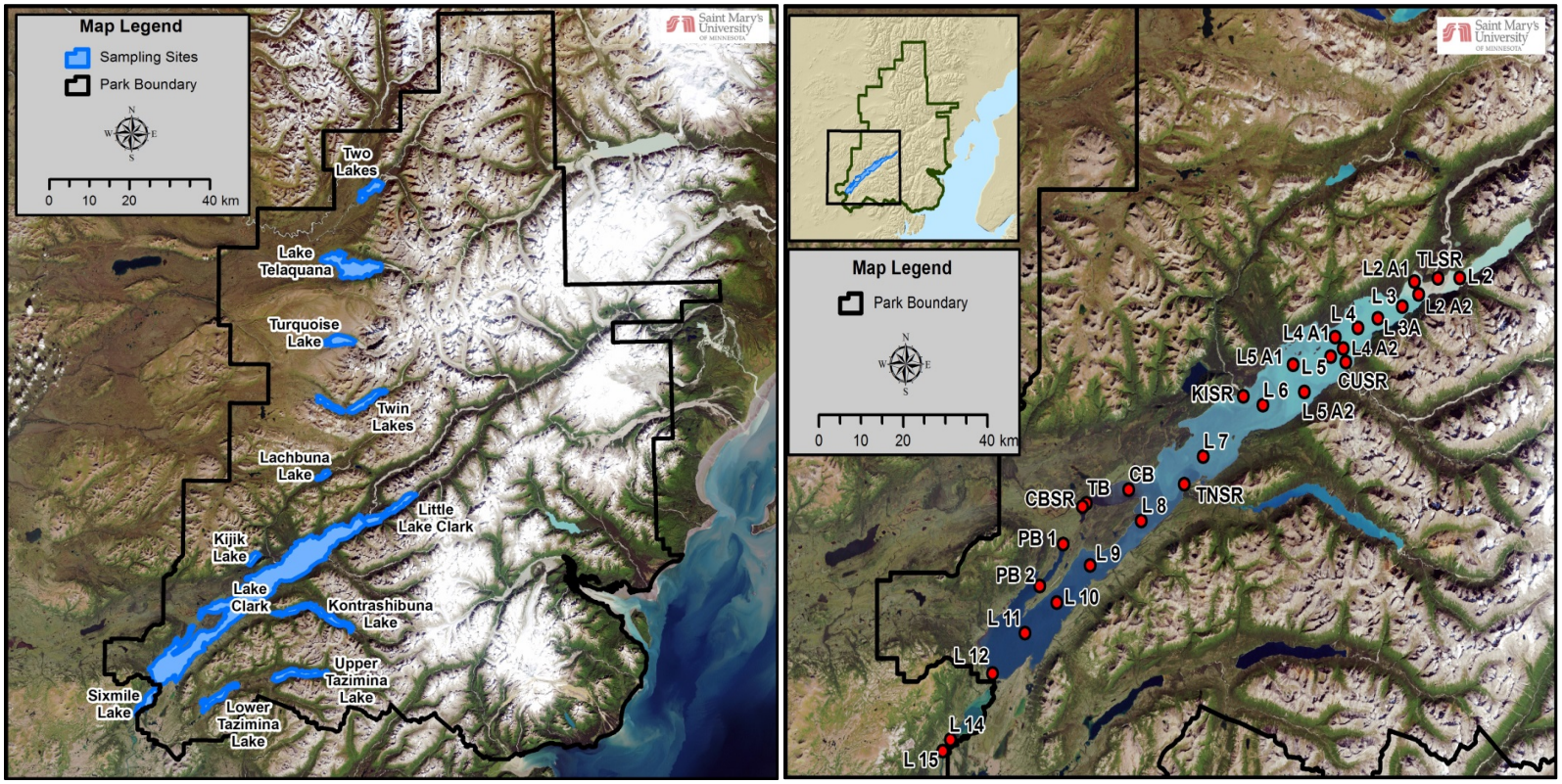


Figure 43. Park-wide lakes (left), and stations at Lake Clark (right) that were sampled for water quality in 1986 (Chamberlain 1988).

Chamberlain (1988) sample lakes include Upper Tazimina Lake (TZ1), Lower Tazimina Lake (TZ2), Kontrashibuna Lake (K), Turquoise Lake (TU), Kijik Lake (K13, K14), Telaquana Lake (TE), Lachbuna Lake (LB), Twin Lakes (TN), and Two Lakes (TW1). There were also several stations sampled on Lake Clark (Figure 43). Five different types of stations were established, including standard sampling, primary productivity, sediment, river, and bacterial sampling. Water quality parameters that were sampled include water temperature, dissolved oxygen (DO), and pH; ions of eight major nutrients, and metal concentrations were also included. The study also focused on the effects of nutrients in limiting primary productivity.

Brabets (2002) conducted a water quality study on the Tlikakila River and the five major tributaries of Lake Clark in 1999 and 2000 (Figure 44). Monthly data samples were collected between May and October to account for different stage and flow rates. A stream gage placed at the mouth of the Tlikakila River was used to collect the data. Water quality parameters recorded during this study include specific conductance, pH, water temperature, and DO. Ions from major nutrients were also collected. A precipitation gage located on the Tanaina Glacier was also used to collect data.

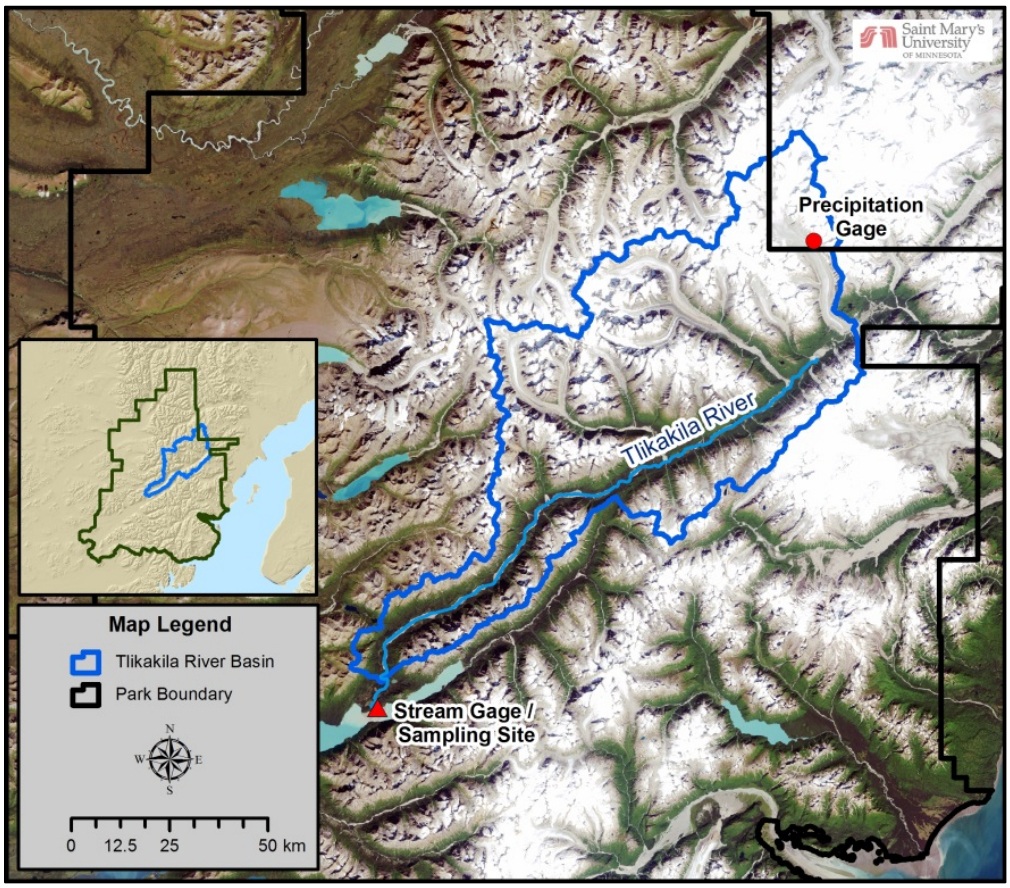


Figure 44. Locations of stream and precipitation gages in relation to the Tlikakila River Basin (Brabets 2002).

Wilkens (2002) conducted a limnology study of Lake Clark in LACL in 1999 and 2000. A mooring buoy was used to mark each of the five sampling stations (Figure 45). These sampling stations were originally used by Anderson (1969). Monthly samples were collectedbetween June and August of these years. Parameters sampled include DO, pH, conductivity, redox potential, water temperature, and total nutrients.

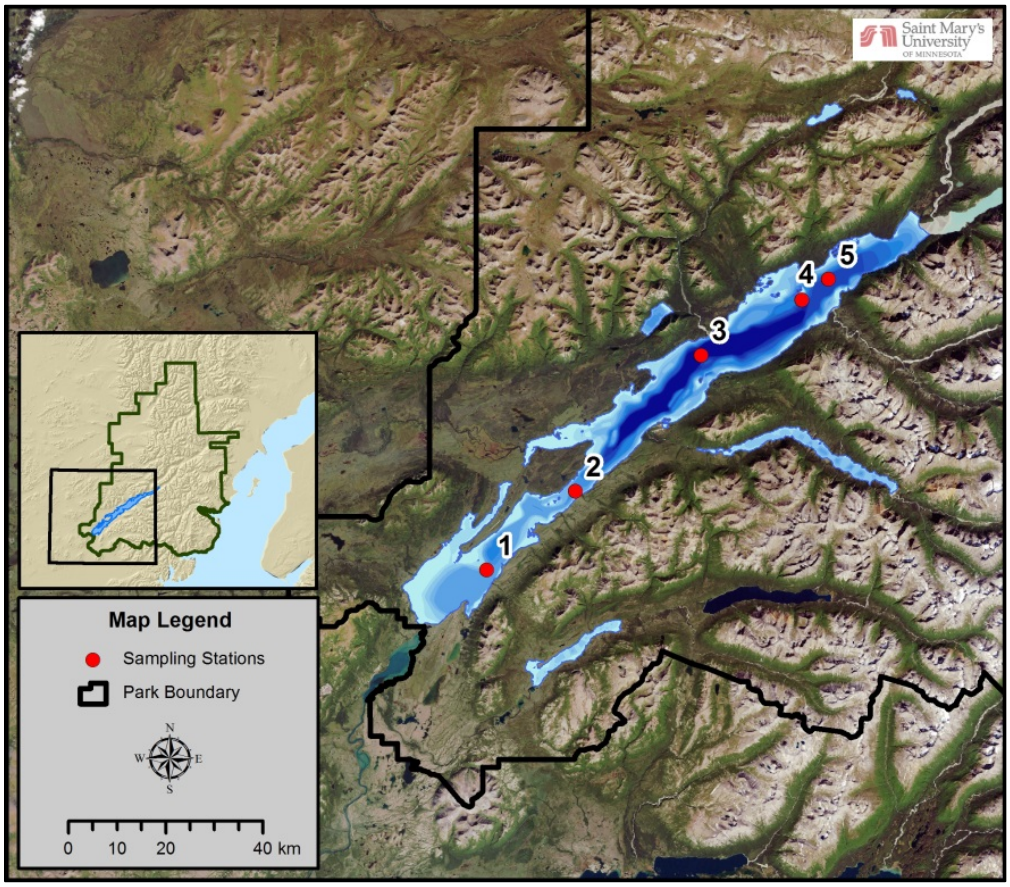


Figure 45. Sampling stations used in the Lake Clark limnology study (Wilkens 2002).

Brabets and Ourso (2006) conducted a water quality study of the Crescent River Basin in LACL in 2003 and 2004. Water samples were taken from three lake sites and three river sites. Stations 1 through 3 are USGS Stations (15294630, 15294640, 15294650), and Stations 4 through 6 are in Crescent Lake. Samples were taken between May and October of 2003 and 2004. A 6.2 liter acrylic Van Dorn sampler was used to collect water samples, a YSI meter was used to measure several water quality measurements (water temperature, DO, specific conductance, pH, and turbidity), and a Dopler current profiler was used to measure discharge. Trace elements were also measured from streambed sediment samples in the Johnson and Crescent Rivers.

Shearer and Moore (2010) conducted an annual water quality study in SWAN. Water quality data for Lake Clark was collected in the summer of 2009. River gaging and water monitoring were established in the Chulitna River in 2009 as a result of it being a major tributary of the high priority

water body (Figure 46). Continuous data from the Chulitna River gage was collected with a YSI 6600V2 multiparameter sonde. This device collected data on the core water quality parameters (water temperature, DO, pH, turbidity, and specific conductivity).

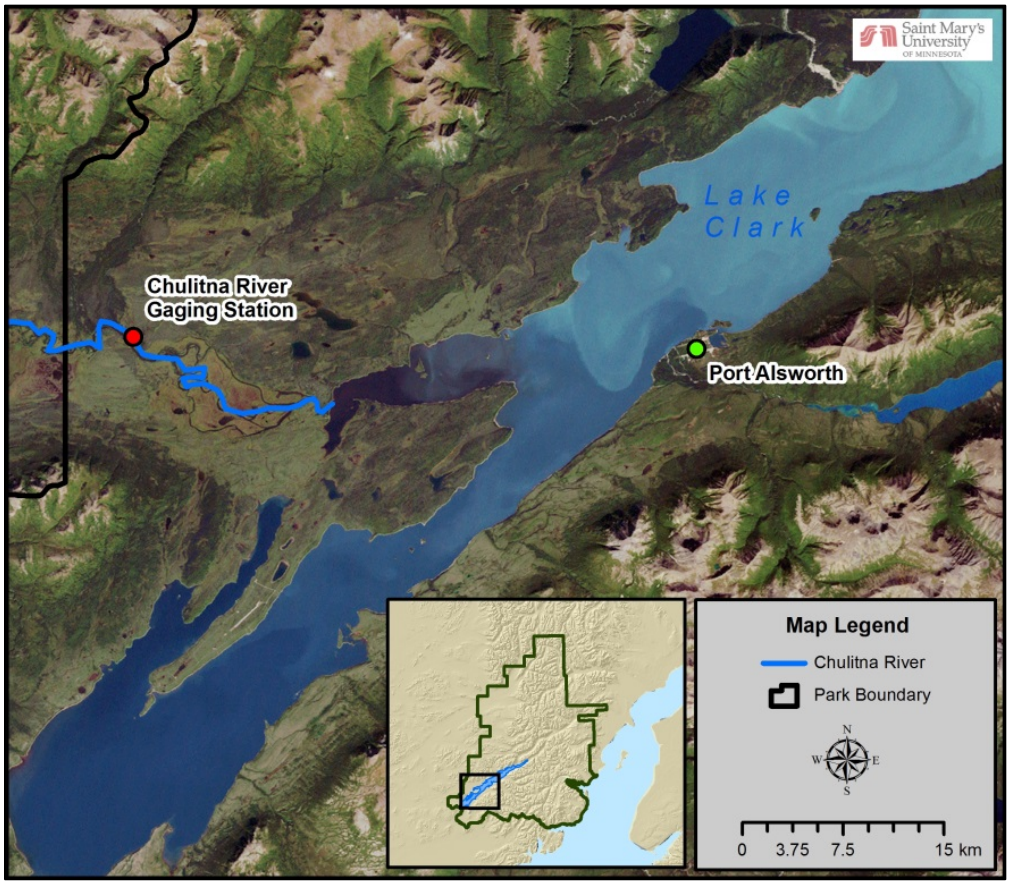


Figure 46. Location of Chulitna River gaging station in relation to Lake Clark and Port Alsworth (USGS 2010, 2011, 2013, 2014).

USGS (2010, 2011, 2012, 2013) compiled water quality data for the Chulitna River Station in LACL for the 2010, 2011, 2012, and 2013 water years. A water year, as defined by the USGS (2014b), begins 1 October and runs through 30 September. The USGS Chulitna River Station has a drainage area of 2,901 km^2 (1,120 mi^2). The location of this gaging station is 8 km (5 mi) upriver from where the Chulitna River enters into Lake Clark (Figure 46). The water quality parameters that were collected include stream specific conductance, pH, water temperature, barometric pressure, DO, and turbidity. Several trace element concentrations were also included in these data summaries (Appendix PP - Appendix QQ).

USGS (2014a) compiled water temperature data for the USGS Chulitna River Station in LACL for the 2014 water year. Most data at this station is taken at 15 minute increments; however, some months only have one days-worth of data or one measurement taken for several days in a month. It should be noted that this dataset is considered provisional, and that revisions could be made to this data after the publication of this document.

USGS (2015) compiled water quality data from the Johnson River in LACL between 1999 and 2004. Samples were collected at the USGS Johnson River stream gage (USGS # 1529470) (Figure 47). The stream gage is approximately 6.4 km (4 mi) from the headwaters at the terminus of Johnson Glacier The water quality parameters that were sampled at this station include temperature, pH, and DO, specific conductance, and turbidity.

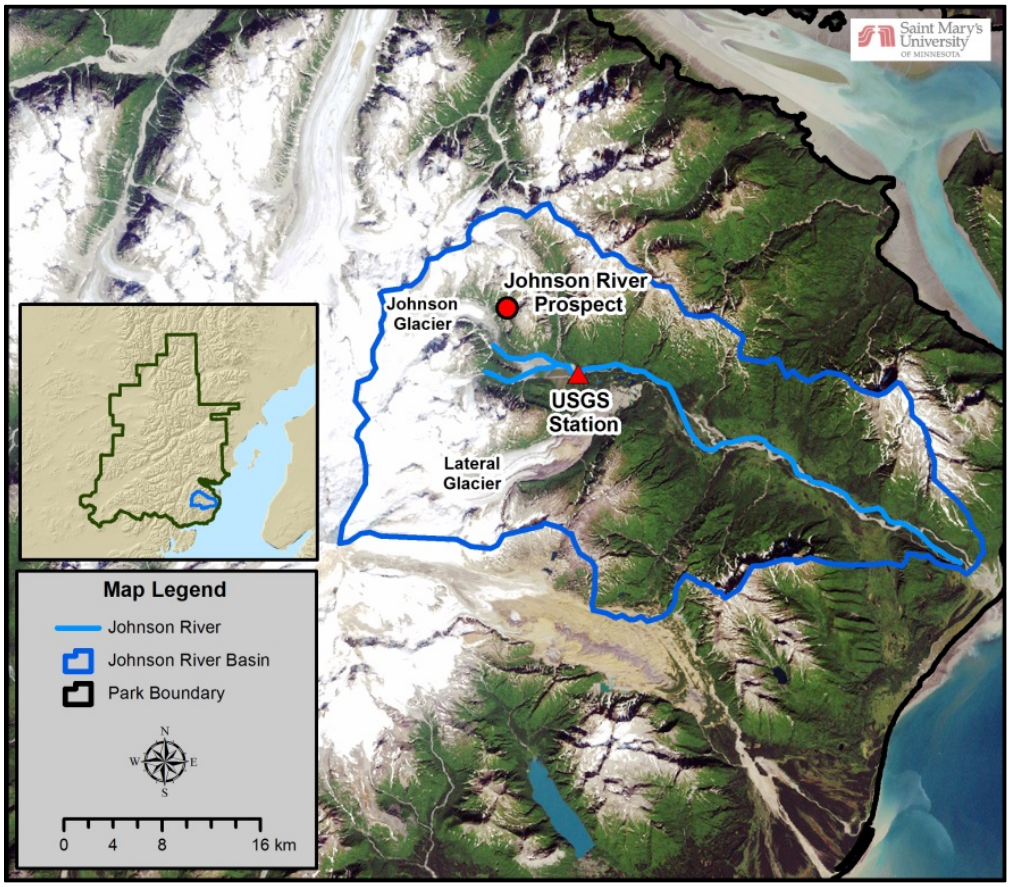


Figure 47. Location of USGS gaging station and Johnson River Prospect in relation to the Johnson River (USGS 2015).

4.11.3 Summary of Data

Coastal Watershed Summary

Johnson River

The Johnson River Basin is characterized by glaciation, high coastal mountains, and high precipitation. This basin drains a 62 km^2 (24 mi^2) area above the gaging station (Brabets 2002). The Johnson River is a management concern because of a hard rock gold mine claim on Native Corporation land near the headwaters (Brabets and Riehle 2003). The Johnson River Prospect (the mine claim), located in the East Fork of the Ore Creek Basin, is a small tributary draining 1.3 km^2 (0.5 mi^2) and connects to the upper part of the Johnson River Basin (Figure 47). This stream has higher concentrations of several trace elements (e.g., cadmium, lead, zinc) (Appendix RR, Brabets and Riehle 2003). Even though trace elements have been identified in this stream, the pH levels have

remained relatively normal, which according to Brabets and Riehle (2003) means the stream may have a sufficient buffer capacity. This may be a result of the runoff from the glaciers that feed this river (e.g., Johnson Glacier, Double Glacier).

The USGS Johnson River gaging station recorded core water quality parameters between 1999 and 2004 (USGS 2015). There were slight fluctuations in the means of each parameter over the years. Annual mean water temperature ranged from 2.26°C to 4.5°C (Table 73). Mean DO levels were high, ranging from 12.94 mg/L to 13.94 mg/L. Mean pH levels ranged from 7.12 to 7.60. Mean specific conductance values ranged from 45.29 uS/cm to 65.80 uS/cm. Turbidity had a mean value of 40.94; values peaked in July (160 FNU) but was at its lowest in September (5 FNU). It should be noted that there were only a few samples recorded each year and that turbidity samples were only recorded in 2004.

Table 73. Annual means for water temperature (°C), DO, specific conductance, pH, and turbidity from the Johnson River station (USGS #1529470) between 1999 and 2004 (USGS 2015). FNU = Formazin Nephelometric Units.

Year	Number of Samples	Water Temp (°C)	DO (mg/L)	Specific Conductance (uS/cm)	pH	Turbidity (FNU)
1998	1	4.50	13.10	48.00	7.30	--
1999	14	4.31	13.08	45.29	7.60	--
2000	5	2.26	13.94	65.80	7.20	--
2001	5	3.42	12.94	56.00	7.12	--
2002	0	--	--	--	--	--
2003	0	--	--	--	--	--
2004	31	3.45	13.15	50.35	7.42	40.94
All years	**57**	**3.58**	**13.19**	**50.93**	**7.41**	**40.94**

-- No data reported or applicable

Brabets and Ourso (2006) documented the range in concentrations of trace elements at eight sites along the Johnson River. All of the primary pollutant trace elements had concentrations that exceeded the Interim Freshwater Sediment Quality Guideline (ISQG) and Threshold Effect Concentration (TEC). Concentrations of arsenic, cadmium, lead, mercury, and zinc exceeded the Probable Effect Level (PEL). Concentrations of arsenic, lead, and zinc even exceeded the Probable Effect Concentration (PEC). Table 74 displays the streambed sediment quality guidelines and the range in trace element concentrations in the Johnson River provided by Brabets and Ourso (2006).

Table 74. Comparison of streambed sediment quality guidelines to concentrations of trace elements measured in Crescent River Basin in 2004 (Retrieved from Brabets and Ourso 2006). It should be noted that all values are in micrograms per gram.

Trace Element	Interim Freshwater Sediment Quality Guideline (ISQG)[A]	Threshold Effect Concentration (TEC)[B]	Probable Effect Level (PEL)[A]	Probable Effect Concentration (PEC)[B]	Range in Johnson River samples
Arsenic	5.90	9.80	17.00	33.00	16 – 64
Cadmium	0.60	0.99	3.50	5.00	< 0.1 – 4.6
Chromium	37.30	43.40	90.00	111.00	14 – 66
Copper	35.70	31.60	197.00	149.00	47 – 92
Lead	35.00	35.80	91.30	128.00	4.0 – 230
Mercury	0.17	0.18	0.49	1.06	0.10 – 0.93
Nickel	--	22.70	--	48.60	4 – 25
Selenium[C]	--	2.50	--	4.00	0.2 – 2.6
Zinc	123.00	121.00	315.00	459.00	85 - 1800

A - Canadian Council of Ministers of the Environment (1999)

B - MacDonald et al. (2000)

C - Van Derveer and Canton (1997)

Crescent River

The Crescent River Basin is located just north of Tuxedni Bay. The Crescent River system drains approximately 647 km^2 (250 mi^2) and is fed primarily by glacial and snow melt. Brabets and Ourso (2006) collected measurements of all five core water quality parameters in the summer of 2004. Water quality monitoring was established for the Crescent River Basin because it has a productive sockeye salmon run, which is important to the Cook Inlet commercial fishing industry (Brabets and Ourso 2006). All five salmon species are present within the Crescent River system with Sockeye counts ranging from 20,000 to 130,000 between 1979 and 2004 (Brabets and Ourso 2006). This may indicate favorable water quality conditions.

Brabets and Ourso (2006) noted an increase in average August temperature (~1.5°C) from 2003 to 2004. There was a smaller range in temperature at the lake sites than at the river sites. Water temperature ranged from 2.7°C to 13.2°C (mean = 8.3°C) at the USGS stream gages (Stations 1 -3; Figure 48). Glacial input and waterbody type affects some of the water quality parameters. Turbidity levels differed between the two forks of the Crescent River. Lower turbidity values were observed in the Lake Fork (≤ 20 NTU) than in the North Fork (≤ 54 NTU), which may be a result of higher flow rates from the river. Values of specific conductance were fairly consistent, varying only slightly among sites. There was a larger range in specific conductance at Stations 1 and 3 (23 to 58 µs/cm) than at Station 2 (23 to 31 µs/cm), which was a result of flow rates at Crescent Lake. According to Hem (1985), natural pH levels range from 6.5 to 8.0 standard units. The pH levels from all six sites ranged from 5.8 to 8.0. Lake pH levels ranged from 5.8 to 6.7. Range in DO concentrations varied slightly between the river stations (9.3 mg/L to 13.6 mg/L) and lake stations (8.4 mg/L to 14.2

mg/L). DO concentrations were considered adequate to support the salmon populations. Table 75 displays a summary of the core water quality parameters collected in the Crescent River Basin in 2004.

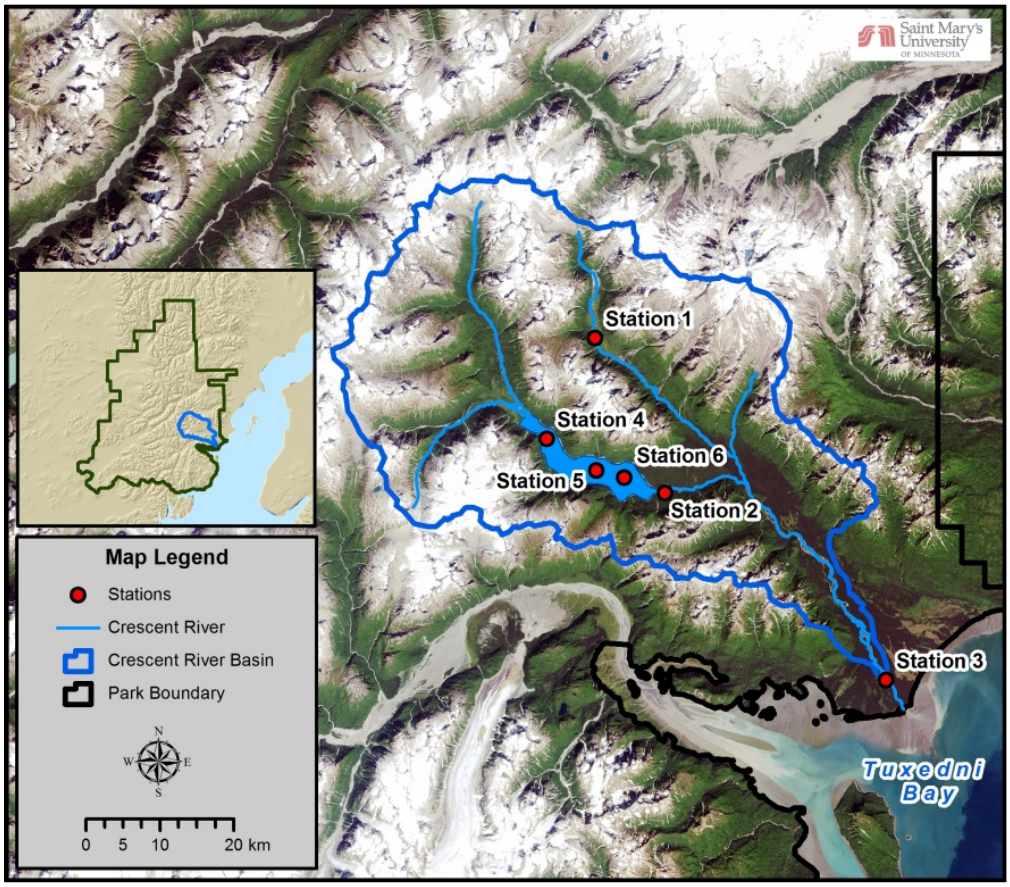


Figure 48. Locations of stations along the Crescent River and in Crescent Lake (Brabets and Ourso 2006).

Brabets and Ourso (2006) also documented trace elements in the Crescent River streambed sediments. None of the primary pollutant trace elements in the Crescent River exceeded the PEL guidelines or the PEC guidelines. Arsenic was the only element to have samples that exceeded the TEC guidelines. There were samples of arsenic, chromium, and copper that exceeded the ISQG. Table 76 displays the four streambed sediment quality guidelines in comparison to the trace elements found in the Crescent River in 2004.

Table 75. Mean water quality measurements for the core water quality parameters at all six stations in the Crescent River Basin (Brabets and Ourso 2006).

Site	Years of Data	Number of Samples	Water Temp (C)	DO (mg/L)	Specific Conductance (uS/cm)	pH	Turbidity (NTU)
Station 1 (USGS 15294630)	2	6	6.48	11.76	39.8	6.58	20.48
Station 2 (USGS 15294640)	1	8	8.7	11.51	53.25	6.52	12.20
Station 3 (USGS 15294650)	2	6	9.38	11.72	41.67	7.11	20.12
Station 4	1	38	6.92	10.57	30.82	6.34	17.59
Station 5	1	51	7.25	11.50	30.33	6.20	14.74
Station 6	1	39	6.72	12.44	32.38	6.21	13.64

Table 76. Comparison of streambed sediment quality guidelines to concentrations of trace elements measured in Crescent River Basin in 2004 (Retrieved from Brabets and Ourso 2006).

Trace Element	Interim Freshwater Sediment Quality Guideline (ISQG)[A]	Threshold Effect Concentration (TEC)[B]	Probable Effect Level (PEL)[A]	Probable Effect Concentration (PEC)[B]	Range in Crescent River samples
Arsenic	5.90	9.80	17.00	33.00	2.9 – 9
Cadmium	0.60	0.99	3.50	5.00	< 0.1 – 0.2
Chromium	37.30	43.40	90.00	111.00	20 – 43
Copper	35.70	31.60	197.00	149.00	44 – 110
Lead	35.00	35.80	91.30	128.00	4 – 8
Mercury	0.17	0.18	0.49	1.06	< 0.02 – 0.04
Nickel	--	22.70	--	48.60	12 – 19
Selenium[C]	--	2.50	--	4.00	< 0.1 – 0.2
Zinc	123.00	121.00	315.00	459.00	72 – 150

A - Canadian Council of Ministers of the Environment (1999)

B - MacDonald et al. (2000)

C - Van Derveer and Canton (1997)

Lake Clark and Lake Clark-Watershed Water Quality Data

A total of six major rivers, the Chokotonk, Tlikakila, Currant, Kijik, Tanalian, and Chulitna provide the main source of inflow to Lake Clark (Figure 49). The Lake Clark watershed drains 7,619 km^2 (2,942 mi^2) and includes numerous other small streams and creeks which terminate in this glacial

lake (Brabets 2002). The inflow of water is seasonal in nature, peaking in the summer, and reaching base flow conditions in late winter.

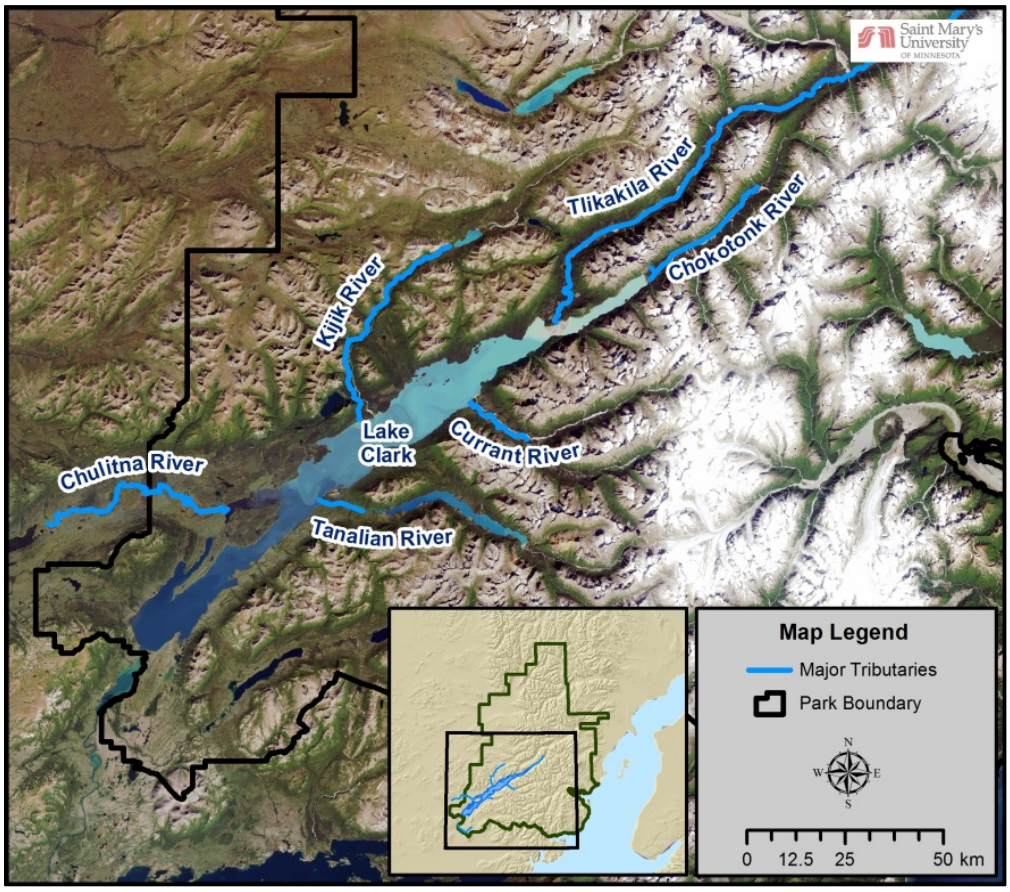


Figure 49. Major tributaries of Lake Clark.

Water Quality – Lake Clark

Chamberlain (1988) recorded the physical parameters of each sampling lake as well as collected core water quality parameters in Lake Clark between 1985 and 1987 (Table 77). Water temperatures, measured in the middle of the lake, were up to 4°C (39.2°F) in the spring. Chamberlain noted that water warmed quickly by summer but never exceeded 13°C (55.4°F). DO levels never dropped below 10 mg/L during this study and the levels were considered close to saturation. Mean pH levels ranged from 6.81 to 7.47, which is considered suitable for fish reproduction. Specific conductivity ranged from 45 µS/cm to 55 µS/cm. Spring runoff was said to have caused the increased specific conductivity. Light extinction coefficients were low at the beginning of June ($0.3 m^{-1}$), but the light extinction coefficient doubled by August ($0.65 m^{-1}$).

Table 77. Physical parameters of Lake Clark and other lakes of interest in LACL (Chamberlain 1988).

Lake	Drainage Area (km^2)	Surface Area (km^2)	Elevation (m)	Glaciation Present
Lake Clark	9,583	370.0	65	Yes
Tazimina Lake				
Upper	--	15.8	235	No
Lower	--	12.1	194	No
Both	725	27.9	*	No
Two Lakes	693	12.9	345	Yes
Kontrashibuna	504	18.9	152	Yes
Telaquana	391	44.7	372	Yes
Lachbuna	353	3.3	411	Yes
Twin Lakes				
Upper	--	14.5	604	Yes
Lower	--	7.6	604	Yes
Both	320	22.1	604	Yes
Turquoise	188	12.6	763	Yes
Kijik	4.4	110.0	107	No

-- Drainage area was not calculated for upper and lower portions of the select lakes.

* elevation varies between the Upper and Lower Tazimina Lakes

Chamberlain (1988) also documented bacterial concentrations from select stations on Lake Clark. Coliform and fecal streptococci bacteria were only countable at four of the eight stations sampled in Lake Clark (Table 78). Stations CB (Chulitna Bay) and TB (Turner Bay) had the highest concentrations of fecal coliform. Chamberlain (1988) also recorded metal concentrations, mean concentrations of major ions, and pH levels at 16 stations on Lake Clark between 1985 and 1987 (Appendix PP- Appendix RR; Figure 43).

Wilkens (2002) documented the core water quality parameters at varying depths in the summers of 1999 and 2000. Water temperatures varied among the stations. Surface water temperature (< 1 m) ranged from 6.11°C to 12.44°C (Appendix SS). Stations 3, 4, and 5 (Figure 45. Sampling stations used in the Lake Clark limnology study (Wilkens 2002). had the warmest maximum temperatures. DO levels were near 100% saturation throughout the study. DO levels also varied slightly by depth, but never dropped below 10 mg/L. pH level remained relatively stable. The pH ranged from 6.8 to 7.8. Most pH measurements were between 7.1 and 7.4. Specific conductivity only ranged between 40 µS/cm and 60 µS/cm. Turbidity, suspended solids (organic, inorganic), chlorophyll-a, and true color were other parameters measured during this study (Table 79). In June, all of the stations had low turbidity readings (<2 NTU). As the summer progressed, turbidity levels increased to as high as 10

NTU, especially at the stations closet to the upper basin (Stations 4 and 5). According to Wilkens (2002), the levels of inorganic suspended solids had a relatively large part in influencing the turbidity fluctuations. Chlorophyll-a readings also varied among the stations. Similar to turbidity levels, the chlorophyll levels increased as summer progressed. Higher concentrations of chlorophyll were in the lower basin (Stations 1 and 2); overall, concentrations ranged from 0.5 µg/L to 1.5 µg/L.

Table 78. Bacterial concentrations from selected stations on Lake Clark. Concentrations of bacteria presented in (100 mls) (Chamberlain 1988).

Station	Total Coliform	Fecal Coliform	Fecal Streptococci	Other Bacteria
CB	8	2 - 22	< 2	> 200
L 7	0	0 - < 2	< 2	4
L 11	0	0 - < 2	< 2	23
PA 1	1	1 - 4	< 2 - 4	43
PA 2	0	0 - 2	< 2 - 2	69
PB 1	0	0 - < 2	< 2	20
PB 2	0	0 - < 2	< 2	15
TB	45	20 - 36	< 2	> 200

Table 79. Mean monthly turbidity, suspended solids, chlorophyll-a and true color readings from Lake Clark, 1999 and 2000 (Wilkens 2002). Daily average means and standard deviation can be seen in the Wilkens (2002) document.

Station	Date	Turbidity (NTU's)	Inorganic Suspended Solids(µg/L)	Organic Suspended Solids (µg/L)	Chlorophyll-a (µg/L)	True Color (platinum-cobalt)
1	June 1999	1.20	0.58	1.43	0.96	13.70
	July 1999	0.90	0.30	1.82	0.95	5.18
	August 1999	1.70	1.06	2.04	1.10	8.33
	June 2000	0.80	0.30	0.70	0.99	8.30
	July 2000	1.00	0.47	1.53	1.38	12.30
	August 2000	2.00	1.20	3.07	0.85	0.00
2	June 1999	1.50	0.40	1.03	0.74	0.00
	July 1999	2.13	0.66	1.63	1.01	4.75
	August 1999	3.66	1.88	1.76	0.70	10.33
	June 2000	1.30	0.67	1.07	0.93	7.70

Table 79 (continued). Mean monthly turbidity, suspended solids, chlorophyll-a and true color readings from Lake Clark, 1999 and 2000 (Wilkens 2002). Daily average means and standard deviation can be seen in the Wilkens (2002) document.

Station	Date	Turbidity (NTU's)	Inorganic Suspended Solids(µg/L)	Organic Suspended Solids (µg/L)	Chlorophyll-a (µg/L)	True Color (platinum-cobalt)
2	July 2000	4.10	2.17	1.13	0.85	18.70
	August 2000	2.30	1.33	2.37	0.63	0.00
3	June 1999	2.10	0.88	2.57	0.57	14.00
	July 1999	4.23	1.42	1.57	0.85	11.08
	August 1999	7.30	3.91	2.03	0.68	10.77
	June 2000	1.30	0.60	0.93	0.68	9.70
	July 2000	6.60	3.17	1.43	0.67	19.30
	August 2000	4.70	2.37	2.30	0.53	3.00
4	June 1999	1.30	0.72	1.13	0.62	0.00
	July 1999	5.67	2.50	1.71	0.76	14.57
	August 1999	7.00	3.25	1.99	0.62	9.23
	June 2000	1.40	0.73	1.57	0.68	0.00
	July 2000	10.20	5.80	1.83	0.61	21.70
	August 2000	6.90	3.30	3.03	0.67	3.70
5	June 1999	1.70	1.05	1.07	0.71	7.70
	July 1999	7.93	3.61	2.14	0.77	18.13
	August 1999	8.03	4.07	1.83	0.66	9.00
	June 2000	1.20	0.60	0.67	0.68	0.00
	July 2000	9.30	5.67	1.83	0.65	20.30
	August 2000	6.50	3.73	1.70	0.65	2.00

Wilkens (2002) also documented nutrient levels from the five Lake Clark stations in 2000. Most nutrients were below the detection limit. Phosphorus and nitrite concentrations were at the detection limit at all stations (Table 80). Ammonia concentrations were above detection limits at Stations 1, 2, and 5. Nitrite + nitrate concentrations were above the detection limit at all of the stations.

Wilkens (2002) documented Secchi Depth (an indicator of water clarity) at the five Lake Clark stations in the summers of 1999 and 2000. Secchi Depths ranged from 0.5 m to 10 m (Table 81). Readings fluctuated by month. The deepest readings occurred in June and decreased as summer progressed. Some readings increased slightly in August. The deepest readings occurred at Station 1 (lower basin), and the most shallow readings occurring in Station 5 (upper basin).

Table 80. Nutrients readings from Lake Clark, samples taken 22 July 2000 (mg L^{-1} as N or P) (Wilkens 2002).

Constituent	Station 1	Station 2	Station 3	Station 4	Station 5	Detection Limit
Ammonia (dissolved)	0.008	0.006	<0.002	<0.002	0.005	0.002
Nitrogen ammonia + organic nitrogen (dissolved)	-0.100	-0.100	-0.100	<0.100	<0.100	0.100
Nitrogen ammonia + total organic nitrogen	<0.100	0.400	-0.800	<0.100	<0.100	0.100
Nitrite + nitrate (dissolved)	0.183	0.180	0.183	0.186	0.190	0.005
Nitrite (dissolved)	0.001	0.001	0.001	0.001	0.001	0.001
Phosphorus (dissolved)	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Orthophosphate (dissolved)	0.001	0.002	0.002	0.002	0.002	0.001
Total Phosphorus	<0.008	-0.005	-0.005	0.009	0.008	0.008

Table 81. Mean Secchi Depth readings (m) of from Lake Clark 1999 and 2000 (Wilkens 2002).

	1999			2000		
Station	June	July	August	June	July	August
1	8.6	7.8	3.6	4.6	2.0	4.2
2	6.6	4.0	1.8	1.4	1.4	2.5
3	6.9	1.4	1.4	1.0	1.3	1.8
4	6.0	0.9	1.1	1.0	0.9	1.4
5	4.5	1.2	1.2	1.0	0.9	1.6

Wilkens (2002) documented Forel-Ule (FU) measurements for Lake Clark in 1999 and 2000. Forel-Ule scale is used to determine the transparency of the water and classify biological activity (e.g., algae, phytoplankton). The Forel-Ule scale ranges from 1 to 21, each number representing a color from blue to brown. Scales from 1 -5 have low nutrient levels; scales 6 – 9 have dissolved matter and sediment present; scales 10 – 13 have increased levels of nutrients and phytoplankton; scales 14 – 17 have high nutrient and phytoplankton concentrations; and scales 18 – 21 have extremely high levels of humic acids (Citclops 2015). FU readings in 1999 and 2000 ranged from scale 4 to scale 11 (Table 82).

Table 82. Forel-Ule Color readings from Lake Clark, 1999 and 2000 (Wilkens 2002).

	1999			2000		
Station	**June**	**July**	**August**	**June**	**July**	**August**
1	F7	F7	F9 – F11	F10	F6	F11
2	F10	F5 – F9	F9 – F11	F9	F10	F9
3	F10	F5 – F10	F9 – F11	F9	F11	F8
4	F9	F4 – F9	F6 – F10	F7	F7	F10
5	F9	F5 – F11	F8 – F10	F7	F7	F11

Shearer and Moore (2010) documented minimum, mean, and maximum water quality values from Lake Clark in 2009. Water temperature was cooler in the lower and middle basins than in the upper basin, even though all of the glacial meltwater inflow enters into the upper basin. pH and specific conductivity were considered stable during this time (Table 83). Overall, pH ranged from 7.16 (lower basin) to 7.49 (middle basin). Specific conductivity ranged from 61 µS/cm to 66 µS/cm in the upper and lower basin, respectively. DO levels varied with water depth, but were considered high and above saturation levels.

Table 83. Water quality parameters collected from Lake Clark in the summer of 2009 (Shearer and Moore 2010).

Parameter	**Observation**	**Upper Basin**	**Middle Basin**	**Lower Basin**
Water Temperature (°C)	Min	10.76	7.05	7.30
	Mean	11.29	9.88	8.93
	Max	12.59	11.98	13.17
pH (standard units)	Min	7.29	7.26	7.16
	Mean	7.36	7.38	7.26
	Max	7.45	7.49	7.39
Specific Conductivity (µS/cm)	Min	61.00	62.00	62.00
	Mean	62.00	62.00	63.00
	Max	63.00	63.00	66.00
DO (mg/L)	Min	11.28	11.11	11.70
	Mean	12.11	11.60	12.10
	Max	13.22	12.33	12.47

Water Quality Data-Lake Clark Watershed

Chamberlain (1988) documented metal concentrations, mean concentrations of eight major ions and pH of effluents (Appendix QQ), and light extinction from all sample lakes. Minimum, mean, and maximum metal concentrations were grouped by stations in Lake Clark, stations at the mouth of major tributaries, and the other lakes of interest during this study (Appendix RR). Light extinction coefficients started low at the beginning of the study, but they increased as the summer progressed (Table 84).

Table 84. Light extinction coefficients for each lake studied during 1987 (Chamberlain 1988).

Lake	June	July	August
Upper Tazimina	0.056	0.077	0.099
Lower Tazimina	0.150	0.077	0.150
Lower Twin	0.072	0.042	0.170
Kijik (K13)	0.130	0.072	0.190
Kijik (K14)	0.100	0.110	0.190
Lake Clark (L7)	0.300	0.350	0.650
Lachbuna Lake	0.160	0.270	0.720
Telaquana	0.110	0.170	0.740
Turquoise	0.180	0.350	0.890
Upper Two Lakes	0.340	0.520	1.400

Brabets (2002) documented the range in water quality values for the core water quality parameters in the Tlikakila River in 1999 and 2000. Water temperature at the stream gage varied throughout the year. Water temperature was approximately 0.0°C through the winter (October – April), but warmed up to approximately 5°C in late spring (May). The water temperatures began to drop again in June when glacial runoff from snowmelt entered the river. Water temperature reached as high as 9.4°C, which probably occurred before snowmelt in the early summer months. DO and pH levels remained relatively stable during this time. DO ranged from 11.0 mg/L to 14.0 mg/L, and pH levels ranged from 7.2 to 8.1. Both DO and pH were considered adequate for fish growth and survival. Specific conductivity varied greatly. Specific conductivity ranged from 31 µS/cm to 117 µS/cm (Table 85). The highest values occurred in March, May, September, and October, the time of low flow and the lowest values occurred in June, July or August, the period of high flow.

Table 85. Water quality samples collected from the Tlikakila River between 1999 and 2000 (Brabets 2002).

Parameter	Minimum	Mean	Maximum
Water Temperature	0.0	5.8	9.4
pH	7.2	7.5	8.1
DO	11.0	12.2	14.0
Specific Conductivity	31.0	61.0	117.0
Alkalinity (mg/L as $CaCO_3$)	13.0	21.0	37.0

USGS Data – Chulitna River

Shearer and Moore (2010) reported early summer, mid-summer, and late summer values for the core water quality parameters at the Chulitna River gaging station in 2009 (Figure 46). Shearer and Moore (2010) noted that water quality may be directly influenced by Lake Clark water levels. Water temperature fluctuated (~5°C to 7°C) within each portion of summer (Table 86). Overall, water temperature ranged from 9.06°C (late summer) to 17.98°C (mid-summer). pH and DO levels were relatively stable with pH ranging from 7.34 to 8.19 and DO ranging from 9.09 mg/L to 12.33 mg/L. Specific conductivity also fluctuated during the study. Specific conductivity seemed to be lower in the early summer months, but it would increase throughout the summer.

Table 86. Water quality parameters from the Chulitna River gaging station in the summer of 2009 (Shearer and Moore 2010).

Parameter	Observation	Early Summer[A]	Mid-Summer[B]	Late Summer[C]
Water Temperature (°C)	Min	11.38	10.88	9.06
	Mean	13.57	13.71	11.75
	Max	16.30	17.98	14.10
pH (standard units)	Min	7.34	7.59	7.48
	Mean	7.50	7.83	7.68
	Max	7.75	8.19	7.98
Specific Conductivity (µS/cm)	Min	66.00	81.00	81.00
	Mean	70.00	87.00	85.00
	Max	73.00	90.00	89.00

A - Deployment period: June 10th – 17th

B - Deployment period: July 17th – 26th

C - Deployment period: August 19th – September 17th

Table 86 (continued). Water quality parameters from the Chulitna River gaging station in the summer of 2009 (Shearer and Moore 2010).

Parameter	Observation	Early Summer[A]	Mid-Summer[B]	Late Summer[C]
DO (mg/L)	Min	9.77	9.53	9.09
	Mean	10.73	10.94	10.73
	Max	11.49	12.33	11.90

A - Deployment period: June 10th – 17th

B - Deployment period: July 17th – 26th

C - Deployment period: August 19th – September 17th

USGS (2010 - 2014) compiled measurements of all five core water quality parameters between 2010 and 2014; however, the 2014 report only contained temperature and discharge data. The USGS station collected continuous water temperature data for the 2010, 2011, and 2014 water years (Appendix UU); water temperature data for the 2012 and 2013 water years has several gaps resulting in data gaps for several months. Annual water temperatures ranged from 0.0°C to 12.6°C from 2010 to 2013 (Appendix VV). Annual specific conductivity also fluctuated. Maximum values for specific conductivity in 2010 and 2011 were high compared to 2012 and 2013. pH and DO levels seemed stable from 2010 to 2013. pH values ranged from 6.9 to 7.6, and DO ranged from 9.9 mg/L to 13.4 mg/L. The core water quality parameters as well as the concentrations of trace elements are presented for this site between 2010 and 2014 (Appendix VV).

Threats and Stressor Factors

Cohn (2009) reported on the effects of climatic and vegetation dynamics on lake productivity in non-anadromous lakes (Hickerson Lake, Kontrashibuna Lake, and Portage Lake) in LACL and states that "recent major changes in lake ecology and landscape are generally attributed to climate warming since the end of the Little Ice Age and to the recent warm phase of the Pacific Decadal Oscillation" (Cohn 2009, p. iii). Cohn (2009) continues by emphasizing that other factors including glacial retreat and volcanism also have the capability to greatly influence water quality parameters. Lake Clark is primarily fed by flowing systems that are heavily influenced by glacial source inputs. The recession of glaciers will create an influx of suspended solids and turbidity in the short term and most certainly impact light gradient levels (Wilkens 2002). These changes have the potential to influence a myriad of water quality parameters within Lake Clark and its tributaries.

The potential resource development projects adjacent to the park boundaries could impact a myriad of water quality parameters in LACL's pristine water bodies, with particular concern on the Chulitna River system. The Chulitna River system is unique in LACL in that its headwaters occur outside of and upstream of the park boundary; all other major watersheds in LACL originate within the park (Jeff Shearer, LACL Chief of Natural Resources, written communication, 12 March 2015). Potential development of mining claims southwest of LACL, oil and gas leasing and increased vessel shipping in Cook Inlet, and infrastructure development on private lands all pose concerns over impacts to water resources (Shearer, written communication, 12 March 2015).

Data Needs/Gaps

In the past, water quality data collection within LACL was primarily driven by area-specific concerns, often associated with potential impacts from projects. The implementation of a long-term monitoring program nationally within the NPS resulted in a shift away from project-driven data collection to a strategic approach to examine resource trends. SWAN has developed a long-term water quality protocol to examine trends in various parameters across a tiered system of lakes (Shearer et al. 2015a, b). Additionally, focused studies by the USGS (Brabets 2002, Brabets and Ourso 2006) have allowed managers to establish baseline water quality and hydrologic conditions. Future project funding will be used to target additional water resources where baseline data are needed, such as on-going work by the USGS on the Chulitna River.

Wilson and Moore (2013) reported quality control concerns with previous collection methods in both field collection protocols and data collection efficiency. Significant differences were found in collected samples after changes regarding calibration, sonde transportation technique, and equilibration methods were established. Changes outlined in Wilson and Moore (2013) and Shearer et al. (2015b) have been implemented to increase data integrity, stream line sampling efforts, reduce cost of sampling, and increase efficiency.

Overall Condition

An evaluation of condition based on data regarding this resource is not appropriate at this time due to lack of reference condition and limited data.

4.11.4 Sources of Expertise

Jeff Shearer, LACL Chief of Natural Resources

Dan Young, LACL Fisheries Biologist

4.11.5 Literature Cited

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4.12 Water Quantity

4.12.1 Description

LACL is considered to have one of the most diverse collections of water resources of any SWAN park. LACL includes over 9,656 km (6,000 mi) of rivers and streams that flow through a variety of environments including glacial, volcanic, coastal, and freshwater ecosystems (Weeks 2003). Diversity of this nature causes water quantity and quality parameters of individual water bodies to be drastically different, even if relatively close geographically (Weeks 2003).



Photo 22. Johnson Glacier terminus at the headwaters of the Johnson River, LACL (NPS photo).

Water quantity parameters are generally described utilizing four measurements: discharge, gage height, tape height and lake elevation. The amount of water flowing through a river or stream is measured in cubic feet per second (cfs) and is referred to as discharge. Discharge is generally recorded by a gage station which also records other water parameters such as temperature or dissolved oxygen on a preset temporal scale. For example, the gage may record water quality and quantity values at defined intervals. Tape-height, gage height, and lake elevation are common measurements to determine the amount and height of water relative to average conditions found in that particular water body. Lake level or lake elevation readings are of particular interest to LACL staff and provide the necessary inputs to calculate lake outflow estimates (cfs) of Lake Clark.

Monitoring the annual, seasonal, and weather-event specific hydrology fluctuations of lakes, rivers, and streams within LACL is important for explaining variations in water quality parameters such as dissolved oxygen, temperature, conductivity, etc. (Bennett 2005). Peak discharges and gage heights of Alaskan water bodies generally occur during mid to late summer; average daily air temperatures peak during this time, causing the most rapid melt of glacial ice and snow. The headwaters of all water bodies within LACL of significant size are supplied by glacial ice and/or snowfield melt waters; therefore, air temperatures are strongly correlated with discharge readings (Photo 22). Peak discharge readings generally occur in the late afternoon hours after the warmest part of each day.

Prior to analysis of this component, LACL Chief of Natural Resources Jeff Shearer (pers. comm., 2013) agreed that an assessment of condition is not appropriate for this component. The gathering of existing data sources and production of data tables for future use was determined to be the most useful exercise for the NRCA. Through data and literature searches, past reports with appropriate water quantity data were collected and compiled into tables. A summary of data sources and tables are provided for the reader here.

4.12.2 Data and Methods

USGS Data for Johnson River Basin

The Johnson River basin in LACL is characterized by glaciation, high coastal mountains, and high precipitation (Photo 22). The Johnson River is an area of management concern because of a potential hard rock gold mine within the river's headwaters. A stream gaging station operated on the Johnson River from 1995 to 2004 approximately 6.4 km (4 mi) from the river's headwaters at the terminus of Johnson Glacier (Figure 50). A core objective of the project was to determine and assess the seasonal and annual variation of discharge and determine the effects on water quality parameters (Bennett 2005). Peak flow values of the Johnson River varied from 1995 to 2004, with the lowest peak flow reading recorded in August of 1996 at 1,600 cfs, and highest peak flow reported in October of 2003 at 11,900 cfs (Bennett 2005). Analysis of the Johnson River utilizing a flow duration curve indicates that a discharge in excess of 4,000 cfs is rare, (occurring 0.1% of the time) while discharge readings over 40 cfs occur over 95% of the time. Table 87 shows monthly averages regarding water quantity parameters from 1999 - 2004 in the Johnson River at USGS station number 15294700. August was observed to have the highest average discharge of all months sampled.

Table 87. Summary data from USGS Station Number 15294700 from 1999 – 2004 (USGS 2015).

Month	# Yrs with Data	# of Measurements	Mean Discharge (ft^3)
May	3	3	79.7
June	4	14	634.2
July	3	14	690.0
August	5	11	807.4
Sept	4	14	210.9
Oct	1	1	200.0

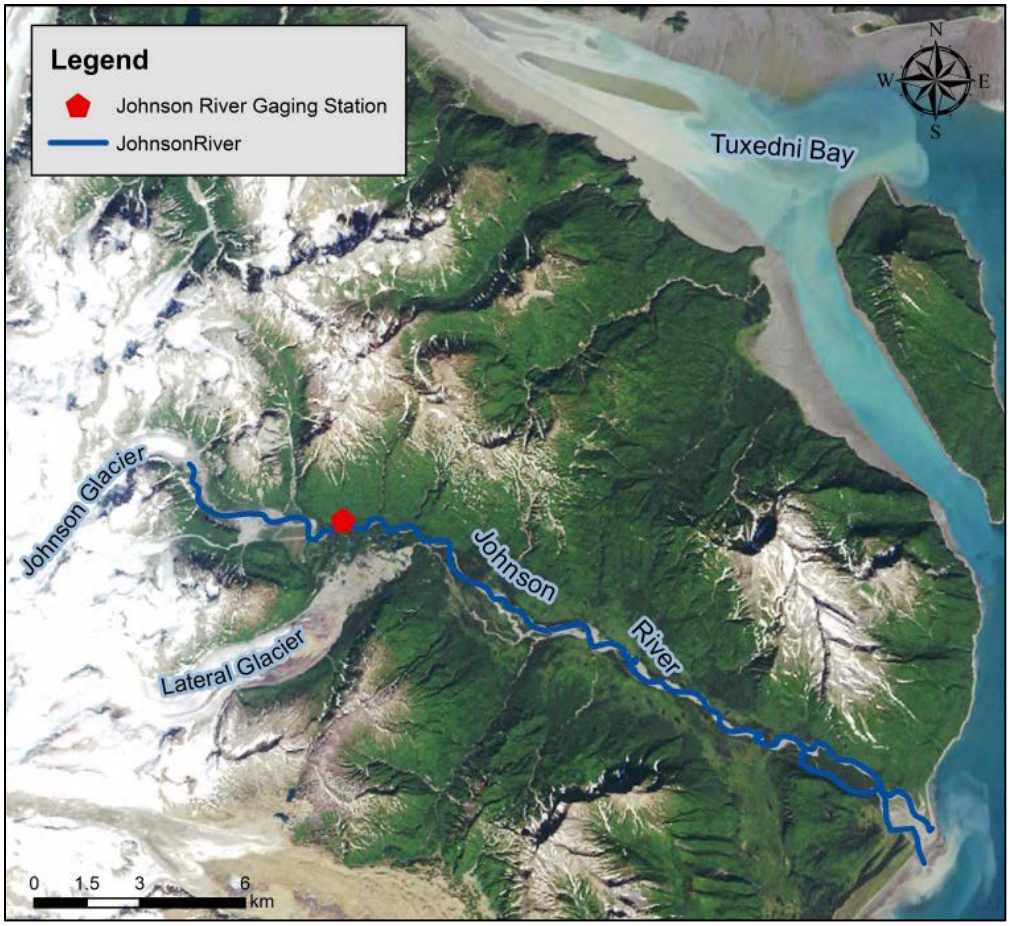


Figure 50. Location of the Johnson River gaging station.

USGS Water Quantity Data for Lake Clark Tributaries and Outlets, Largely Derived from Brabets (2002).

A total of six major tributaries (Figure 51) including the Chokotonk River, Tlikakila River, Currant Creek Kijik River, Tanalian River, and Chulitna River were studied between 1999 and 2001 in an effort to rectify the lack of hydrologic data for the region and determine the cause of a declining sockeye salmon population. These tributaries provide a majority of the inflow to Lake Clark. Brabets (2002) presents a breakdown of each tributary's discharge contribution into Lake Clark along with other parameters of interest including specific conductance, pH, water temperature, and dissolved oxygen. These other parameters are essential to determine the source of the tributaries and the influence each has on the water quality and quantity dynamics of Lake Clark. Table 88 and Table 89 show the water budget of Lake Clark and the discharge contribution of the major tributaries respectively from 1999 to 2001 (Brabets 2002).

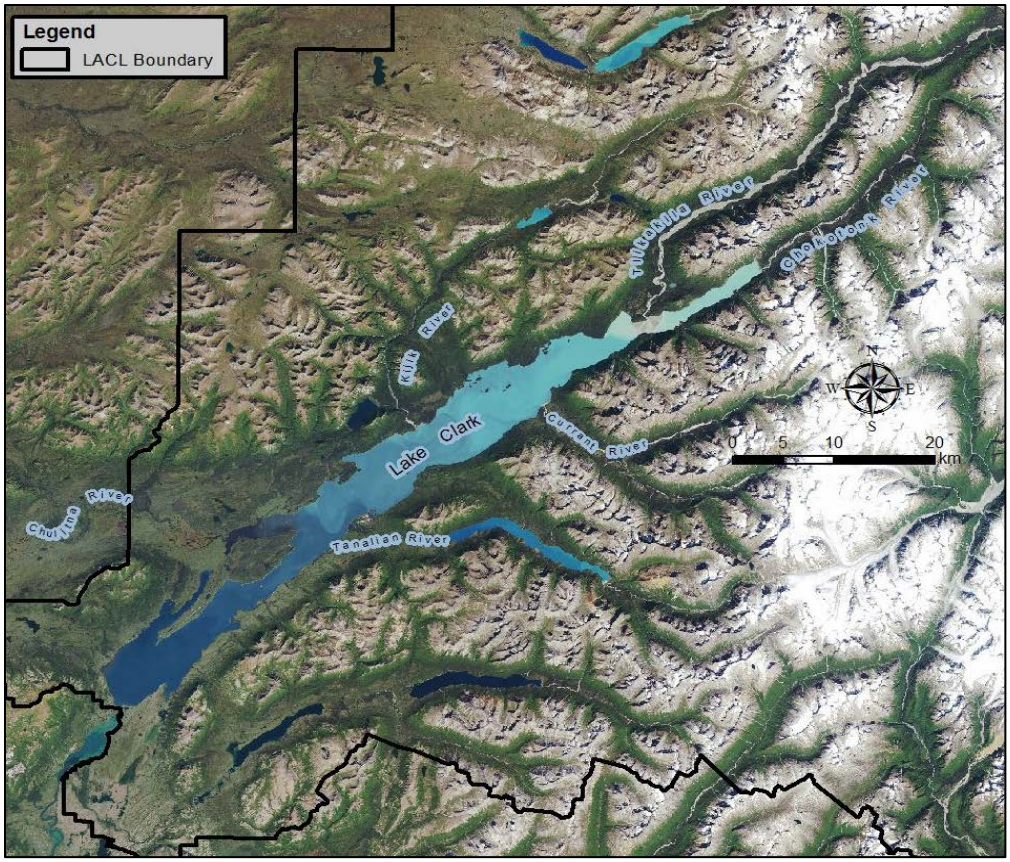


Figure 51. Locations of the six major tributaries that flow into Lake Clark presented in Table 89.

Table 88. Water budget of Lake Clark in 1999 to 2001 and the contribution of the Tlikakila River, responsible for the greatest discharge readings into the Lake of any other tributary. Values are in million acre-feet and rounded (Brabets 2002).

Time Period	Inflow to Lake Clark	Outflow From Lake Clark	Change in storage of Lake Clark	Tlikakila Contribution	Tlikakila Contribution Percent
June 1999	1.17	0.78	0.04	0.43	37
July 1999	1.19	1.19	0.00	0.62	55
August 1999	1.12	1.18	-0.06	0.49	43
September 1999	0.76	0.86	-0.10	0.20	27
Total 1999	**4.24**	*	*	**1.74**	**41**
June 2000	0.62	0.44	0.18	0.23	37
July 2000	1.04	0.92	0.12	0.38	36
August 2000	0.79	0.88	-0.09	0.27	34
September 2000	0.56	0.61	-0.05	0.80	14
Total 2000	**3.01**	*	*	**0.95**	**32**

Table 88 (continued). Water budget of Lake Clark in 1999 to 2001 and the contribution of the Tlikakila River, responsible for the greatest discharge readings into the Lake of any other tributary. Values are in million acre-feet and rounded (Brabets 2002).

Time Period	Inflow to Lake Clark	Outflow From Lake Clark	Change in storage of Lake Clark	Tlikakila Contribution	Tlikakila Contribution Percent
June 2001	1.53	1.00	0.53	0.53	35
July 2001	1.43	1.49	-0.06	0.60	42
August 2001	1.09	1.26	-0.17	0.58	54
September 2001	0.59	0.80	-0.20	0.37	62
Total 2001	**4.65**	*	*	**2.09**	**45**

Table 89. Ranges in discharges and selected water-quality constituents for six major tributaries to Lake Clark, 1999–2001 (Brabets 2002).

Tributary	Discharge (ft^3/s)	Specific Conductance (µs/cm)	pH	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Alkalinity (mg/L as CaCo3)	Suspended Sediment (mg/L)
Chokotonk River	258–2,190	28–74	7.0–8.2	0.0–10.0	11.3–14.3	11–24	9–211
Tlikakila River	25–12,000	31–117	7.2–8.1	0–9.4	11–14	13–37	5–710
Currant Creek	279–2,760	36–74	6.9–7.6	1.7–7. 5	11.1–14.9	11–20	3–282
Kijik River	432–3,000	70–88	7.0–7.8	3.5–12.5	9.4–13.7	24–28	2–123
Tanalian River	179–5,920	44–54	7.0–7.8	5.5–13.5	10.1–13.8	10–13	1–5
Chulitna River	1,320–7,420	53–85	7.0–7.8	1.0–14.5	10.0–13.2	21–36	4–9
Lake Clark outlet	8,530–23,800	55–62	7.0–7.9	4.5–11.5	10.3–14.1	20–21	1–5

The low sediment range for the Lake Clark outlet, Tanalian River, and Chulitna River is a characteristic found in rivers which have a lake above the sample site to settle particles out of the water.

Chulitna River

Along the Chulitna River, a USGS gaging station monitors the stream flow conditions of this system with a drainage area of 2,901 km^2 (1,120 mi^2) (NPS 2013c). The location of this gaging station is 8 km (5 mi) upriver from where the Chulitna enters Lake Clark (Figure 52). Stream flow data collections are planned to be on going until 2017, continuing the effort to determine the seasonal and

annual variation within this drainage. Field measurements, 18 in total, were recorded by USGS staff members from 2009 to 2013 (Table 90). Data records are discontinuous in 2012 as the last collection was made in June, neglecting recordings for the rest of the summer and early fall. Stream flow data was also recorded automatically each day resulting in the ability to calculate monthly and yearly averages for the sampled dates from 2009 to 2013 (Table 91, Table 92).

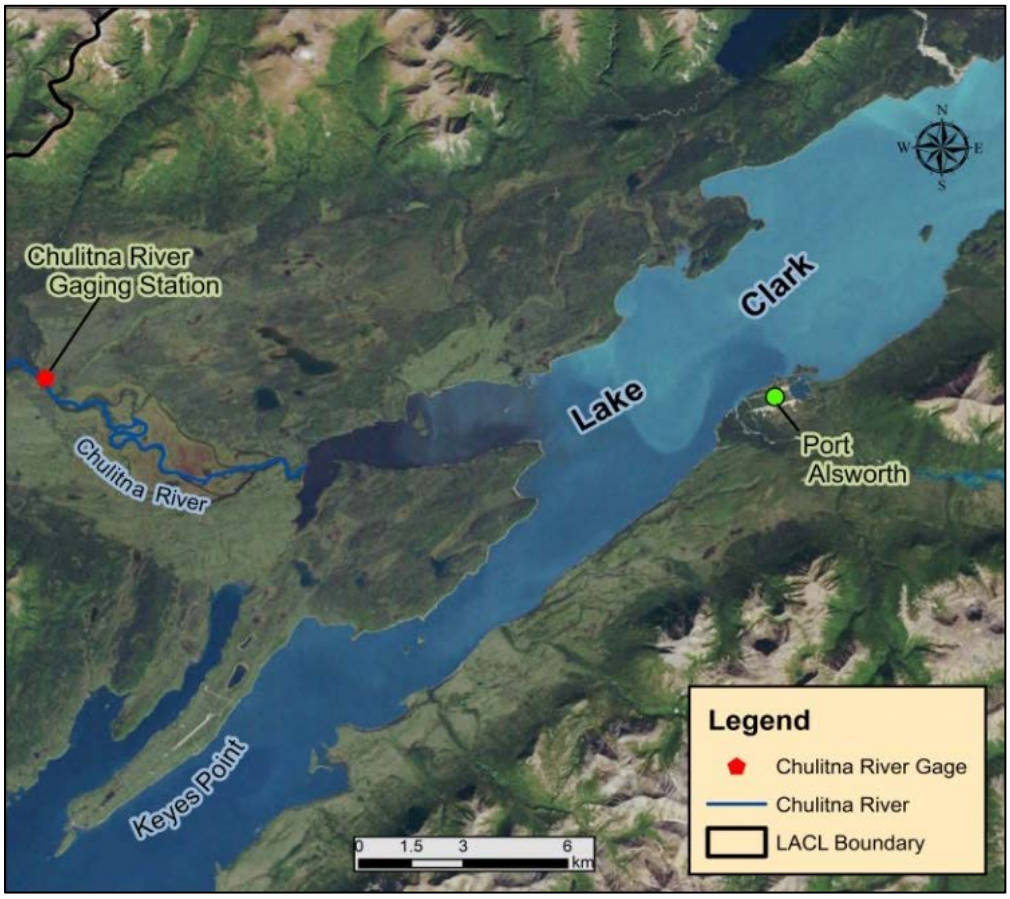


Figure 52. Location of the Chulitna River gaging station (NPS 2013c).

Table 90. Instantaneous stream flow field measurements from the Chulitna River gaging station, 2009 to 2013 (NPS 2013a).

Year	Month	Day	Stream Flow (cfs)	Gage Height (ft)
2009	10	7	1,500	17.30
2010	3	23	277	17.41
2010	5	25	2,280	18.02
2010	7	21	2,780	18.52
2010	8	18	5,870	20.74

Table 90 (continued). Instantaneous stream flow field measurements from the Chulitna River gaging station, 2009 to 2013 (NPS 2013a).

Year	Month	Day	Stream Flow (cfs)	Gage Height (ft)
2010	9	29	1,790	17.64
2011	3	9	331	17.89
2011	5	26	2,580	18.22
2011	7	13	2,730	18.33
2011	8	24	3,240	18.86
2011	9	27	2,020	17.77
2012	3	14	467	--
2012	6	19	3,490	18.81
2013	5	23	3,220	18.17
2013	7	2	2,700	17.90
2013	8	20	2,160	17.57
2013	9	20	2,550	17.84
2013	10	29	6,890	20.64

Table 91. Average monthly stream flow rates of the Chulitna River (cfs) between 2009 and 2011 (NPS 2013b).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2009	--	--	--	--	--	--	--	--	--	1,792	878	478
2010	357	279	270	432	2,611	1,599	2,165	4,446	2,837	1,743	897	526
2011	389	352	332	973	2,971	2,660	2,560	3,560	2,523	--	--	--
Average	**373**	**316**	**301**	**703**	**2,790**	**2,130**	**2,360**	**4,000**	**2,680**	**1,770**	**887**	**502**

Table 92. Peak flow readings and corresponding gage height of the Chulitna River for 2010 and 2011 (NPS 2013b).

Year	Date	Gage Height (ft)	Stream Flow (cfs)
2010	Aug. 18, 2010	20.92	6,160
2011	Aug. 09, 2011	20.03	4,790

Table 93. Physical properties and water-quality constituents of stream flow samples from the Chulitna River, June 1999 through September 2001 (USGS station number 15298050) (Brabets 2002).

Date	Time	Discharge (ft^3/s)	Specific Conductance (µs/cm)	pH	Water Temperature (°C)	Dissolved Oxygen (mg/L)
06/17/1999	1430	4,090	58	7.1	11.5	10.6
07/20/1999	1710	1,400	77	7.7	12.4	10.8
08/16/1999	1515	4,060	70	7.4	11.2	10.5
09/13/1999	1615	3,160	76	7.5	9.0	11.2
10/13/1999	1245	2,570	76	7.4	1.0	13.2
06/19/2000	1700	1,340	69	7.4	10.0	11.2
07/19/2000	1325	1,570	78	7.8	11.0	10.3
08/28/2000	1900	1,320	85	7.8	11.0	10.0
09/22/2000	1300	3,960	66	7.0	8.0	12.2
06/04/2001	1800	7,420	53	7.1	9.5	12.9
07/09/2001	1830	2,230	71	7.8	14.5	10.1
08/20/2001	1445	2,370	81	7.6	12.0	10.0
09/25/2001	1345	1,870	82	7.0	7.5	11.4

The largest volume of water recorded at the Chulitna River gaging station was 6,160 cfs on 18 August 2010. The greatest flow recorded in 2011 was 4,790 cfs, on 9 August 2011 (Table 92). The average flows in 2010 and 2011 were 1,523 cfs and 1,633 cfs respectively. Although the peak flow rate was 1,370 cfs greater in 2010 than in 2011, the average volume of flow did not follow this trend and was 110 cfs greater in 2011 compared to 2010 (NPS 2013b).

Tlikakila River

The Tlikakila River enters at the dividing line between Little Lake Clark and Lake Clark on the Northwest part of the lake (Figure 51). The Tlikakila River Basin drains 1,611km^2 (622mi^2) and comprises 21 percent of the Lake Clark watershed but its inflow contributions are the greatest of the six major tributaries discussed for this component; discharges ranged from 32 to 45 percent of the total inflow into Lake Clark from 1999 to 2001 (Brabets 2002).

Table 94. Physical properties and water-quality constituents of stream flow samples, June 1999 through September 2001 (USGS station number 15298050). Units displayed include: ft^3/s = cubic feet per second; µs/cm = microsiemens per centimeter; °C = degrees Celsius; mg/L = milligrams per liter (Brabets 2002).

Date	Time	Discharge (ft^3/s)	Specific Conductance (µs/cm)	pH	Water Temperature (°C)	Dissolved Oxygen (mg/L)
03/16/1999	1700	25	117	7.5	0.0	11.8
05/13/1999	1417	510	89	7.6	9.0	11.7
06/16/1999	1130	7,500	40	8.1	6.0	12.2
07/26/1999	1730	12,000	31	7.6	7.0	11.3
08/18/1999	1610	6,160	32	7.4	7.0	11.7
09/16/1999	1430	3,070	55	7.2	6.0	13.3
10/14/1999	1115	871	91	7.3	0.0	11.6
05/16/2000	1815	950	76	7.6	9.4	13.6
06/20/2000	1645	3,320	48	7.5	7.5	11.0
07/18/2000	1315	6,440	37	7.6	5.0	14.0
08/31/2000	1345	3,330	44	7.5	5.0	13.0
09/21/2000	1620	750	71	7.5	8.0	11.0

Chokotonk River

The Chokotonk River enters Little Lake Clark at the very top of the lake (Figure 51) and drains an area of 168 km^2 (65mi^2). The Chokotonk drainage area receives the highest mean annual precipitation (203 cm, 80 inches) of any other drainage that feeds Lake Clark (Table 95, Brabets 2002).

Table 95. Physical properties and water-quality constituents of stream flow samples, June 1999 through September 2001 (USGS station number 15298050). Units displayed include: ft^3/s = cubic feet per second; µs/cm = microsiemens per centimeter; °C = degrees Celsius; mg/L = milligrams per liter (Brabets 2002).

Date	Time	Discharge (ft^3/s)	Specific Conductance (µs/cm)	pH	Water Temperature (°C)	Dissolved Oxygen (mg/L)
06/16/1999	1416	2,190	28	8.2	6.0	12.5
07/22/1999	1515	1,200	33	7.6	10.0	*
08/17/1999	1145	1,950	31	7.3	5.5	11.3
10/14/1999	1330	258	74	7.1	0	11.6
06/20/2000	1300	944	40	7.2	6.0	12.5
07/18/2000	1120	1,500	30	7.4	4.5	14.3

Table 95 (continued). Physical properties and water-quality constituents of stream flow samples, June 1999 through September 2001 (USGS station number 15298050). Units displayed include: ft^3/s = cubic feet per second; µs/cm = microsiemens per centimeter; °C = degrees Celsius; mg/L = milligrams per liter (Brabets 2002).

Date	Time	Discharge (ft^3/s)	Specific Conductance (µs/cm)	pH	Water Temperature (°C)	Dissolved Oxygen (mg/L)
07/10/2001	1200	*	35	7.6	4.5	12.8
08/22/2001	1130	*	30	7.0	4.5	12.1
09/17/2001	1450	*	45	7.2	6.5	12.2

Currant Creek

Currant Creek enters Lake Clark on the upper one-third of the lake (Figure 51). Currant Creek drains a 427 km^2 (165 mi^2) area to the east of Lake Clark.

Table 96. Physical properties and water-quality constituents of stream flow samples, June 1999 through September 2001 (USGS station number 15298050). Units displayed include: ft^3/s = cubic feet per second; µs/cm = microsiemens per centimeter; °C = degrees Celsius; mg/L = milligrams per liter (Brabets 2002).

Date	Time	Discharge (ft^3/s)	Specific Conductance (µs/cm)	pH	Water Temperature (°C)	Dissolved Oxygen (mg/L)
06/16/1999	1655	2,670	45	7.4	7.5	12.1
07/21/1999	1415	1,590	36	7.5	7.0	*
08/17/1999	1425	1,280	40	7.4	7.5	11.1
09/15/1999	1515	885	51	7.0	6.0	12.6
10/17/1999	1720	279	74	7.3	2.0	11.6
06/21/2000	1100	776	37	7.6	5.4	14.0
07/18/2000	1510	2,760	37	7.5	5.5	13.8
08/29/2000	1215	1,230	36	7.4	6.5	12.0
09/19/2000	1725	297	71	7.4	6.5	14.9
06/05/2001	1200	1,050	54	7.6	6.0	14.3
07/10/2001	1430	1,470	43	7.4	6.0	12.4
08/22/2001	1500	1,620	38	6.9	7.5	11.4
09/25/2001	1645	671	55	7.0	5.5	13.7

Kijik River

The Kijik River enters Lake Clark on the Central part of the lake on the western shore, draining an area of 427 km^2 (298 mi^2) (Figure 51). The Kijik River deposits very little sediment into Lake Clark as the lakes throughout its drainage settle much of the suspended material (Brabets 2002).

Table 97. Physical properties and water-quality constituents of stream flow samples, June 1999 through September 2001 (USGS station number 15298050). Units displayed include: ft^3/s = cubic feet per second; µs/cm = microsiemens per centimeter; °C = degrees Celsius; mg/L = milligrams per liter (Brabets 2002).

Date	Time	Discharge (ft^3/s)	Specific Conductance (µs/cm)	pH	Water Temperature (°C)	Dissolved Oxygen (mg/L)
06/17/1999	1600	1,750	76	7.6	7.5	12.7
07/20/1999	1415	857	80	7.6	10.5	11.1
08/17/1999	1730	1,130	78	7.7	12.5	9.4
09/14/1999	915	758	88	7.1	7.5	12.3
10/13/1999	1445	432	88	7.3	3.5	11.2
06/21/2000	1630	586	84	7.6	12.0	11.6
07/20/2000	930	1,230	78	7.8	9.0	11.6
08/29/2000	1410	620	80	7.7	9.5	10.6
09/19/2000	1550	600	85	7.6	7.5	13.5
06/05/2001	1300	3,000	70	7.7	6.5	13.7
08/20/2001	1630	817	73	7.6	12.0	10.2
09/25/2001	1530	447	86	7.0	8.5	11.7

Tanalian River

Historical data regarding the discharge of the Tanalian River exist from 1951 to 1956. During this time period, a USGS gaging station located at the outlet of Lake Kontrashibuna reported the daily discharge rates at the Tanalian River mouth, these data could also be considered as lake outflow readings. Average maximum, minimum, and mean flows (units are in cfs) are reported monthly over the aforementioned time period and are represented graphically in Figure 53 (Weeks 2003).

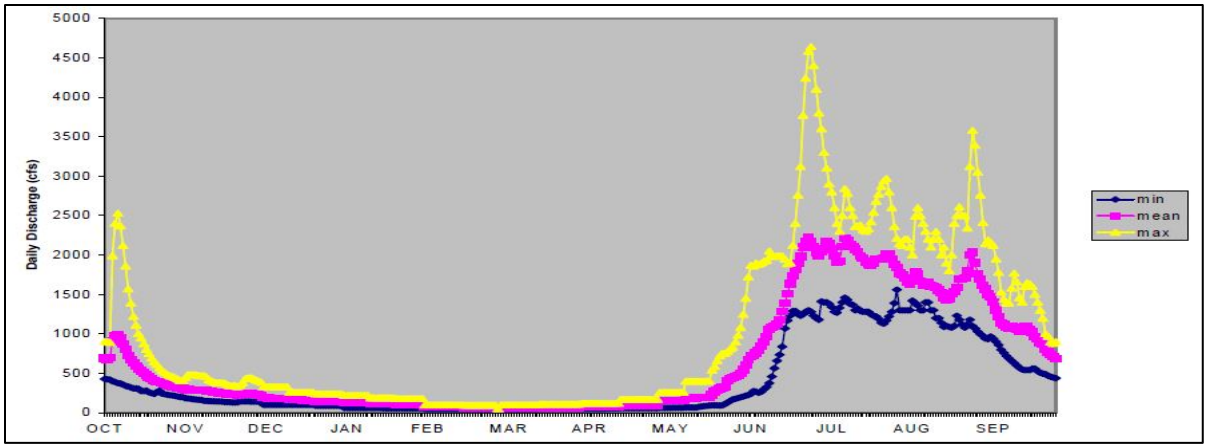


Figure 53. Average daily discharge summary (cfs) for the Tanalian River from 1951 to 1956 (Weeks 2003).

Table 98. Physical properties and water-quality constituents of stream flow samples from the Tanalian River, June 1999 through September 2001 (USGS station number 15298050). Units displayed include: ft^3/s = cubic feet per second; µs/cm = microsiemens per centimeter; °C = degrees Celsius; mg/L = milligrams per liter (Brabets 2002).

Date	Time	Discharge (ft^3/s)	Specific Conductance (µs/cm)	pH	Water Temperature (°C)	Dissolved Oxygen (mg/L)
06/17/1999	1800	5,920	54	7.4	7.0	13.0
07/19/1999	1845	1,620	44	7.5	11.3	11.4
08/16/1999	1640	1,850	44	7.2	11.5	11.3
09/13/1999	1801	650	50	7.1	10.5	10.4
10/14/1999	1650	543	52	7.0	5.5	10.3
05/15/2000	1500	179	54	7.4	8.5	11.5
06/21/2000	1820	750	47	7.7	10.5	11.4
07/19/2000	1530	1,640	46	7.8	11.5	10.1
08/30/2000	1315	656	45	7.3	11.0	10.5
09/20/2000	1100	489	50	7.2	8.5	12.0
06/05/2001	1545	1,560	54	7.5	7.0	13.8
08/20/2001	1730	2,090	45	7.5	13.5	13.4
09/24/2001	1700	450	44	7.0	10.0	11.4

Lake Clark Water Level and Discharge Data

Water quantity readings have been recorded for Lake Clark from 1999 to present. The lake levels are recorded using two measurement types: tape height and lake elevation (Brabets 2002, NPS 2013d). Tape height is a measurement recorded in feet from a fixed benchmark with a surveyed elevation

down the shoreline profile to the water's edge. Utilizing the tape height recording, the corresponding lake elevation value (reported in feet) can then be calculated from the following equation (Brabets 2002):

$$\text{Lake elevation} = -(0.133 * \text{tape reading}) + 301.77$$

The discharge or outflow from Lake Clark (reported in cfs) can then be derived from the lake elevation value utilizing the following equation.

$$\text{Flow (cfs)} = 3620 * (\text{elevation} - 295) + 3050$$

An example of the relationship between the parameters which measure the water quantity within Lake Clark can be observed on 3 July 2012. The tape height on that day was 7.5 feet; lake elevation was then calculated at 300.77 feet, and the corresponding discharge was 23,946 cfs. Annual average tape height, lake elevation, and discharge readings for Lake Clark were recorded from 1999 to 2013, and have been continually recorded manually since that time during ice free periods (Table 99, Brabets 2002; NPS 2013d).

Table 99. Annual average tape height, lake elevation, and discharge readings for Lake Clark from 1999 to 2013 (NPS 2013d).

Year	Tape Height (ft)	Lake Elevation (ft)	Lake Discharge (cfs)	Lake Discharge (6/1) to (10/31) (cfs)
1999	19.69	298.88	17,087	17,087
2000	*	297.21	11,589	12,844
2001	33.83	299.16	18,235	19,892
2002	18.01	299.10	10,804	9,109
2003	33.77	296.92	13,661	15,045
2004	29.32	298.25	14,808	14,808
2005	22.46	298.78	17,101	18,874
2006	23.29	298.67	17,668	18,156
2007	37.25	296.82	13,501	13,590
2008	28.78	297.94	14,232	15,623
2009	25.30	298.43	15,450	15,826
2010	27.80	298.12	14,490	15,043
2011	34.10	297.23	12,930	13,838
2012	17.54	299.54	19,522	20,745
2013	25.83	298.33	*	*

The above relationship between tape height, lake elevation, and outflow within Lake Clark is dependent upon the surface area of the lake (128 mi^2) remaining similar while fluctuating within its normal range of water levels; elevation heights between 297 to 303 feet. It is important to note the relationship was derived specifically for the conditions found within the Lake Clark system and should not be applied to other water bodies.

Table 100. Physical properties and water-quality constituents of stream flow samples collected from Lake Clark outlet, June 1999 through September 2001 (USGS station number 15299000).

Date	Time	Discharge (ft^3/s)	Specific Conductance (µs/cm)	pH	Water Temperature (°C)	Dissolved Oxygen (mg/L)
06/17/1999	1030	13,500	62	7.9	4.5	12.5
07/19/1999	1705	19,100	56	7.8	6.0	13.6
08/16/1999	1300	21,400	57	7.6	10.5	10.3
09/14/1999	1400	15,300	58	7.3	11.0	11.8
10/12/1999	1620	10,800	62	7.3	6.5	11.2
06/19/2000	1230	8,620	55	7.3	5.0	11.8
07/19/2000	1115	17,100	58	7.6	9.5	11.4
08/28/2000	1645	11,600	58	7.8	11.5	11.0
09/22/2000	1100	8,690	58	7.0	8.5	12.4
06/04/2001	1600	8,530	59	7.9	6.0	14.1
07/09/2001	1630	23,800	60	7.8	7.5	11.6
08/20/2001	1230	21,600	58	7.6	7.6	10.4
09/25/2001	1100	10,600	57	7.2	10.0	10.8

Table 101. Monthly mean discharge readings (cfs) for the Chakachamna River from 1959 to 2011, excluding the years between 1973 and 2007 (USGS 2012).

Month	Mean	Max	Water Year (Max)	Min.	Water Year (Min)
October	2,500	4,072	1966	1,351	1972
November	1,224	1,822	1970	902	1972
December	801	1,007	1964	623	2009
January	609	817	1961	480	1966
February	508	780	1961	381	1960

Table 101 (continued). Monthly mean discharge readings (cfs) for the Chakachamna River from 1959 to 2011, excluding the years between 1973 and 2007 (USGS 2012).

Month	Mean	Max	Water Year (Max)	Min.	Water Year (Min)
March	449	550	1970	325	1960
April	448	692	1971	250	1960
May	1,225	4,025	2009	471	1964
June	6,028	10,930	1971	2,114	1964
July	11,930	14,470	1971	9,960	1970
August	11,850	16,710	1971	8,416	1969
September	6,041	10,260	1965	3,347	1969

Chakachamna River Gage Station Summary

The gaging station on the Chakachamna River was operational from June 1958 through September 1972, and again from November 2008 to September 2011 (Table 101, USGS 2012). The station location monitored the outflow from Chakachamna Lake and was located just downstream from the lake outlet, 30 km (19 mi) upstream from Straight Creek, on the right bank. Although outside LACL, park staff agrees that the inclusion of this gage data is applicable as a majority of the source streams and creeks that feed Chakachamna Lake and eventually the Chakachamna River originate in LACL (Figure 54).

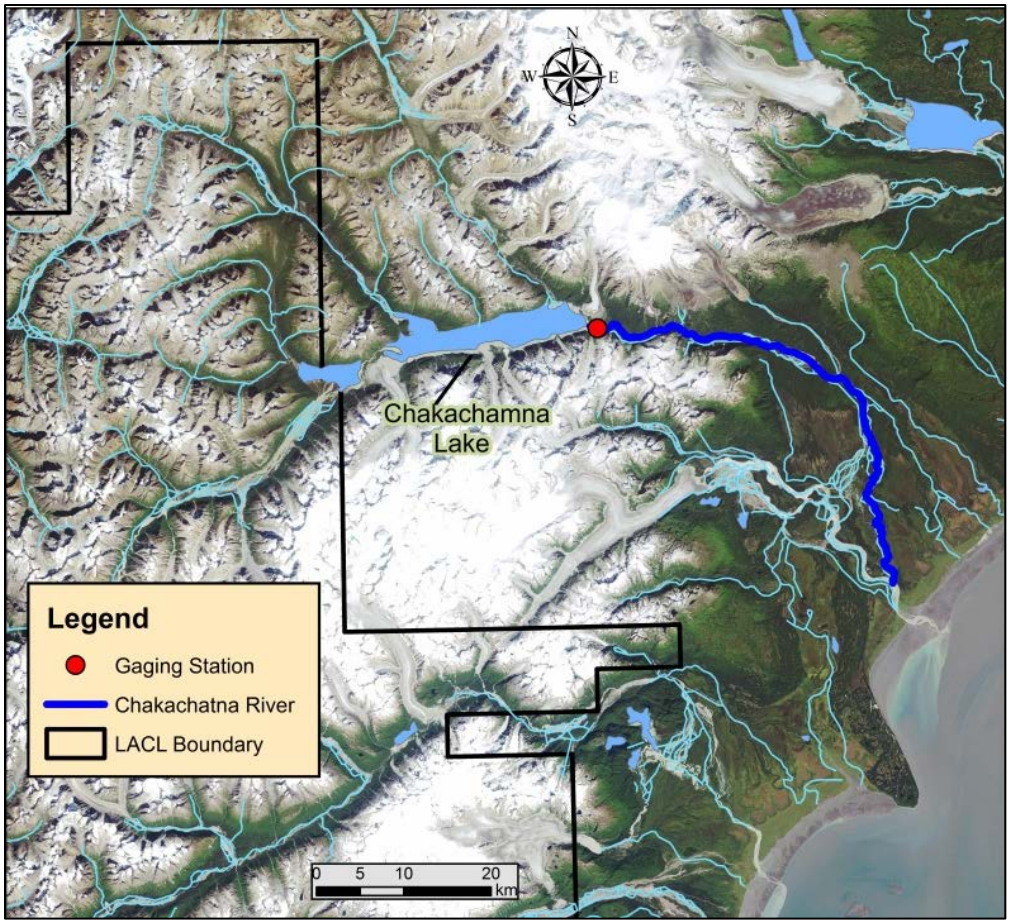


Figure 54. Location of Chakachamna gaging station (USGS 2012).

Newhalen River, USGS Gage Station Summary

The Newhalen River gage station sits 64 m (210 ft) above sea level and monitors a drainage area of (427 km^2) 3,478 mi^2 (USGS 2014). The monitoring site is located about one third of the way down the Newhalen River between Sixmile Lake and Iliamna Lake (Figure 55). Although the rivers extent is outside LACL it provides the main passage for spawning salmon and other fish to migrate into Lake Clark, therefore the discharge of the Newhalen River was considered to be important by park staff. Discharge was recorded from 1 July 1951 to 30 September 1986 (Table 102 and Table 103). Past readings can provide a benchmark for comparison of future discharge observations.

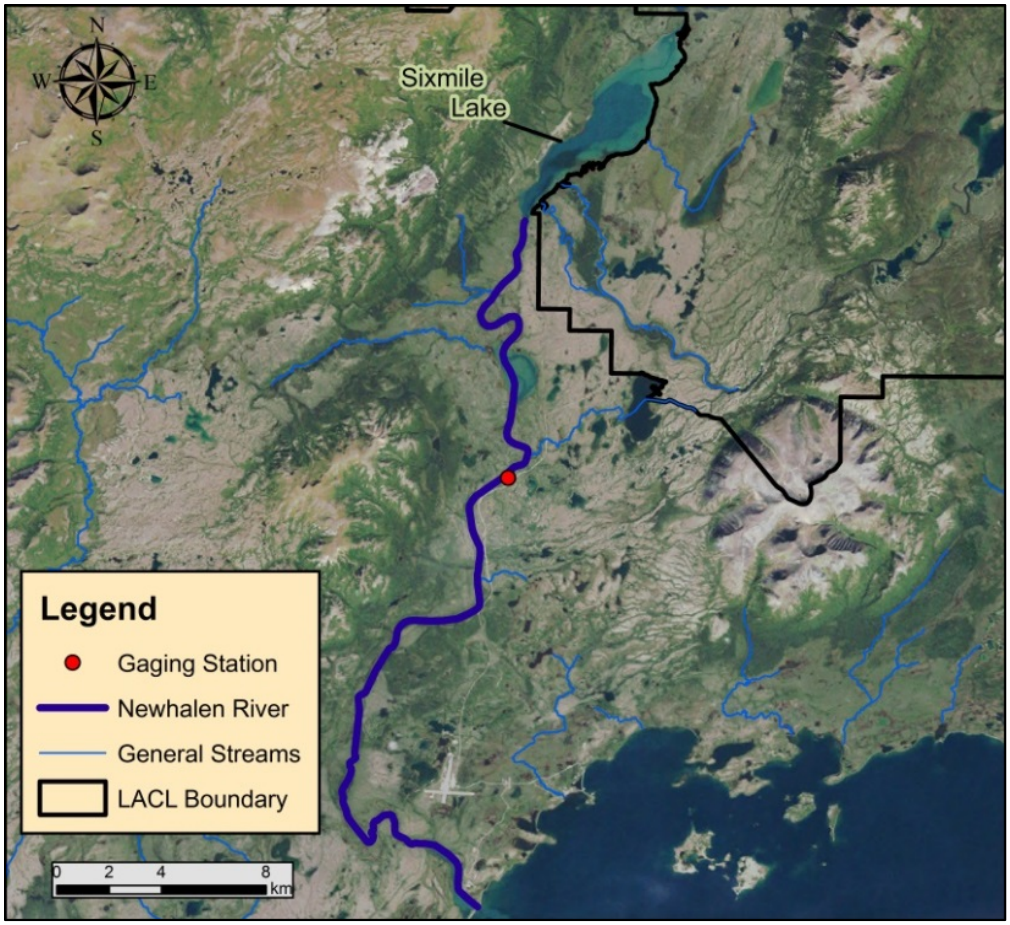


Figure 55. Location of the Newhalen River gage station (USGS 2012).

Table 102. Date, gage height, and peak flow values of the Newhalen River; stream flow values are estimated based on the gage height reading (USGS 2014).

Water Year	Date	Gage Height (ft)	Stream Flow (cfs)
1951	Sep. 06, 1951	7.33	26,300
1952	Jul. 30, 1952	7.40	26,600
1953	Jul. 01, 1953	8.03	29,600
1954	Aug. 26, 1954	6.66	23,200
1955	Jul. 28, 1955	7.52	27,200
1956	Aug. 19, 1956	7.16	25,500
1957	Sep. 15, 1957	7.05	25,100
1958	Jun. 24, 1958	7.07	25,200
1959	Aug. 30, 1959	9.19	36,000

Table 102 (continued). Date, gage height, and peak flow values of the Newhalen River, stream flow values are estimated based on the gage height reading (USGS 2014).

Water Year	Date	Gage Height (ft)	Stream Flow (cfs)
1960	Aug. 09, 1960	6.58	22,900
1961	Sep. 15, 1961	7.91	29,900
1962	Jul. 12, 1962	7.00	24,900
1963	Aug. 28, 1963	8.54	32,600
1964	Jun. 30, 1964	7.47	27,200
1965	Sep. 29, 1965	7.66	27,600
1966	Jul. 12, 1966	7.00	24,900
1967	Aug. 19, 1967	8.93	34,600
1969	Sep. 15, 1969	6.24	21,300
1970	Sep. 1970	6.12	20,700
1971	Aug. 16, 1971	10.68	44,200
1972	Sep. 1972	7.42	26,900
1973	1973	5.92	19,800
1974	1974	5.20	16,600
1975	Sep. 09, 1975	7.02	25,000
1976	Sep. 1976	5.77	19,000
1977	Aug. 1977	8.88	34,400
1982	Sep. 23, 1982	7.16	25,600
1983	Aug. 13, 1983	5.61	18,400
1984	Aug. 29, 1984	6.00	20,200
1985	Jul. 11, 1985	7.75	28,600
1986	Oct. 02, 1985	6.63	23,100

Table 103. Mean monthly discharge readings for the Newhalen River from 1951 to 1986 (USGS 2014).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1951	*	*	*	*	*	*	22,540	19,580	23,550	13,050	6,642	3,587
1952	2,242	1,552	1,652	1,950	3,117	11,710	22,720	23,500	13,930	13,070	7,795	5,587
1953	3,823	1,893	2,152	2,750	6,376	16,960	25,790	23,540	22,660	11,610	4,652	2,800
1954	1,800	1,300	1,500	2,400	4,600	10,130	16,050	21,520	18,770	12,040	6,601	2,239
1955	2,255	1,793	2,652	3,000	5,443	12,670	23,250	22,510	18,160	9,056	3,400	1,800
1956	1,200	1,000	1,000	1,400	4,974	11,920	20,590	22,850	17,010	8,674	3,950	3,177
1957	1,997	1,554	1,400	1,750	3,584	16,040	18,680	17,240	21,640	12,700	10,900	6,407
1958	4,594	3,068	2,397	2,233	5,980	18,880	22,380	21,530	13,760	9,103	4,122	2,500
1959	2,300	1,800	1,400	1,400	2,978	12,430	17,410	19,720	22,450	9,173	5,253	3,539
1960	2,997	2,255	1,848	1,200	5,477	14,900	18,510	21,570	16,620	11,930	8,200	5,500
1961	3,300	2,400	1,700	1,300	3,810	14,130	22,000	24,240	25,430	19,900	8,850	3,423
1962	2,348	2,346	2,200	2,731	4,384	15,470	22,920	18,210	16,210	7,555	4,719	3,300
1963	2,800	2,700	2,400	1,800	5,800	12,780	23,410	25,560	23,320	13,520	5,767	3,345
1964	2,094	1,503	1,397	1,300	2,448	19,750	21,960	17,650	15,320	9,359	6,050	3,987
1965	3,100	2,600	2,500	2,600	3,832	10,500	16,700	20,000	20,920	16,660	8,200	5,100
1966	3,300	2,300	1,700	1,500	2,812	12,500	18,650	22,430	16,910	13,390	8,917	5,745
1967	3,832	2,743	2,174	2,173	6,284	17,790	24,490	29,880	20,490	*	*	*
1982	*	*	*	*	3,722	10,920	17,720	19,890	20,700	15,140	6,687	3,842
1983	2,474	2,214	2,200	2,585	5,593	12,370	16,670	15,880	9,585	9,841	7,967	5,726
1984	4,319	3,528	3,332	3,271	4,345	11,360	18,240	18,260	12,980	7,146	4,507	3,561

Table 103 (continued). Mean monthly discharge readings for the Newhalen River from 1951 to 1986 (USGS 2014).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1985	3,197	2,936	2,832	2,708	4,056	15,580	25,940	22,910	19,170	18,320	7,263	4,177
1986	3,294	2,989	2,900	2,917	3,797	8,129	16,730	19,010	18,150	*	*	*
Mean Monthly Discharge	**2,860**	**2,220**	**2,070**	**2,150**	**4,450**	**13,700**	**20,600**	**21,200**	**18,500**	**12,100**	**6,520**	**3,970**

Tazimina River, USGS Gage Station Summary

The Tazimina River gage station sits 186 m (610 ft) above sea level and monitors a drainage area of (847 km^2) 327 mi^2 (USGS 2014). The monitoring site is located about half way down the Tazimina River between Lower Tazimina Lake and Iliamna Lake. This waterway provides the main passage for spawning salmon and other fish to migrate into Lower and Upper Tazimina Lake, therefore the discharge of the Tazimina was considered to be important by park staff (Figure 56). Discharge was recorded from 1 July 1981 to 30 September 1986. Past readings can provide a benchmark for comparison of future discharge observations (Table 104).

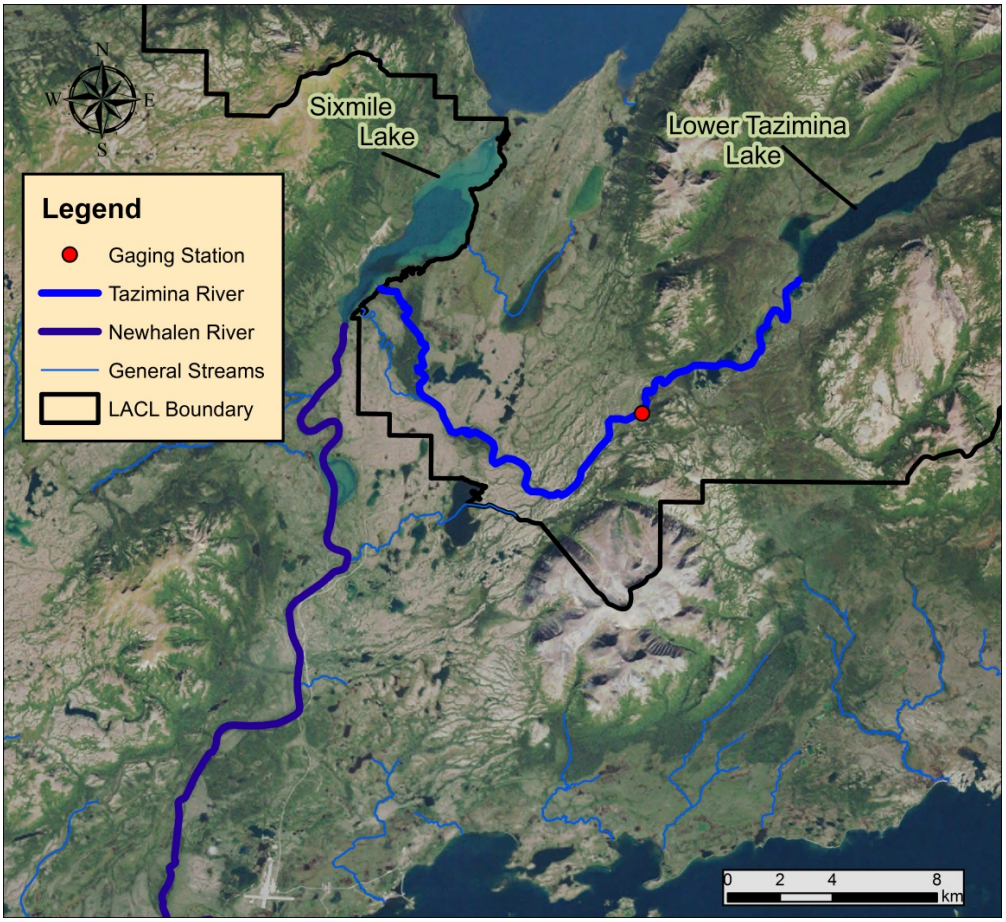


Figure 56. Location of the Tazimina River gage station.

Table 104. Mean monthly discharge readings for the Tazimina River from 1981 to 1986 (USGS 2014).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	*	*	*	*	*	*	2,556	2,305	898.7	689.7	639.3	342.6
1982	255.8	280.9	187.8	158.1	446.9	2,175	2,022	1,413	2,653	1,059	425.5	255.6
1983	177.6	140	140	191.2	732.9	1,916	1,350	963.6	671.3	1,662	703.1	716.3
1984	237.1	210	296.5	226.1	516.2	1,906	1,552	1,358	885	586.5	253.8	184.8
1985	162.3	153.6	150	147	592.6	2,523	2,692	2,370	2,022	1,997	398.1	220.2
1986	175.2	161.8	160	161.7	413.2	1,602	1,680	1,723	1,904	*	*	*
Mean Monthly Discharge	**202**	**189**	**187**	**177**	**540**	**2,020**	**1,980**	**1,690**	**1,510**	**1,200**	**484**	**344**

Telaquana Lake Outlet

A summary of the USGS gaging station at the Telaquana Lake (Figure 57) outlet is presented from 2006 to 2007 and is considered to have a drainage area of 150 km^2 (58 mi^2) (USGS 2014). Readings of gage height (feet) and outflow (CFS) were recorded during this time period (Table 105).

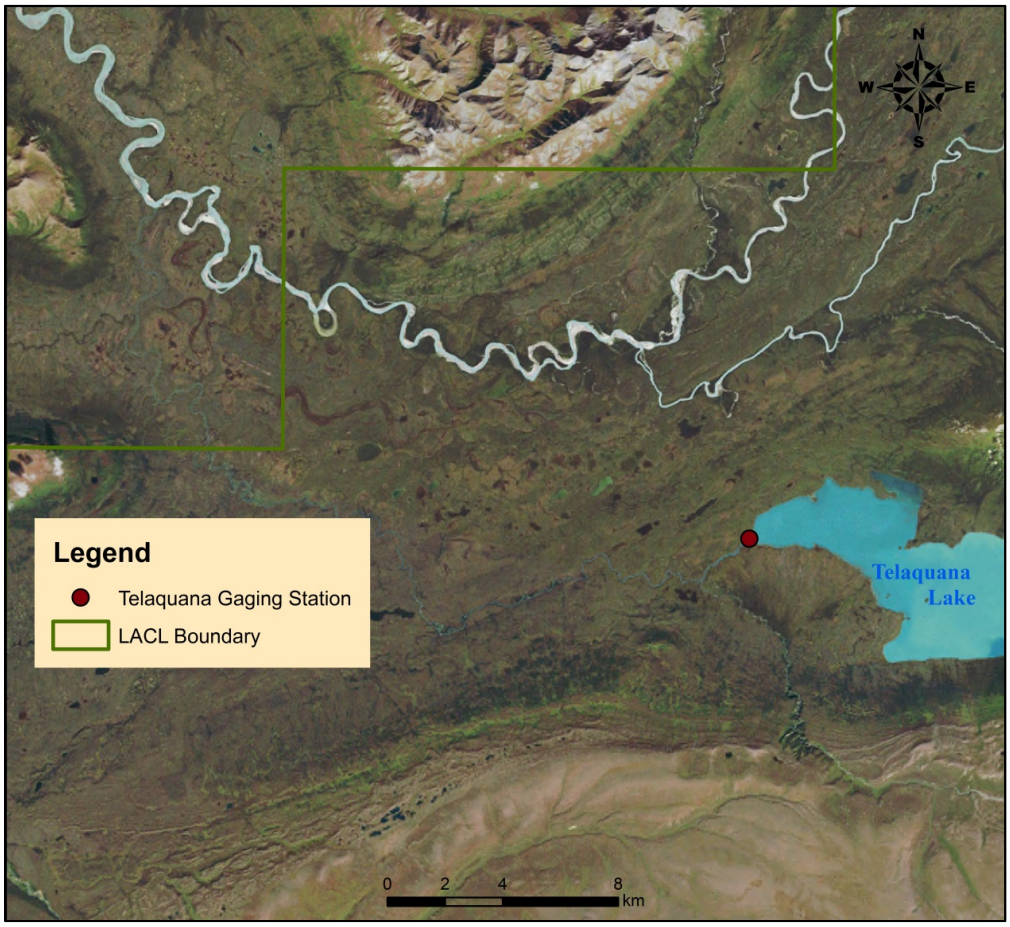


Figure 57. Location of the USGS gaging station at the Telaquana Lake outlet (USGS 2014).

Table 105. Gaging station readings at the Telaquana Lake outlet from 2006 to 2007 (USGS 2014).

Date	Stream Flow (ft^3/s)	Gage Height (ft)
26-Sep-07	537	9.64
20-Aug-07	1,210	10.90
18-Jul-07	911	10.24
30-May-07	194	8.48
21-Sep-06	647	9.95
25-Aug-06	1,480	11.37
18-Jul-06	1,370	11.04
21-Jun-06	622	9.80

Chilikadrotna Lake Outlet

A summary of the USGS gaging station at the outlet of Twin Lakes (Figure 58) on the Chilikadrotna River is presented from 2006 to 2007 (Table 106) and is considered to have a drainage area of 136 km^2 (53 mi^2) (Smith 2007). Readings of gage height (feet) and discharge (CFS) were recorded during this time period.

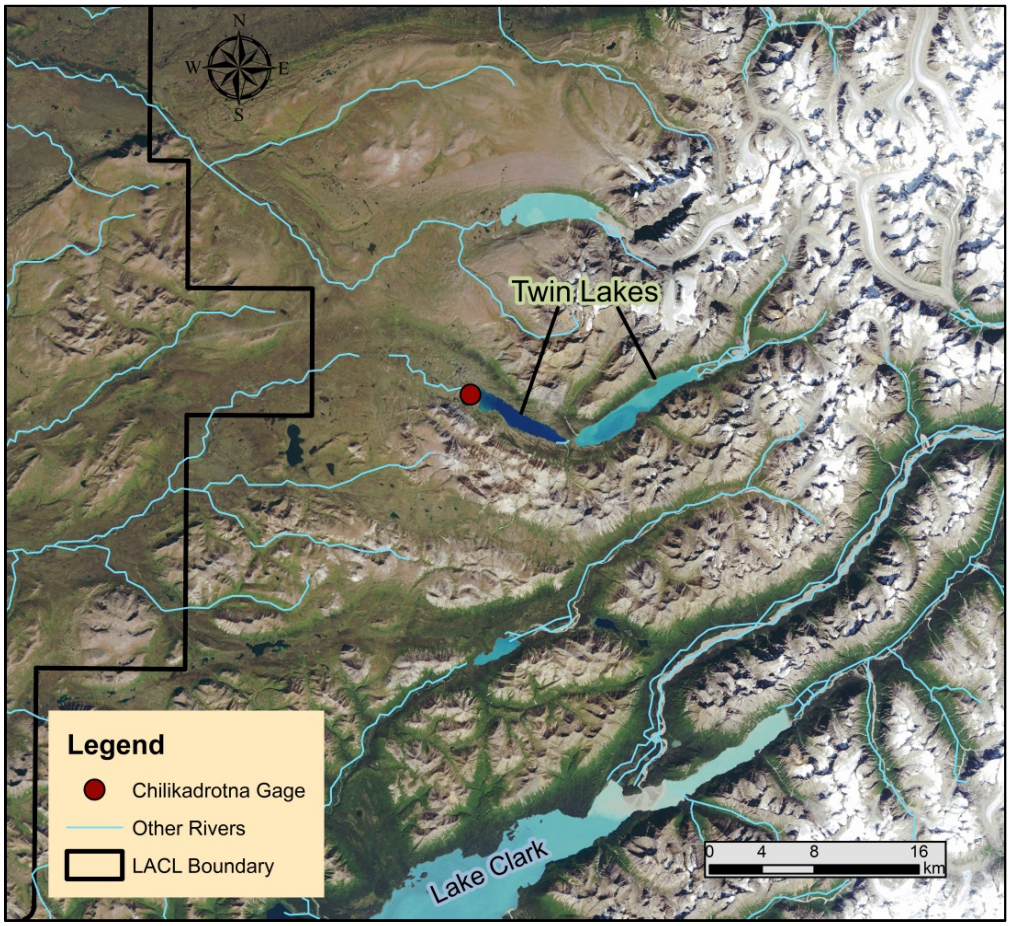


Figure 58. Location of the gaging station on the Chilikadrotna River (Smith 2007).

Table 106. 2006 to 2007 summary from the gaging station located on the Chilikadrotna River near the outlet of Twin Lakes (Smith 2007).

Date	Gage Height (feet)	Discharge (CFS)
21-Jun-2006	20.5	685
18-Jul-2006	20.64	*
25-Aug-2006	20.98	1150
21-Sept-2006	19.74	393
30-May-2007	18.47	74

* - Dangerous conditions of high winds and waves prevented the measurement

Table 106 (continued). 2006 to 2007 summary from the gaging station located on the Chilikadrotna River near the outlet of Twin Lakes (Smith 2007).

Date	Gage Height (feet)	Discharge (CFS)
18-Jul-2007	20.32	490
20-Aug-2007	20.51	707
26-Sept-2007	20.10	502

* - Dangerous conditions of high winds and waves prevented the measurement

Threats and Stressor Factors

Climate change and fluctuations can affect the water quantity parameters discussed in this component on a park-wide scale. Climate is one of the most important factors influencing ecosystems. In Alaska, climate is constantly fluctuating on multiple temporal scales, including several natural cycles. One climate fluctuation of particular importance in Alaska is the Pacific Decadal Oscillation (PDO) (Lindsay 2011). Mantua et al. (1997) formally identified this pattern of climate variability in a study relating climate oscillation to salmon production. The PDO, which is related to sea surface temperatures in the northern Pacific Ocean, affects atmospheric circulation patterns and alternates between positive and negative phases (Wendler and Shulski 2009). A positive phase is associated with a relatively strong low pressure center over the Aleutian Islands, which moves warmer air into mainland Alaska, particularly during the winter (Wendler and Shulski 2009). Some of the variation in Alaska's climate over time can be explained by major shifts in the PDO which occurred in 1925 (negative to positive), 1947 (positive to negative), and 1977 (negative to positive) (Mantua et al. 1997). Hartmann and Wendler (2005) found that much of the warming that occurred in Alaska during the last half of the twentieth century was likely due to the PDO shift in 1976-77.

Over the time period of 1949 to 2008, an increase in summer and winter temperatures was reported from two different long-term climate stations located in SWAN park regions (Lindsay 2011). The mean annual temperature over this time period increased by 1.8°C (3.4°F) at weather stations in both King Salmon and Homer, Alaska (Lindsay 2013). SWAN park region average annual temperatures are estimated to increase by about 0.5-0.6°C (0.9-1.1˚ F) per decade (Scenarios Network for Alaska Planning 2009). Increased annual average temperatures result in higher discharge values and gage heights for lakes, rivers, and streams within LACL predominantly fed by snow fields and glacial melt waters. The risk of extirpation of the snow and glacial fields which feed many LACL water bodies is also a distant threat. The loss of these water storage sources would result in severely decreased flows and gage heights, compromising the system's ability to sustain itself and the biological life which relies on them.

Water quantity parameters are or could potentially be affected in select areas of the park due to human influences by park visitors or mining operations. Potential external mining impacts and the proposed hydroelectric project at Chakachamna Lake are both looming threats to the water quantity resources of LACL (Young, pers. comm., 2014). A hydroelectric project has been pursued recently in the Susistna River, however, if the project does not come to fruition, LACL water resources could again be in jeopardy (Young, pers. comm., 2014). Weeks (2003) indicates that human impacts to

LACL water bodies are not currently a major concern and are certainly not impactful enough to warrant specific assessment projects.

The potential impact of proposed mining operations to the southwest of LACL, however, could drastically impact the natural hydrologic flows of LACL's pristine water bodies with particular concern on the Chulitna River system. Although no authorization has been permitted to begin mining the massive deposits of gold, copper, and molybdenum, estimated impacts include the construction of over 161 km (100 mi) of roads, which would include hundreds of culverts (NPCA 2009). Specific concerns for the hydrology of the region include the vast volume of water to support mining operations, dam building to pool the needed resources and hold contaminated water, and the depletion and/or contamination of ground water reserves (NPCA 2009).

Data Needs/Gaps

Discharge values collected on the Newhalen River include data gaps between the years of 1968 and 1981 (Table 103) for monthly mean discharges and from 1978 to 1981 (Table 102) for the peak flow.

Numerous water-related issues persist within LACL. Weeks (2003) indicates that the main reason water-related issues arise in LACL is due to the fact that basic information regarding the water resources of the park are almost non-existent. The general lack of baseline data regarding water quantity parameters for the water bodies presented in this document and all water bodies within Lake Clark make identifying trends and deciding on management actions difficult.

Lake Clark lake elevation, and discharge/out flow readings are measured manually using tape height. Due to a lack of automation, readings are not recorded consistently through the year or between years. This inconsistency, along with gaps in the data for certain days on which no readings were reported, makes comparative analysis between years difficult.

Overall Condition

An evaluation of condition based on data regarding this resource is not appropriate at this time due to lack of reference condition and limited data.

4.12.3 Sources of Expertise

Jeff Shearer, LACL, Chief of Natural Resources

Dan Young, LACL Fisheries Biologist

4.12.4 Literature Cited

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4.13 Climate

4.13.1 Description

Climate is widely recognized as one of the most fundamental drivers of ecological condition and ecological change, particularly in Alaska (NPS 2011). As a primary driver of many other ecosystem components (vegetation, wildlife, disturbance regime, etc.), climate also has numerous management consequences and implications. Climate was selected by the SWAN I&M program as a high-priority Vital Sign for southwest Alaska parks (Bennett et al. 2006).

The climate in LACL can be described as boreal, continental, and maritime; the climate to the west of the mountain range is boreal and continental, but the climate to the east of the mountain range, located along the coast, is maritime (Lindsay 2011, 2013). The mountains also influence the wide range in annual temperatures and precipitation levels (Lindsay 2011, 2013; Plate 27– Plate 28). Annual average temperatures were lower at interior locations in the northern part of the park (Stoney River remote automated weather station site) than at interior low elevations (Port Alsworth site; Plate 29). Average minimum and maximum temperatures range from -20°C to 6.7° C (-4°F to 44°F) at the Stoney River site, but ranged from -13.6°C to 16.6°C (8°F to 62°F) at the Port Alsworth site (WRCC 2014). Maximum temperature extremes for SWAN occur in LACL. Maximum temperatures have ranged from 36.6°C (98°F) in the Port Alsworth to 34.4°C (94°F) at the Stoney River site. Minimum temperature extremes have also occurred at the Stoney River site, dropping as low as -48.3°C (-55°F) (WRCC 2014). Total annual precipitation ranges from 1,525 mm to 5,341 mm (60 in – 208 in) at high elevations along the mountains. Total annual precipitation ranges from 381 mm to 1,525 mm (15 in to 60 in) in the lower elevations (SNAPS et al. 2009; Plate 28).

4.13.2 Measures

- Temperature
- Precipitation
- Snow depth/ice thickness and water equivalent (SWE)

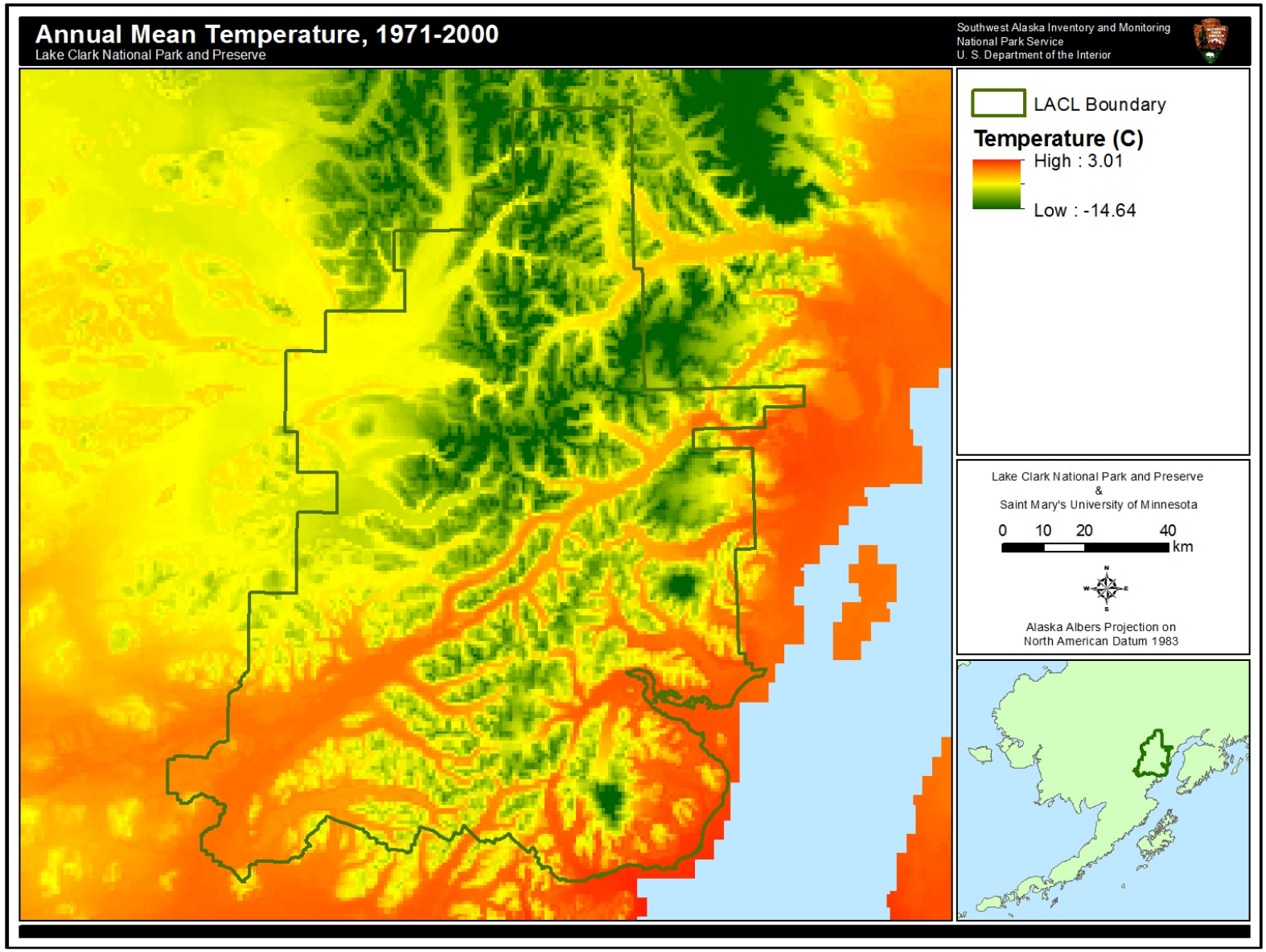


Plate 27. Annual mean temperature (°C) for LACL between 1971 and 2000 (PRISM 2010).

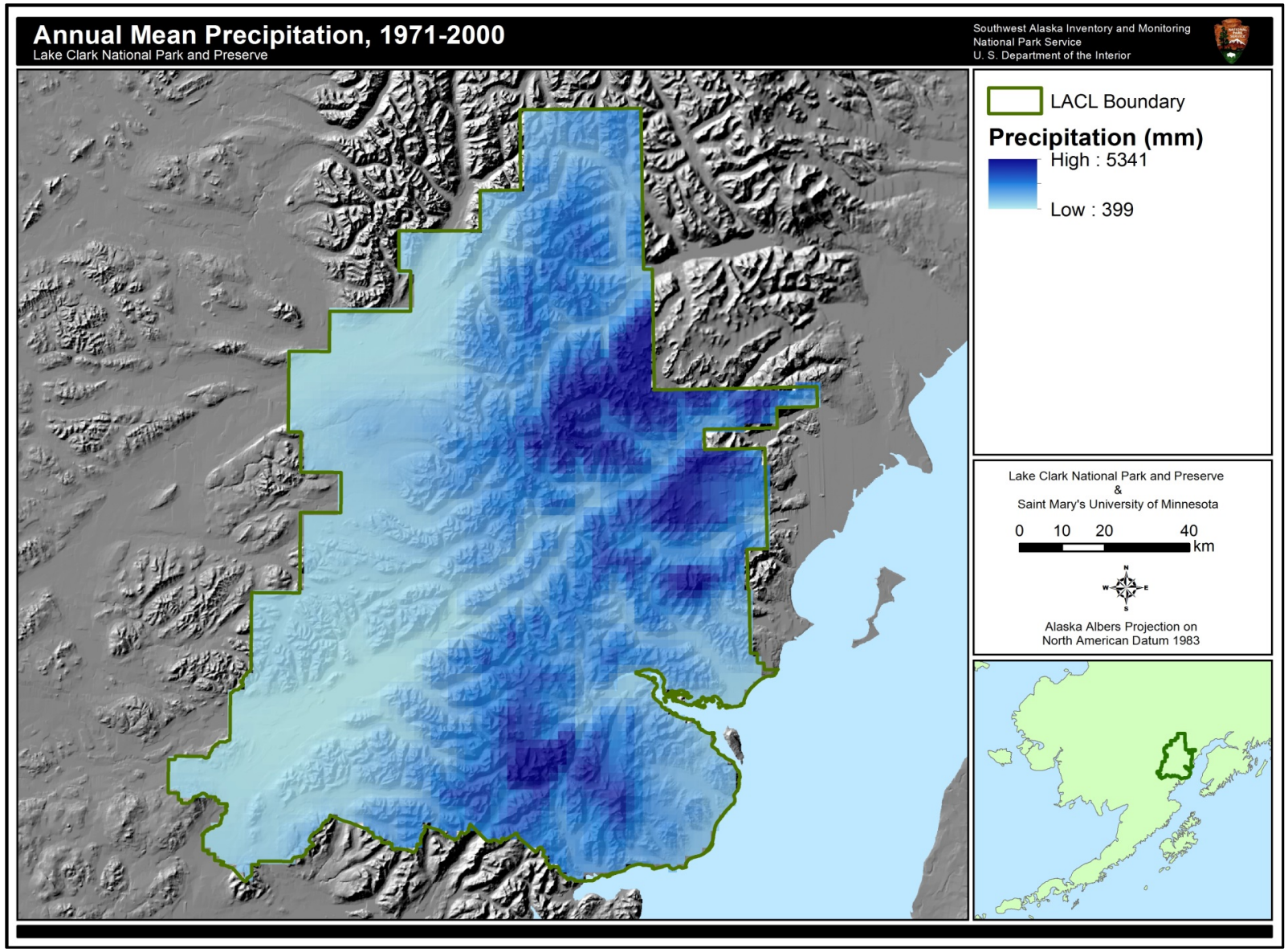


Plate 28. Annual mean precipitation (mm) for LACL between 1971 and 2000 (PRISM 2010).

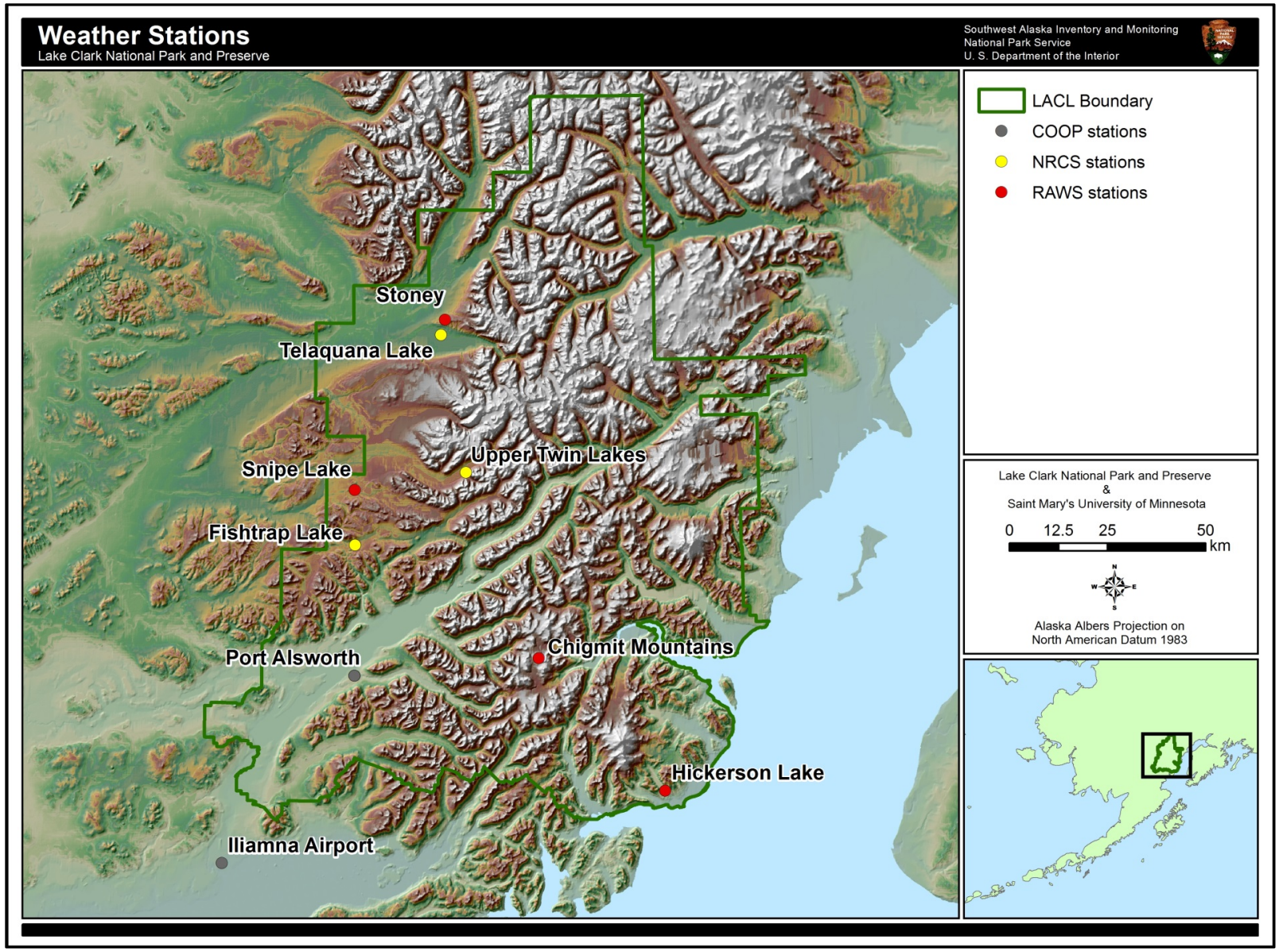


Plate 29. Weather stations found within and near the southern boundary of LACL.

4.13.3 Reference Conditions/Values

The reference condition for LACL climate has not been determined; however, 30-year climate normals will be used as a reference condition for this assessment. Climate normals are averages of climate variables (e.g., temperature and precipitation) over a 30-year time period (NCDC 2014). Climate normals were taken from the Alaska Climate Research Center (ACRC) database and include average monthly temperature, precipitation, and snowfall (only at Port Alsworth). Both Port Alsworth and Iliamna Airport stations had the most current climate normals (1981 – 2010) available (ACRC 2014). Table 107 displays climate normals (1981 – 2010) for the Iliamna Airport station and Table 108 displays normals (1981 – 2010) for the Port Alsworth station.

Table 107. Climate normals for 1981 – 2010 at the Iliamna Airport station. Climate normals include average monthly temperature and precipitation (ACRC 2014).

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Average Temperature (°C)	-4.7	-3.2	-0.8	4.4	10.8	15.2	17.1	16.2	12.2	4.8	-0.9	-2.9	5.7
Average Total Precipitation (mm)	32	27	19	22	29	34	73	106	116	82	54	39	633

Table 108. Climate normals from 1981 – 2010 at the Port Alsworth station. Climate normals include average monthly temperature, precipitation, and snow fall (ACRC 2014).

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Average Temperature (°C)	-9.2	-7.4	-4.3	1.8	7.8	12.4	14.4	13.1	8.6	1.4	-4.6	-7.0	2.3
Average Total Precipitation (°C)	21	21	17	12	10	19	34	48	56	38	37	23	336
Average Total Snowfall (mm)	378	307	297	178	18	0.0	0.0	0.0	5.0	132	480	457	2,253

4.13.4 Data and Methods

NOAA (2013) recorded lake ice thickness and snow depth measurements for Port Alsworth between 1961 and 2002. Data are presented by "winter year" (e.g., winter year 1961 refers to the winter of 1960-1961; winter year 1962 is the winter season of 1961-1962). NPS documented and summarized these data. There were 614 records of lake ice depth and snow depth for that time period. An average, minimum, and maximum measurement for the data were calculated. It should be noted that the

number of measurements per year varied between one and 33 records. There are several years without records, including 1985 and 1998 – 2000.

In 2008 and 2009, three Remote Automated Weather Stations (RAWS) were placed in LACL (Lindsay 2011). These stations are Chigmit Mountains, Hickerson Lake, and Snipe Lake (Plate 29). The Port Alsworth Climate Reference Network site was added in 2009; however, the data from this station were not included in this assessment. Temperature, precipitation, and snow depth data from these stations were obtained through the Western Regional Climate Center website (WRCC 2014). Data were available from October 2008 through February 2013 for Hickerson Lake and Snipe Lake stations, but data collection at the Chigmit Mountains station did not begin until June 2009. However, Chuck Lindsay (SWAN Physical Scientist, email communication, 28 March 2013) raises concerns regarding the collection of winter (November-April) precipitation data at RAWS stations. These stations utilize unheated tipping buckets to collect precipitation and are only accurate in measuring liquid precipitation, not snow or snow water equivalent (Lindsay, written communication, 28 March 2013). Sometimes ice or snow that has been stored in the gauge for weeks or even months suddenly melts, resulting in a "delayed" report of precipitation. Buckets can also shake during high winds and cause false precipitation reports. Lindsay (email comm., 28 March 2013) believes that precipitation readings taken when the temperature is below -0.5°C (31.1°F) or when the wind speed is above 126 km/hr (78 mi/hr) are likely not reliable. It should be noted that the Silver Salmon Creek site will be added in 2013, and the Hickerson Lake site will be removed from service in 2014.

NRCS (2014) recorded 22 years of average monthly snow depth and water equivalent (SWE) data from four stations in LACL, including Port Alsworth, Telaquana Lake, Fishtrap, and Upper Twin Lakes. Average snow depths and SWE were recorded every year from January through May; however, records for April and May were not used in this analysis as a result of little to no data.

The NPS also requested evaluation of available weather station data using the RClimDex tool. This tool computes a suite of indices from daily precipitation, maximum temperature, and minimum temperature data with the R Statistical Environment. In total, the tool calculates 27 core indices developed by the Expert Team for Climate Change Detection Monitoring and Indices (ETCCDMI) (Zhang and Yang 2004). Of the 27 indices, the NPS requested reporting of Frost Days, Ice Days, Growing Season Length, Warm Minimum Temperatures "Warm Nights", Cool Maximum Temperatures "Cool Days", and Annual Total Precipitation. There were four long-term weather stations available for the park that were analyzed using this toolset: Iliamna Airport - USW00025506, Port Alsworth - USC00507570, Stoney River, and Telaquana Lake. The amount of data obtained varies by station. These stations include data for the entire duration of monitoring at each station (regardless of method or purpose). RClimDex requires various minimum records (i.e., intra-year records, or years of data) depending on the index. Other stations had data that were too limited in time frame to utilize the RClimDex tools. It should be noted that although there were 16 years of available data for the Telaquana Lake Station, only five years were analyzed using RClimDex due to the lack of data obtained for several months during several years.

4.13.5 Current Condition and Trend

Temperature

WRCC (2014) has documented yearly average temperatures at locations in LACL from 2009 to 2013. The Hickerson Lake station recorded the highest average temperatures, while the Chigmit Mountains station recorded the coldest average temperatures. Average temperatures at the Hickerson Lake station fluctuated between 1.7°C (2012) and 3.0°C (2010). Average temperatures decreased at the Chigmit Mountains and Snipe Lake stations between 2009 and 2012. Both stations recorded an increase in average temperature in 2013.

Table 109. Yearly average temperatures (°C) for Chigmit Mountains, Hickerson Lake, and Snipe Lake station in LACL (WRCC 2014).

Year	Chigmit Mountains	Hickerson Lake	Snipe Lake
2009	-0.4	2.6	-0.5
2010	-4.0	3.0	-0.9
2011	-5.4	2.2	-1.4
2012	-5.2	1.7	-2.6
2013	-3.3	3.3	0.6

Precipitation

WRCC (2014) documented precipitation for three stations in LACL. The Hickerson Lake station recorded the highest annual precipitation among the three stations, while Snipe Lake station had the least precipitation. Total precipitation at Hickerson Lake increased between 2009 and 2013, with the exception of 2010. The Chigmit Mountains station recorded a fluctuation in total precipitation ranging from 587.9 mm (2010) to 1504 mm (2009). Total precipitation at Snipe Lake increased between 2008 and 2012, but slightly decreased in 2013. Table 110 displays total precipitation for the three short-term stations within LACL.

Table 110. Yearly average precipitation (mm) for Chigmit Mountains, Hickerson Lake, and Snipe Lake station in LACL (WRCC 2014).

Year	Chigmit Mountains	Hickerson Lake	Snipe Lake
2009	1504.0	1124	284.1
2010	587.9	1016	340.2
2011	805.6	1176	341.2
2012	651.5	1289	472.2
2013	902.8	1337	411.4

Snow Depth/Ice Thickness and Water Equivalent

NOAA (2013) recorded lake ice thickness data for Port Alsworth between 1961 and 2002. Between 1961 and 1976, ice was gone by 31 May, and ice was back by 1 November. The overall average maximum lake ice thickness between 1961 and 2002 was 756.1 mm. The average maximum lake ice thickness for the 1960s was 996.2 mm, but it declined to 924.6 mm for the 1970s. By the 1980s, the average maximum was 508 mm, and 701.7 mm in the 1990s. It should be noted that only one measurement was recorded in 1985, 1986, 1989, and 1997. A 10-period moving average was calculated to help show a relative trend in the data. This average displays a decreasing trend; it decreased from approximately 1,000 mm in the early 1970s to below 600 mm in the late 1980s. The average increased slightly by 1996 but remained under 700 mm. Figure 59 displays the yearly maximum ice thickness and the 10-period moving average for Port Alsworth.

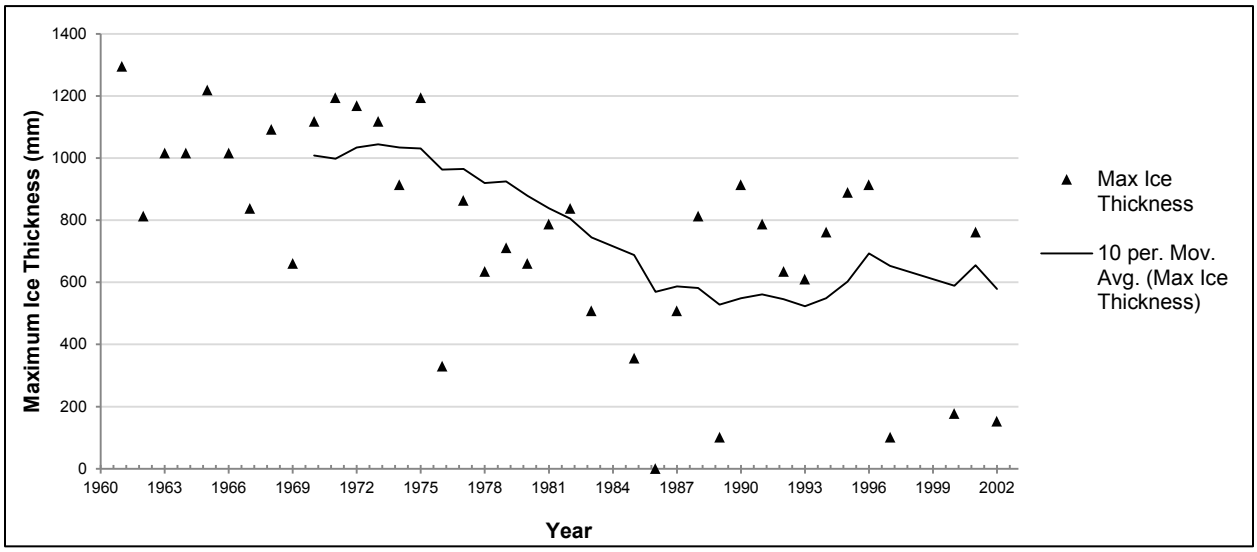


Figure 59. Yearly maximum lake ice thickness (mm) for Port Alsworth station (NOAA 2013).

NOAA (2013) recorded snow depth measurements at Port Alsworth by winter year between 1961 and 2002. The overall maximum snow depth was recorded in 1961 (609.6 mm). Most years after 1961 had maximum snow depths below 400 mm with the exception of 1966 (406.4 mm), 1970 (508 mm), and 1981 (406.4 mm). The average snow depth was 38.8 mm (n=614). The average annual snow depth ranged from 0.0 mm (1983 and 2001) to 192.2 mm (1962). The 10-period moving average for maximum snow depths showed an overall decreasing trend. Figure 60 displays the maximum snow depths by winter year at Port Alsworth.

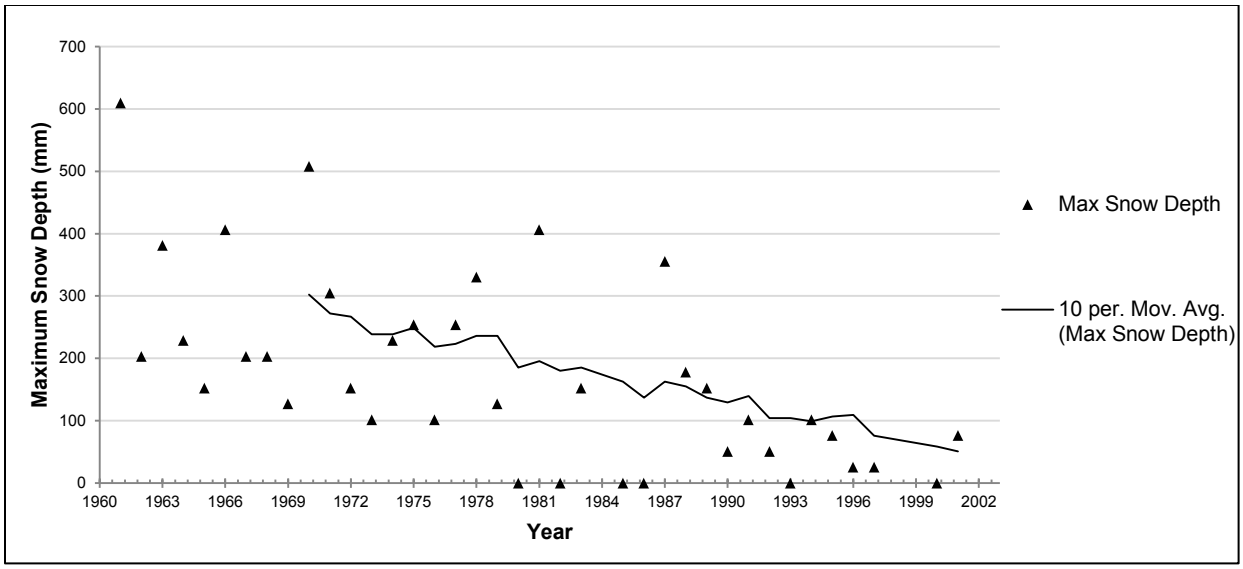


Figure 60. Maximum snow depth (mm) by winter year for Port Alsworth station (NOAA 2013).

NRCS (2014) documented snow course data for four stations in LACL. The Fishtrap Lake station recorded the highest averages of snow depth and SWE among the four stations, while the Port Alsworth station recorded the lowest average snow depth and SWE. Fishtrap Lake had a yearly average snow depth and SWE of 888.5 mm and 221.9 mm (n=20), respectively. The snow depth at Fishtrap Lake ranged from 292.1 mm (2003) to 1282.7 mm (1993). The SWE at Fishtrap Lake ranged from 87.6 mm (2003) to 367.0 mm (1993). Port Alsworth had a yearly average snow depth and SWE of 357.9 mm and 85.7 mm (n=20), respectively. The snow depth at Port Alsworth ranged from 0 mm (2003) to 673.1 mm (2010, and 2011). The SWE at Port Alsworth ranged from 0 mm (2003) to 155.9 mm (1995). Table 111 displays yearly average snow depth and SWE for four stations in LACL.

Table 111. Yearly average snow depth (mm) and SWE (mm) for Port Alsworth, Telaquana Lake, Fishtrap Lake, and Upper Twin Lakes stations (NRCS 2014).

	Port Alsworth		Telaquana Lake		Fishtrap Lake		Upper Twin Lakes	
Date	Snow Depth	SWE	Snow Depth	SWE	Snow Depth	SWE	Snow Depth	SWE
1992	465.7	108.4	495.3	97.9	1092.2	227.3	--	--
1993	349.3	92.1	516.5	110.1	1282.7	367.0	756.4	179.1
1994	196.9	54.0	389.5	109.2	905.9	274.3	499.5	165.9
1995	514.4	156.9	654.1	167.0	952.5	282.0	804.3	215.9
1996	393.7	87.6	546.1	102.9	977.9	208.3	520.7	96.5
1997	177.8	42.3	571.5	114.3	812.8	215.9	660.4	170.2

Table 111 (continued). Yearly average snow depth (mm) and SWE (mm) for Port Alsworth, Telaquana Lake, Fishtrap Lake, and Upper Twin Lakes stations (NRCS 2014).

	Port Alsworth		Telaquana Lake		Fishtrap Lake		Upper Twin Lakes	
Date	Snow Depth	SWE	Snow Depth	SWE	Snow Depth	SWE	Snow Depth	SWE
1998	387.4	80.0	516.5	99.9	749.3	180.4	753.5	171.9
1999	419.1	74.3	584.2	109.2	984.3	215.9	901.7	212.1
2000	584.2	136.3	516.5	96.5	795.9	204.9	516.5	109.2
2001	254.0	66.9	313.3	59.3	1219.2	340.3	711.2	176.6
2002	431.8	133.4	635.0	112.6	956.7	232.0	753.5	169.3
2003	0.0	0.0	93.1	14.4	292.1	87.6	25.4	3.8
2004	474.1	109.2	457.2	103.3	863.6	200.6	635.0	145.6
2005	88.9	31.8	647.7	161.3	1066.8	297.2	660.4	172.7
2006	152.4	28.0	660.4	114.3	--	--	711.2	147.3
2007	228.6	48.3	152.4	35.6	584.2	124.5	355.6	101.6
2008	--	--	609.6	147.3	1143.0	241.3	812.8	182.9
2009	635.0	152.4	622.3	157.5	939.8	226.1	711.2	167.6
2010	59.3	15.3	222.3	47.7	474.1	89.7	355.6	81.3
2011	673.1	148.6	387.4	68.6	863.6	213.4	558.8	175.3
2012	673.1	148.6	552.5	101.6	--	--	--	218.5
2013	--	--	387.4	88.9	812.8	209.6	457.2	95.3

WRCC (2014) documented snow depth for three stations in LACL throughout the calendar year. The Chigmit Mountains station accumulated the most snow depth among the three stations, while the Snipe Lake station had the lowest snow depth. Snow depth in the Chigmit Mountains ranged from 324.4 mm (2009) to 446.0 mm (2011). Hickerson snow depth ranged from 119.7 mm (2010) to 231.5 mm (2012). Snow depth at Snipe Lake ranged from 8.7 mm (2008) to 29.3 mm (2010). Table 112 displays the average annual snow depths for the three short-term stations within LACL.

Table 112. Yearly average snow depth (mm) for Chigmit Mountains, Hickerson Lake, and Snipe Lake station in LACL (WRCC 2014).

Year	Chigmit Mountains	Hickerson Lake	Snipe Lake
2009	324.4	176.7	12.4
2010	254.8	119.7	29.3
2011	446.0	203.9	21.8
2012	432.4	231.5	25.9
2013	401.1	199.2	15.2

RClimDex Indices

Table 113 provides descriptions of each index calculated using RClimDex.

Table 113. Descriptions of RClimDex indices (Zhang and Yang 2004).

Index	Description
Frost Days	Annual count of days when the minimum temperature is less than 0°C.
Ice Days	Annual count of days when the maximum temperature is less than 0°C
Growing Season Length	Annual count of days between the first 6-day period where the temperature is greater than 5°C and the first 6-day period where the temperature is less than 5°C.
Warm Minimum Temperatures "Warm Nights"	Percentage of days when the minimum temperature is above the 90th percentile.
Cool Maximum Temperatures "Cool Days"	Percentage of days when the maximum temperature is below the 10th percentile.
Annual Total Precipitation	Annual total precipitation during days when precipitation is greater than 1mm.

Iliamna Airport Station USW00025506

Station USW00025506 at Iliamna Airport includes weather records dating back to 1940. Since 1943, nearly continuous daily records of minimum temperature, maximum temperature, and precipitation are available (Figure 61). Indices were calculated from 1943 to 2013, when records were consistent in year-long recording of the three parameters. It should be noted that there was a lack of continuous data between 1970 and 1976, so those years were not included in the indices.

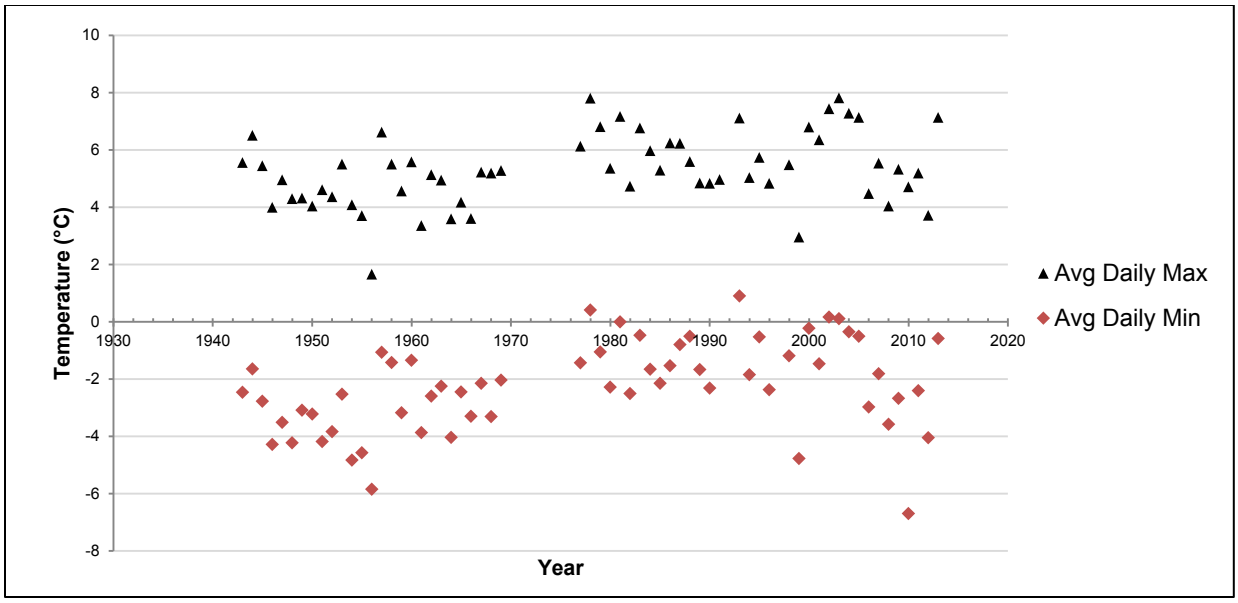


Figure 61. Yearly average minimum and maximum daily temperature at USW00025506, Iliamna Airport.

Yearly Frost Days (FD) at the Iliamna Airport station averaged 172 days (n=60) from 1943 to 2013. FD ranged from 130 days (1993) to 212 days (1956) (Figure 62). The 10-period moving average decreased from an average of 185 days from the 1940s to 1970s to an average of 162 days from the 1980s to 2010s.

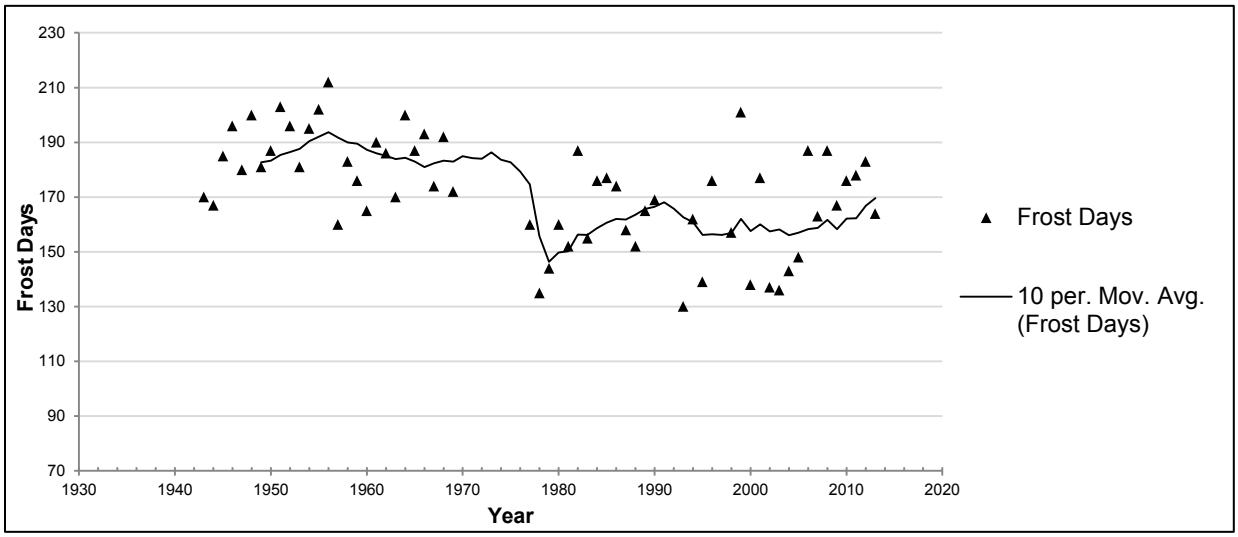


Figure 62. Yearly frost days at USW00025506, Iliamna Airport. Calculated using RClimDex toolset with 10-period moving average.

Yearly Ice Days (ID) at the Iliamna Airport station averaged 83.9 days (n=61) from 1943 to 2013. ID ranged from 35 days (2000) to 126 days (1956). Similar to FD, the ID 10-year moving average decreased by approximately 20 days after the 1970s. Between the early 1940s and the late 1960s, the

10-period moving average was 92 days; the ID decreased to 78 days between the 1980s and 2013 (Figure 63).

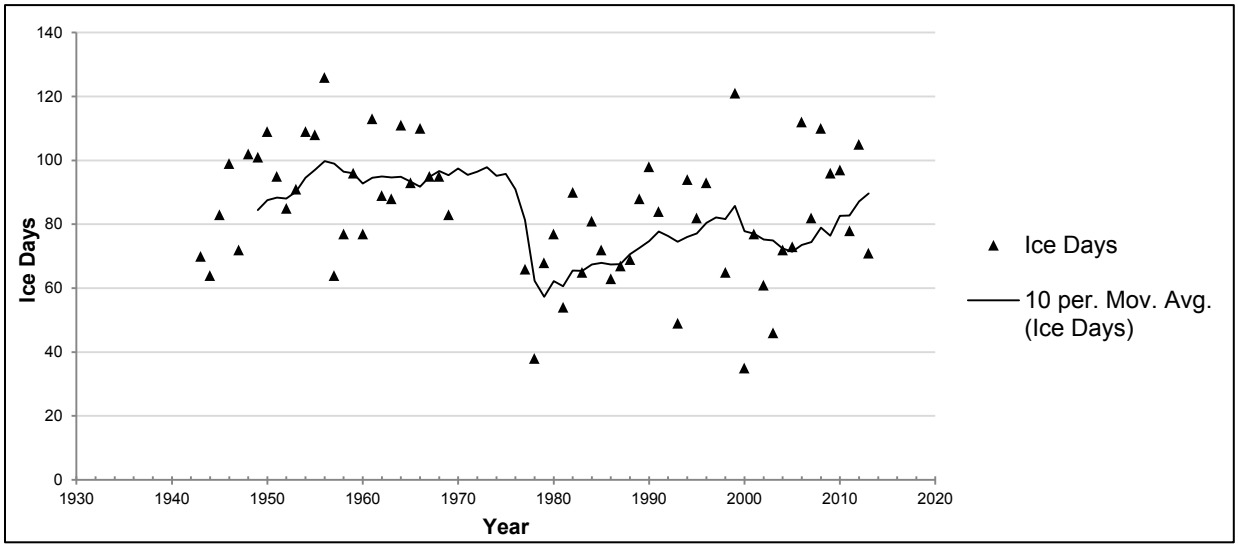


Figure 63. Yearly ice days at USW00025506, Iliamna Airport. Calculated using RClimDex toolset.

Yearly Growing Season Length (GSL) at the Iliamna Airport station averaged 149 days (n=61) from 1943 to 2013. GSL ranged from 123 days (1956) to 179 days (2002). The 10-period moving average shows an increasing trend over the years despite the fluctuations in the trend line (Figure 64).

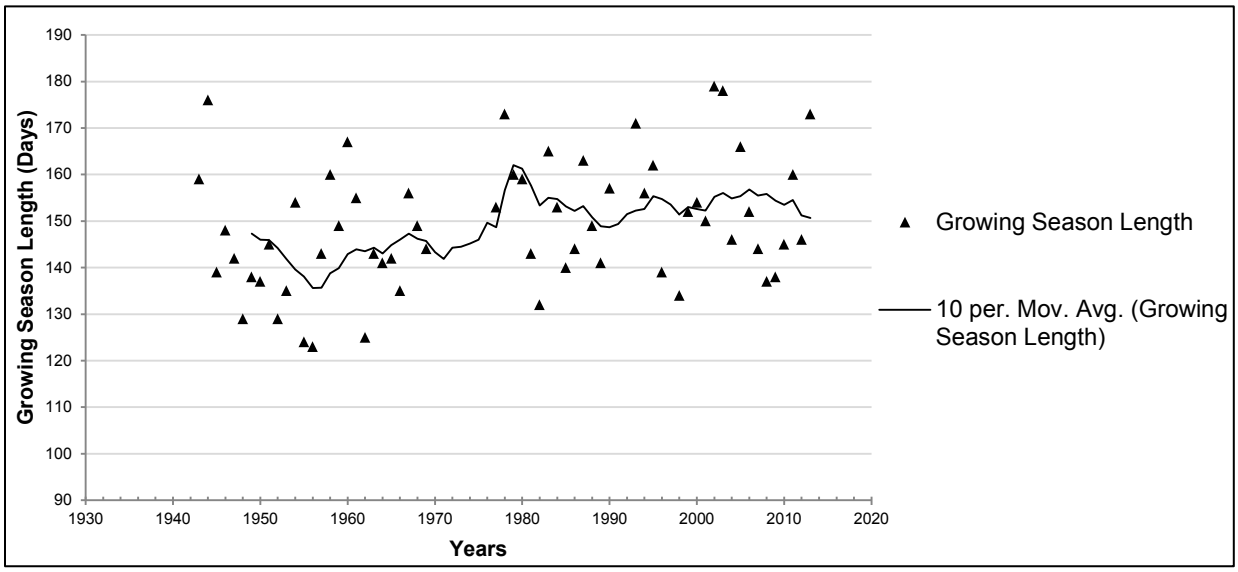


Figure 64. Yearly growing season length at USW00025506, Iliamna Airport. Calculated using RClimDex toolset.

Yearly percent warm minimum temperatures at the Iliamna Airport station averaged 6.6% (n=61) from 1943 to 2013. The minimum percentage of warm minimum temperatures was 1.1% (1946,

1948, 1952, 1955, 1956) and the maximum was 25.3% (1993). The percent warm minimum temperatures seemed to show an increasing trend until the mid-1990s. The 10-period moving average displays that trend, along with a decreasing trend starting in the late 1990s though 2010 (Figure 65).

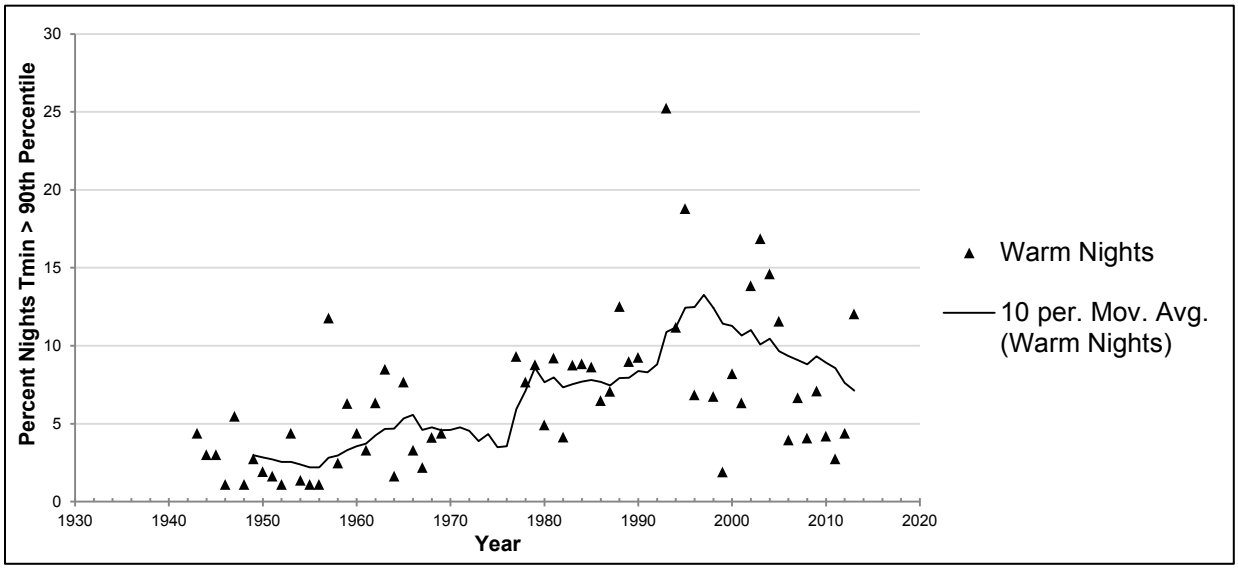


Figure 65. Yearly percent warm minimum temperatures at USW00025506, Iliamna Airport. Calculated using RClimDex toolset.

Yearly percent cool maximum temperatures at the Iliamna Airport station averaged 11.4% (n=61) from 1943 to 2013. The minimum percentage of cool maximum temperatures was 1.1% (1978) and the maximum was 27.0% (1956). The 10-period moving average decreased slightly after the 1970s. The percent cool maximum temperatures averaged 12.7% before 1980 and 10.2% after 1980 (Figure 66).

Yearly total precipitation at the Iliamna Airport station averaged 649 mm (n=61) from 1943 to 2013. Total precipitation ranged from 371 mm (1968) to 1,022 mm (1985) (Figure 67).

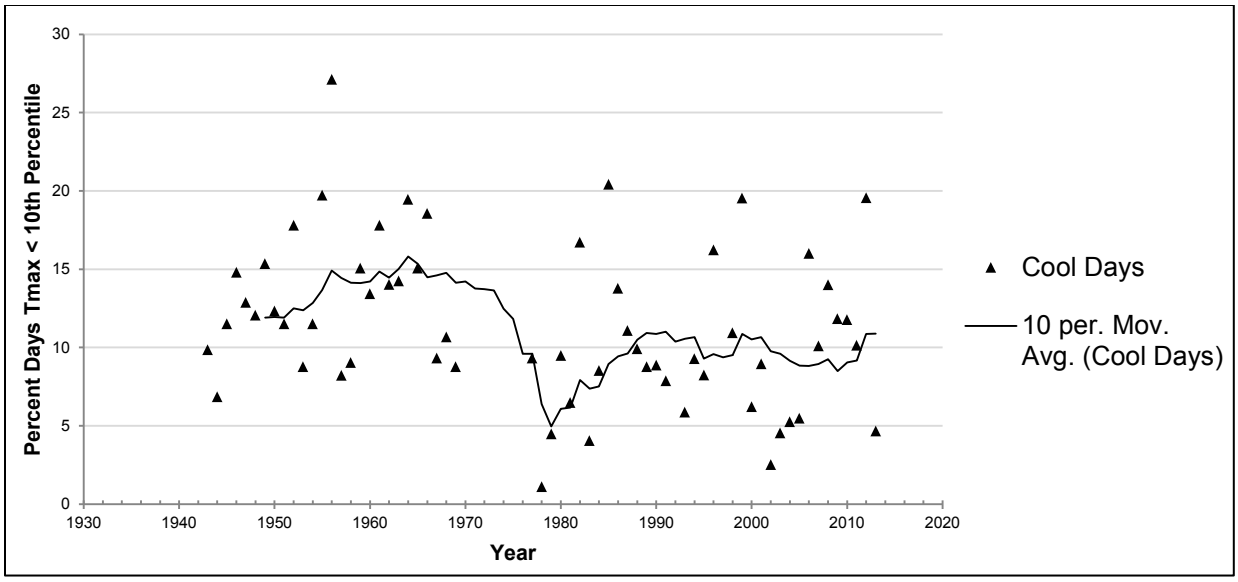


Figure 66. Yearly cool maximum temperatures at USW00025506, Iliamna Airport. Calculated using RClimDex toolset.

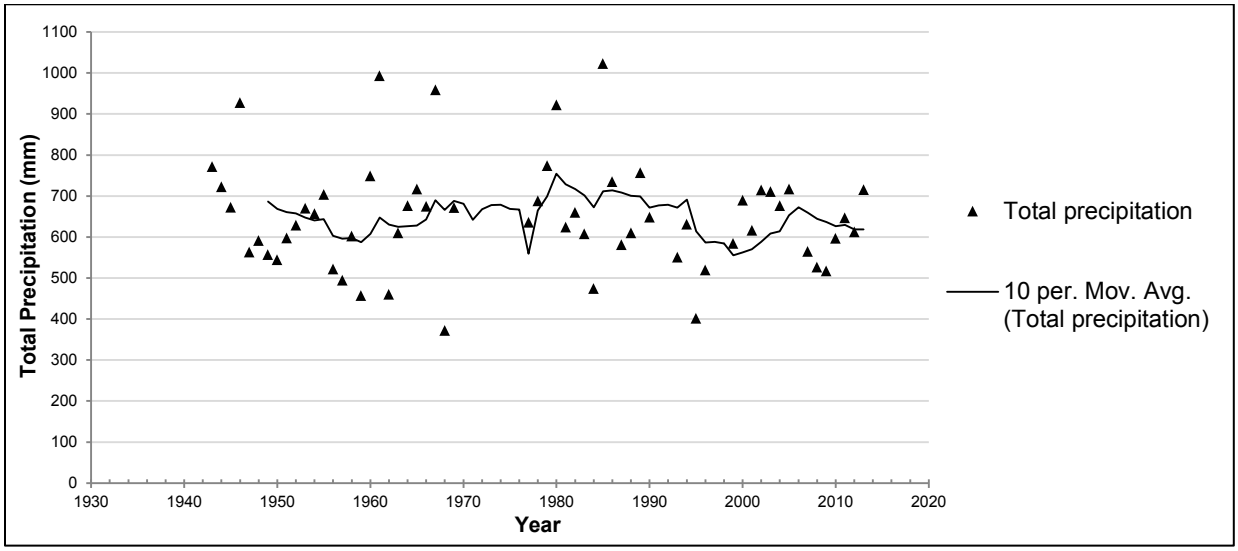


Figure 67. Yearly total precipitation at USW00025506, Iliamna Airport. Calculated using RClimDex toolset.

Port Alsworth Station USC00507570

Station USC00507570 at Port Alsworth includes weather records dating back to 1960. Since 1961, nearly continuous daily records of minimum temperature, maximum temperature, and precipitation are available (Figure 68). Indices were calculated beginning in 1961, when records were consistent in year-long recording of the three parameters. It should be noted that RClimDex stopped analysis at 2007 for some of the indices in this analysis.

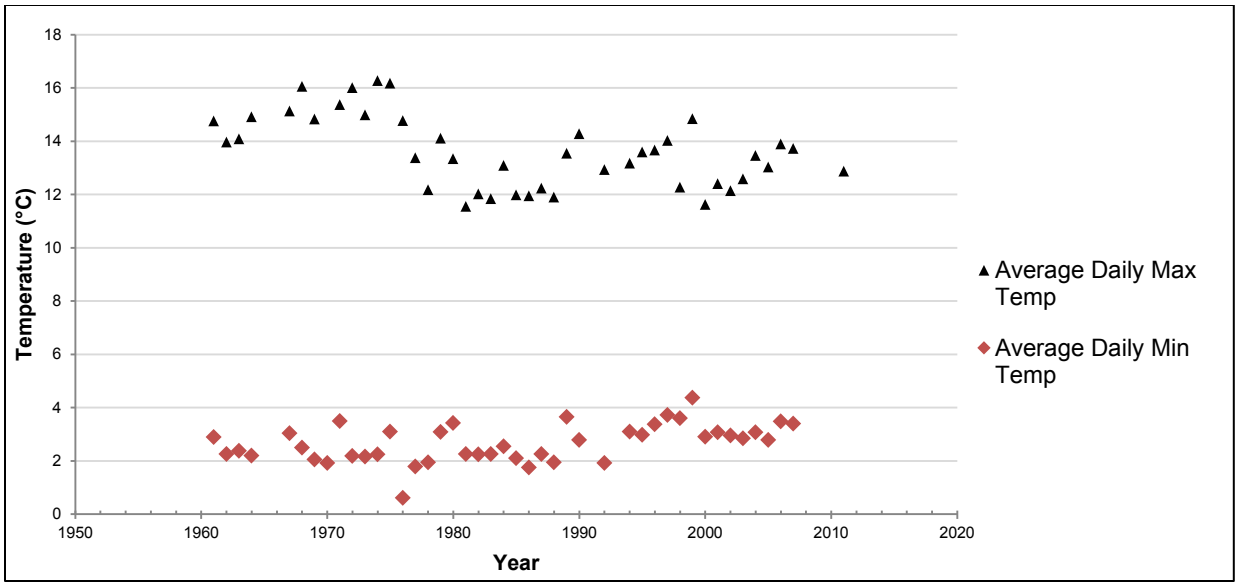


Figure 68. Yearly average minimum and maximum daily temperature at USC00507570, Port Alsworth.

Yearly Frost Days (FD) at the Port Alsworth station averaged 134 days (n=43) from 1961 to 2007. FD ranged from 106 days (1998) to 173 days (1976) (Figure 69). The 10-period moving average displays a decrease in FD over time.

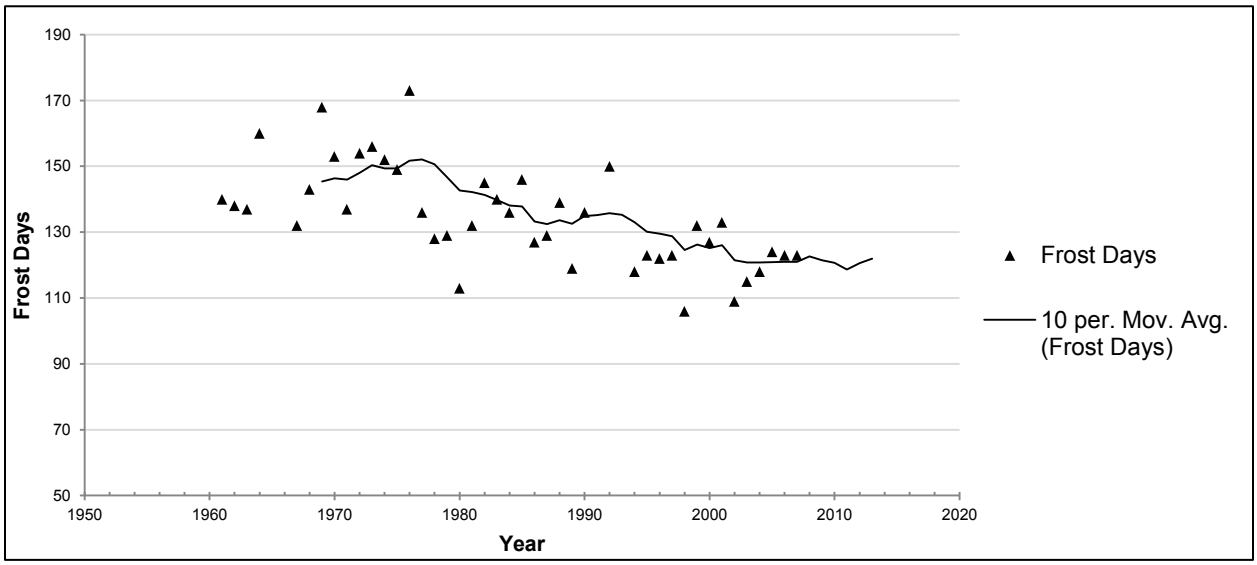


Figure 69. Yearly frost days at USC00507570, Port Alsworth. Calculated using RClimDex toolset with 10-period moving average.

Yearly Ice Days (ID) at the Port Alsworth station averaged 9.7 days (n=43) from 1961 to 2011. ID ranged from 2 days (1975, 1976, 2000) to 22 days (1983). Between 1978 and 1998, the 10-period moving average increased from a low of 4 days to a high of 14 days. Since the increase, the moving average has remained between 10 and 15 days (Figure 70).

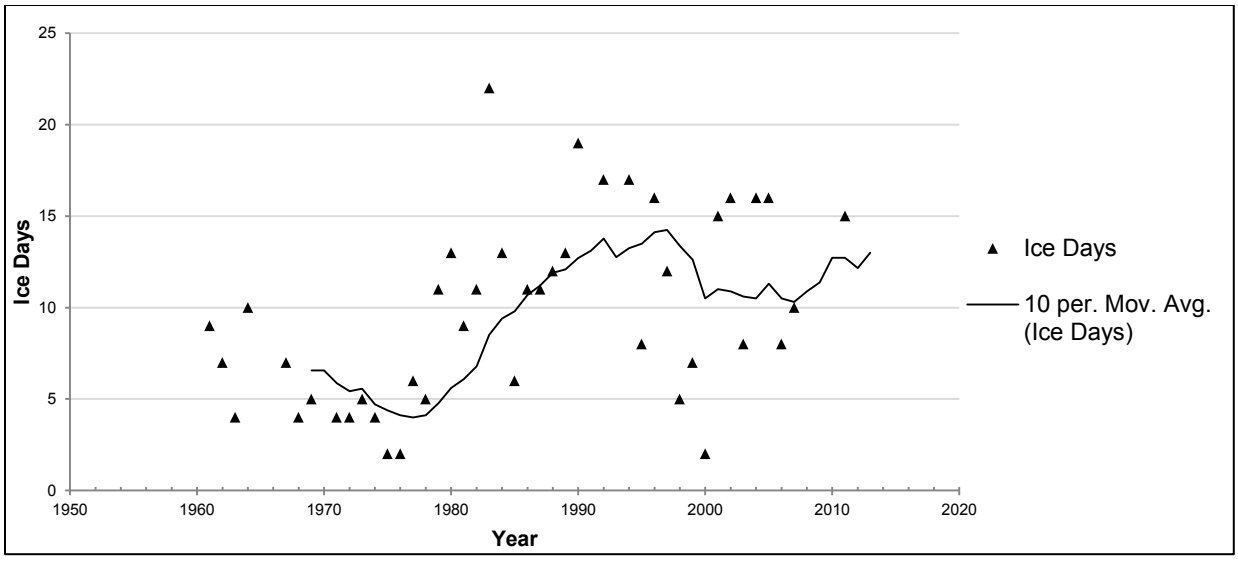


Figure 70. Yearly ice days at USC00507570, Port Alsworth. Calculated using RClimDex toolset.

Yearly Growing Season Length (GSL) at the Port Alsworth station averaged 265 days (n=42) from 1961 to 2007. GSL ranged from 148 days (2003) to 315 days (1976). The 10-period moving average seemed to be decreasing from the 1970s through the early 2000s, but evened out before increasing by 2012 (Figure 71). There were two outlying years, 2001 and 2003, with low measurements of 173 and 148, respectively.

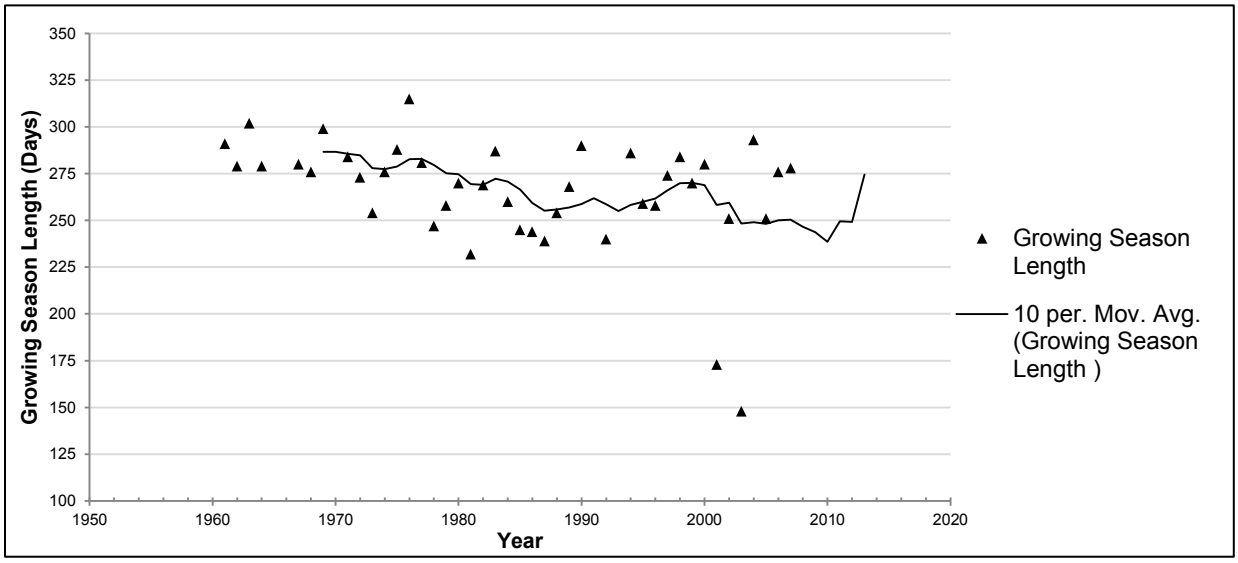


Figure 71. Yearly growing season length at USC00507570, Port Alsworth. Calculated using RClimDex toolset.

Yearly percent warm minimum temperatures at the Port Alsworth station averaged 9.5% (n=43) from 1961 to 2007. The minimum percentage of warm minimum temperatures was 2.5% (1978) and the maximum was 16.6% (1997). The percent warm minimum temperatures decreased between the mid-

1970s and the mid-1980s; however, the percent started to increase in the mid-1980s as shown by the 10-period moving average. The average has increased from 8.0% to 12% over the past two decades (Figure 72).

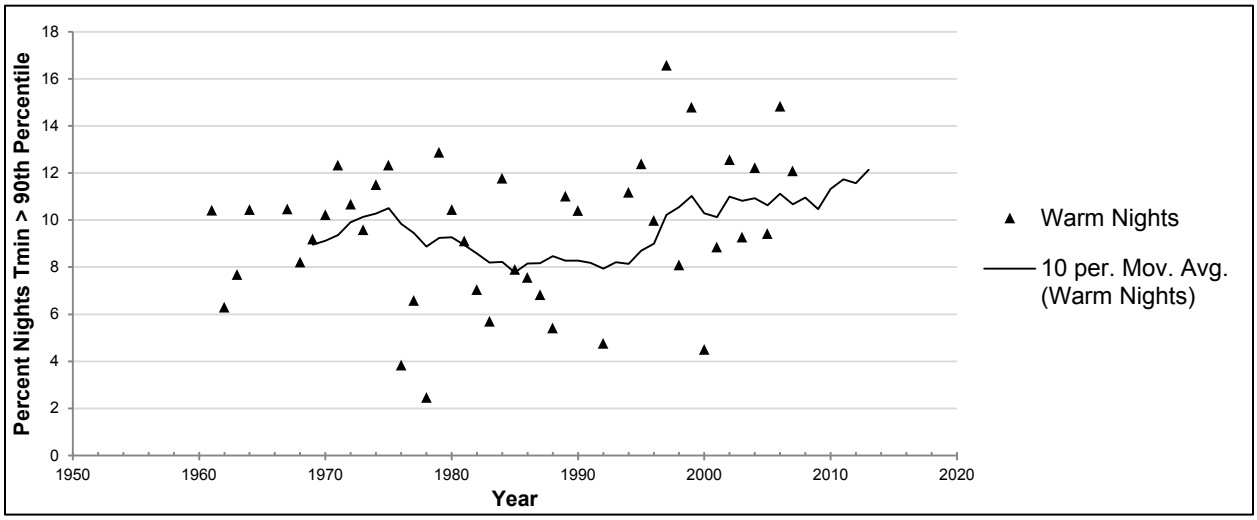


Figure 72. Yearly percent warm minimum temperatures at USC00507570, Port Alsworth. Calculated using RCimDex toolset.

Yearly percent cool maximum temperatures at the Port Alsworth station averaged 8.6% (n=43) from 1961 to 2011. The minimum percentage of cool maximum temperatures was 2.5% (1974) and the maximum was 17.0% (1992). The 10-period moving average of yearly percent cool maximum temperatures increased until the early 1970s to nearly 40% and then decreased to less than 20% in the 2000s (Figure 73).

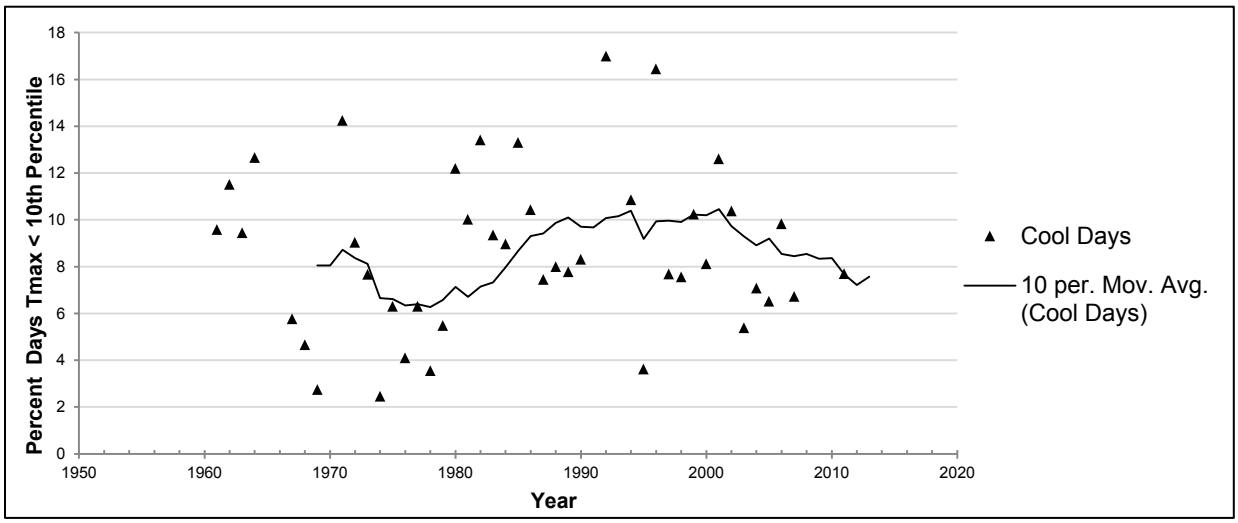


Figure 73. Yearly cool maximum temperatures at USC00507570, Port Alsworth. Calculated using RClimDex toolset.

Yearly total precipitation at the Port Alsworth station averaged 366 mm (n=41) from 1961 to 2007. Total precipitation ranged from 146 mm (1989) to 710 mm (1961) (Figure 74).

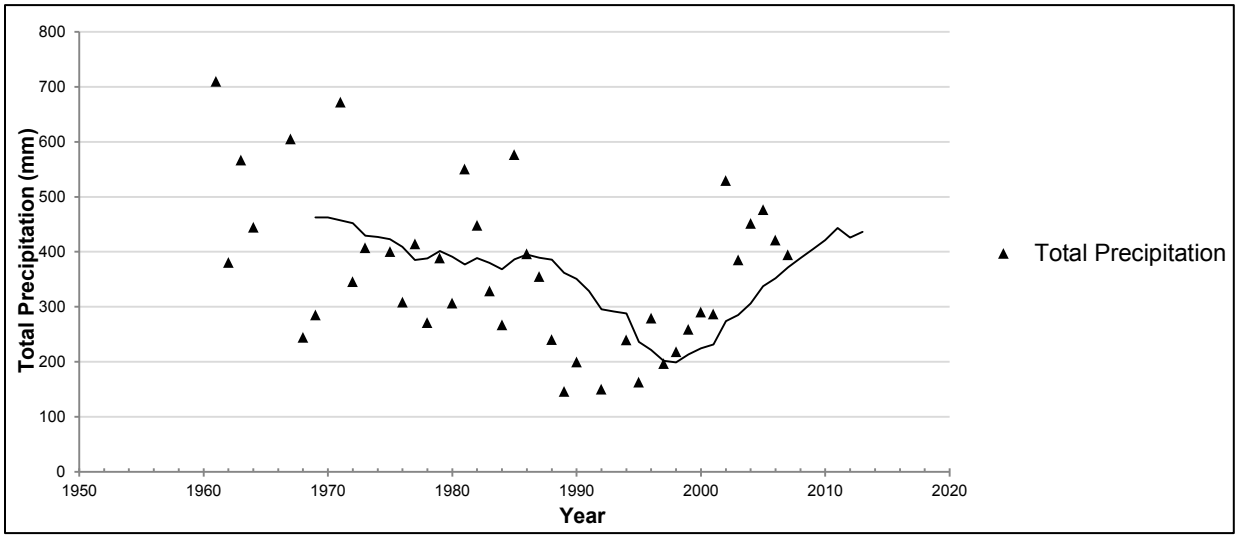


Figure 74. Yearly total precipitation at USC00507570, Port Alsworth. Calculated using RClimDex toolset.

Stoney River Station

The station at Stoney River includes weather records dating back to 1992. Since 2000, nearly continuous daily records of minimum temperature, maximum temperature, and precipitation are available (Figure 75). Indices were calculated from 2000 to 2011, when records were consistent in year-long recording of the three parameters.

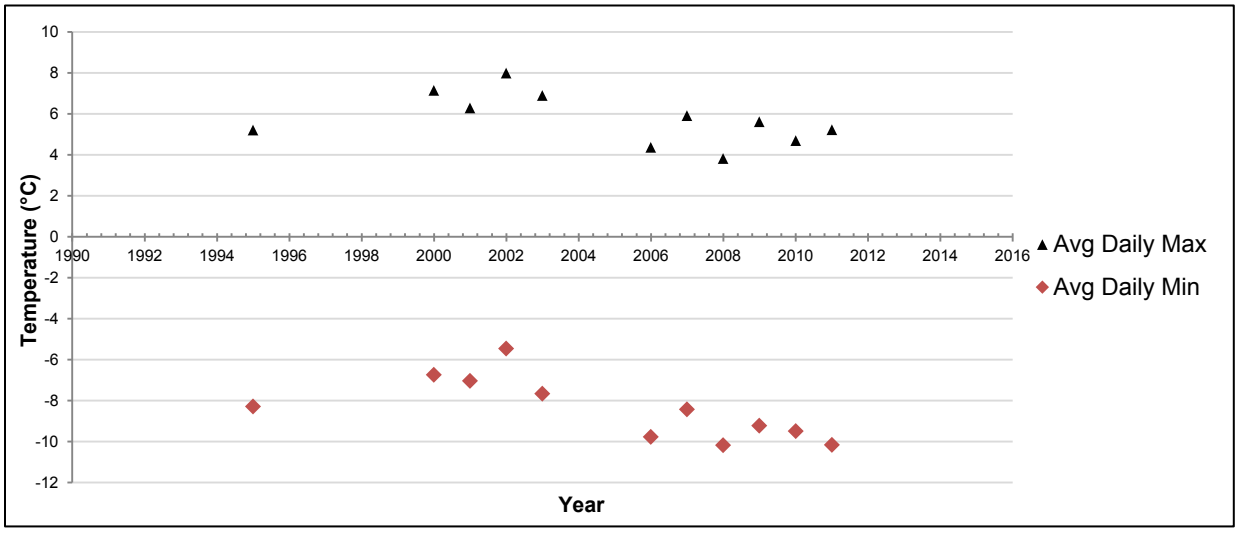


Figure 75. Yearly average minimum and maximum daily temperature at Stoney River. Calculated using RClimDex toolset.

Yearly Frost Days (FD) at the Stoney River station averaged 249 days (n=11) from 1995 to 2011. FD ranged from 226 days (2002) to 266 days (2008) (Figure 76).

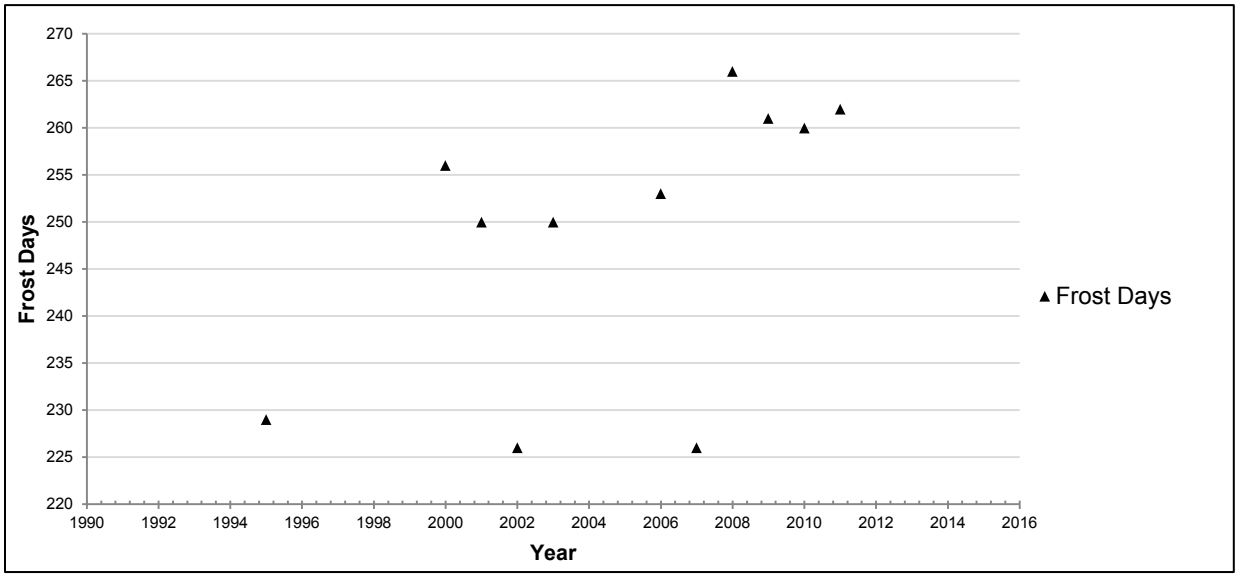


Figure 76. Yearly frost days at Stoney River. Calculated using RClimDex toolset.

Yearly Ice Days (ID) at the Stoney River station averaged 103 days (n=11) from 1995 to 2011. ID ranged from 52 days (2000) to 137 days (1956) (Figure 77).

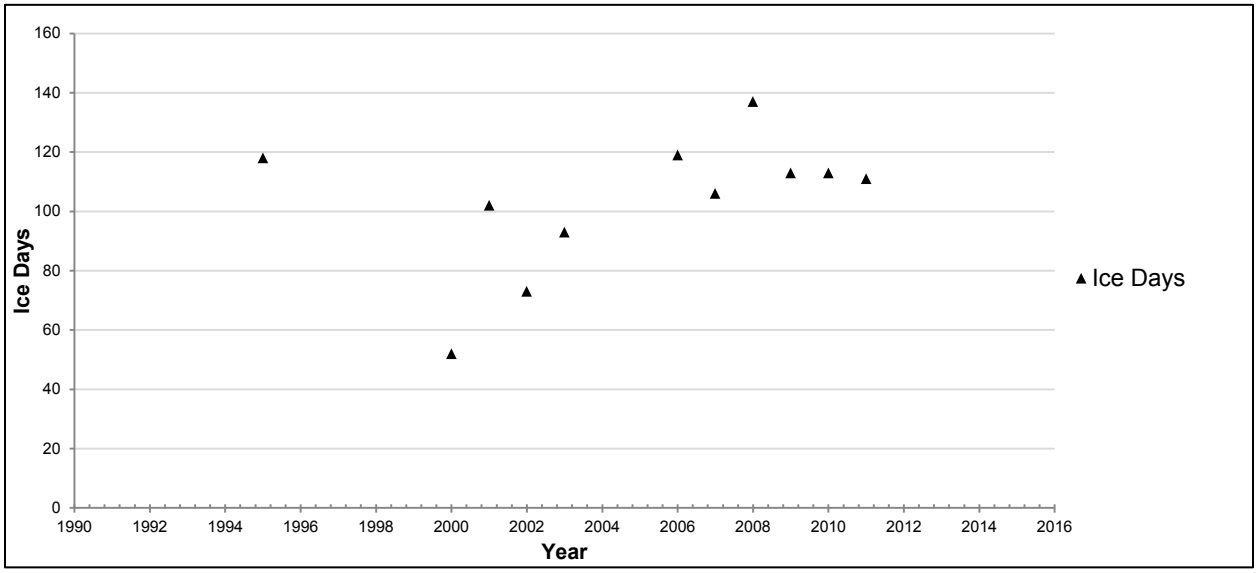


Figure 77. Yearly ice days at USR0000ASTO, Stoney River. Calculated using RClimDex toolset.

Yearly Growing Season Length (GSL) at the Stoney River station averaged 136 days (n=11) from 1995 to 2011. GSL ranged from 117 days (2003) to 154 days (2006) (Figure 78).

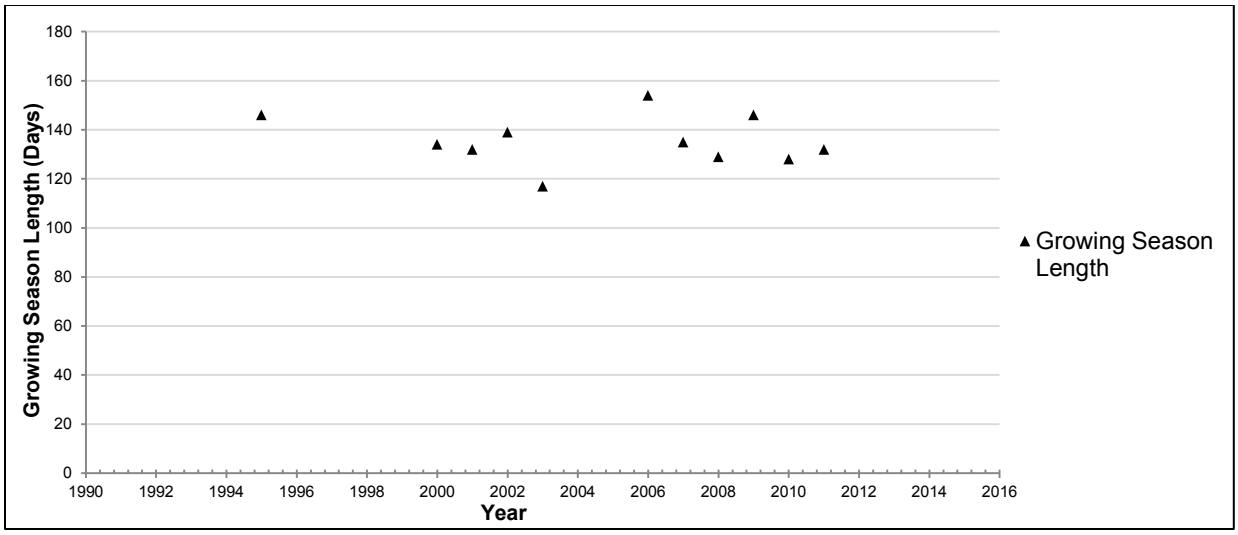


Figure 78. Yearly growing season length at Stoney River. Calculated using RClimDex toolset.

Yearly percent warm minimum temperatures at the Stoney River station averaged 6.3% (n=11) from 1995 to 2011. The minimum percentage of warm minimum temperatures was 3.5% (2002) and the maximum was 8.7% (2009) (Figure 79).

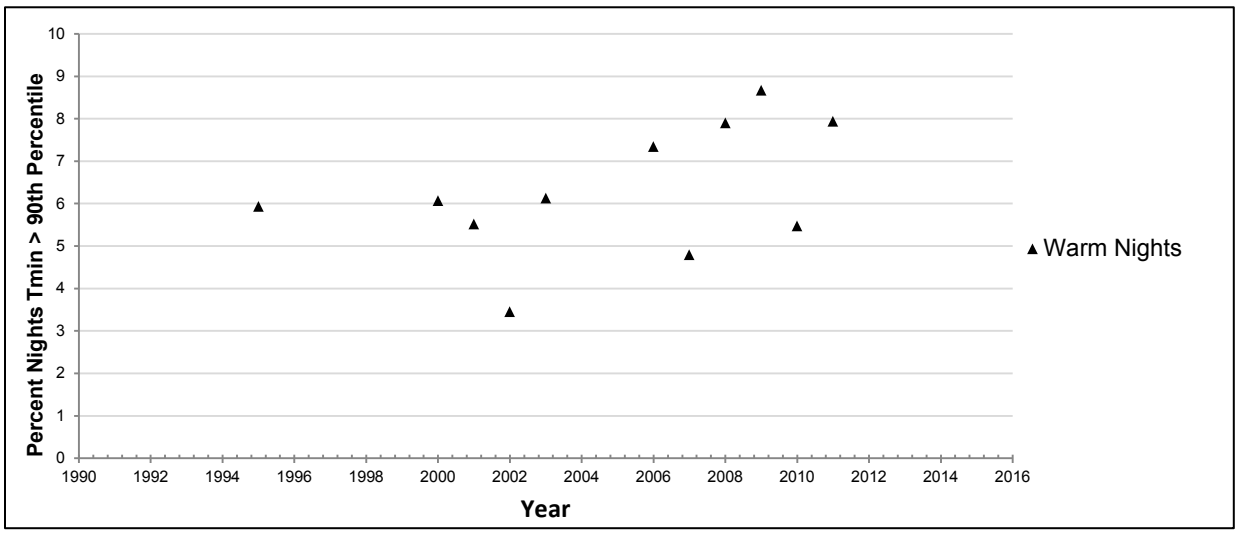


Figure 79. Yearly percent warm minimum temperatures at Stoney River. Calculated using RClimDex toolset.

Yearly percent cool maximum temperatures at the Stoney River station averaged 5.7% (n=11) from 1995 to 2011. The minimum percentage of cool maximum temperatures was 3.9% (2003) and the maximum was 7.7% (2008) (Figure 80).

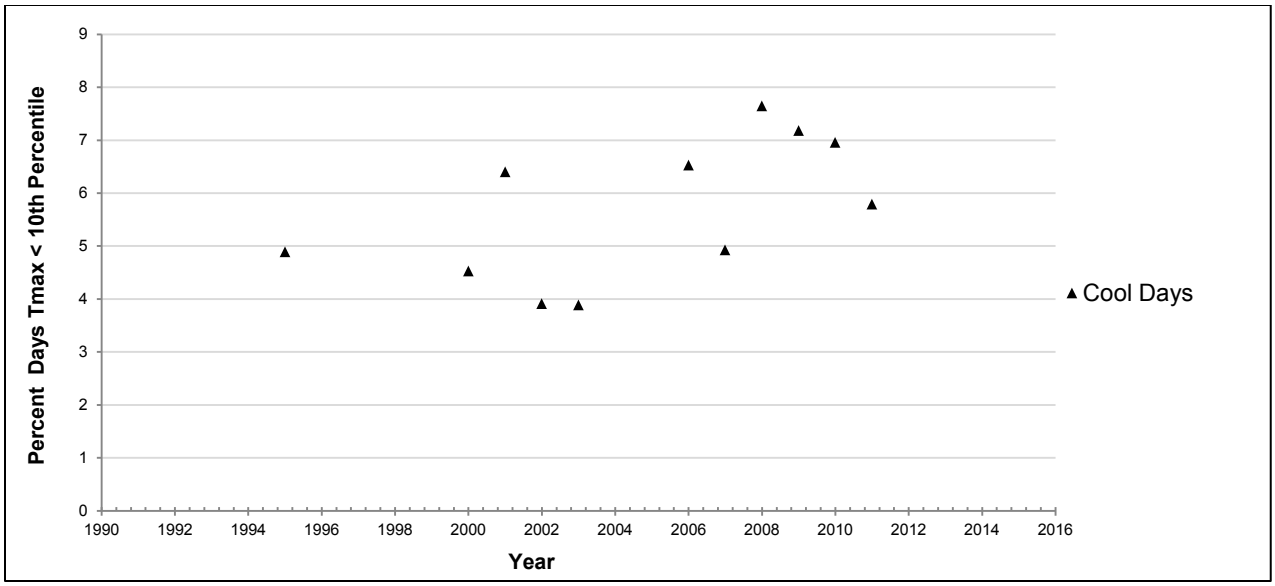


Figure 80. Yearly percent cool maximum temperatures at Stoney River. Calculated using RCimDex toolset.

Yearly total precipitation at the Stoney River station averaged 360 mm (n=10) from 2000 to 2011. Total precipitation ranged from 265 mm (2000) to 475 mm (2010) (Figure 81).

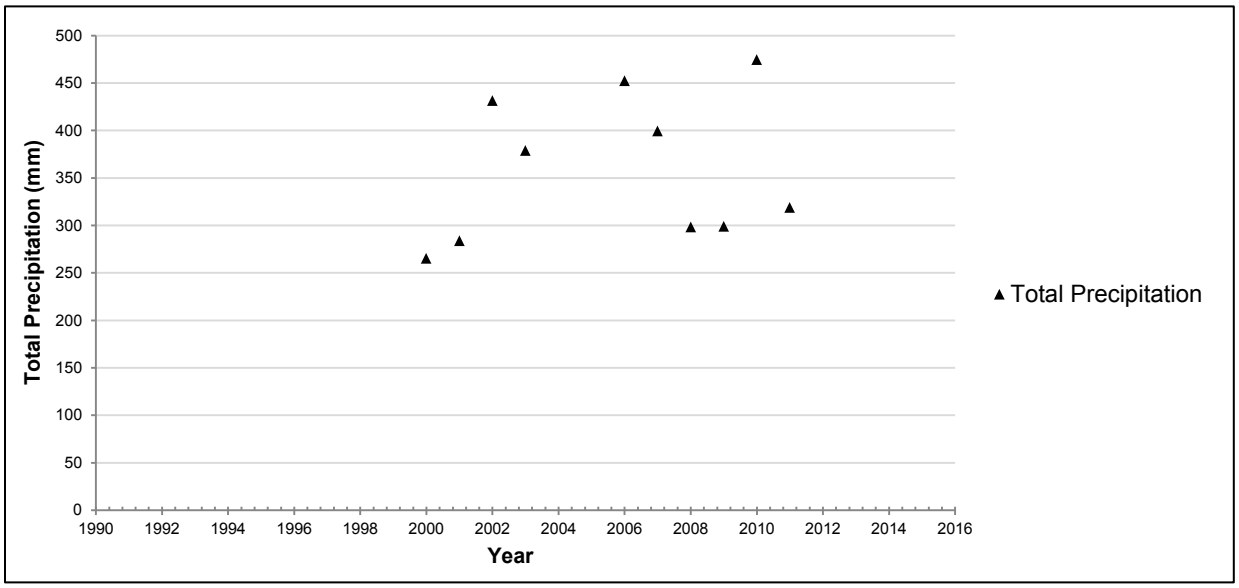


Figure 81. Yearly total precipitation at Stoney River. Calculated using RClimDex toolset.

Telaquana Lake

The station at Telaquana Lake includes weather records dating back to 1997. Since 2006, nearly continuous daily records of minimum temperature, maximum temperature, and precipitation are available (Figure 82). Indices were calculated beginning in 2006, when records were consistent in year-long recording of the three parameters.

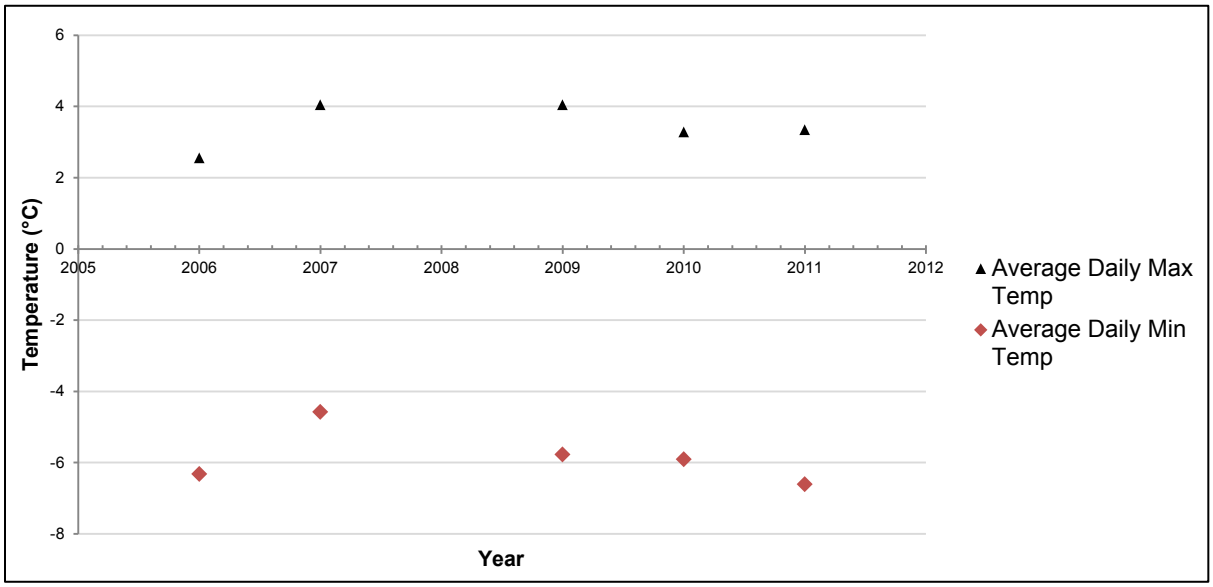


Figure 82. Yearly average minimum and maximum daily temperature at Telaquana Lake. Calculated using RClimDex toolset.

Yearly Frost Days (FD) at the Telaquana Lake station averaged 206.8 days (n=5) from 2006 to 2011. FD ranged from 190 days (2007) to 221 days (2010) (Figure 83).

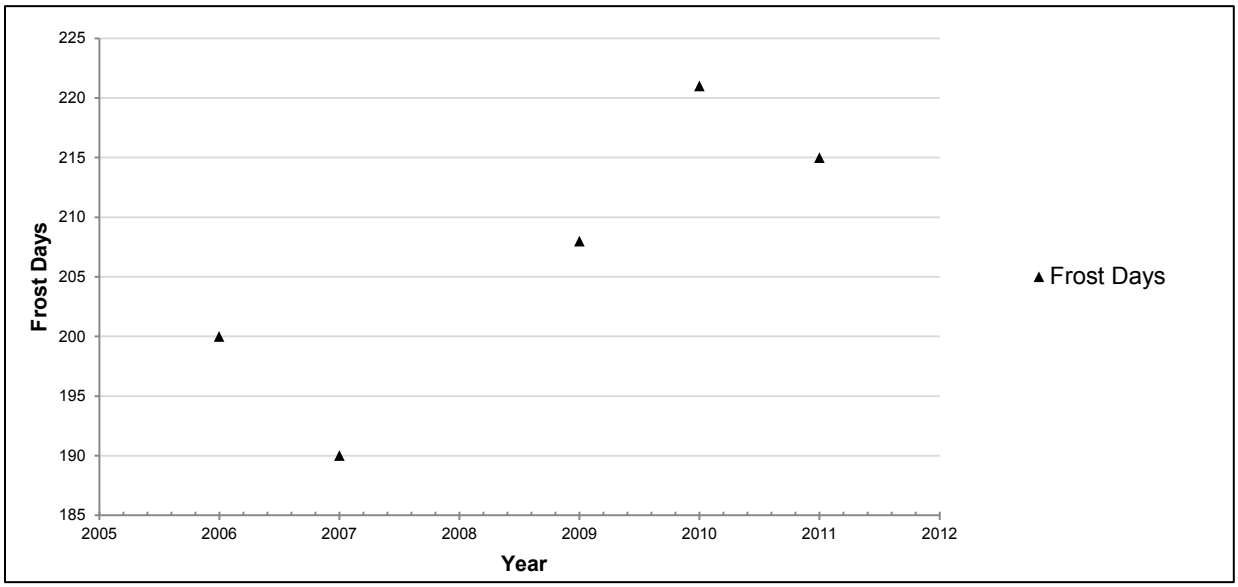


Figure 83. Yearly frost days at Telaquana Lake. Calculated using RClimDex toolset.

Yearly Ice Days (ID) at the Telaquana Lake station averaged 120 days (n=5) from 2006 to 2011. ID ranged from 115 days (2007, 2011) to 129 days (2006) (Figure 84).

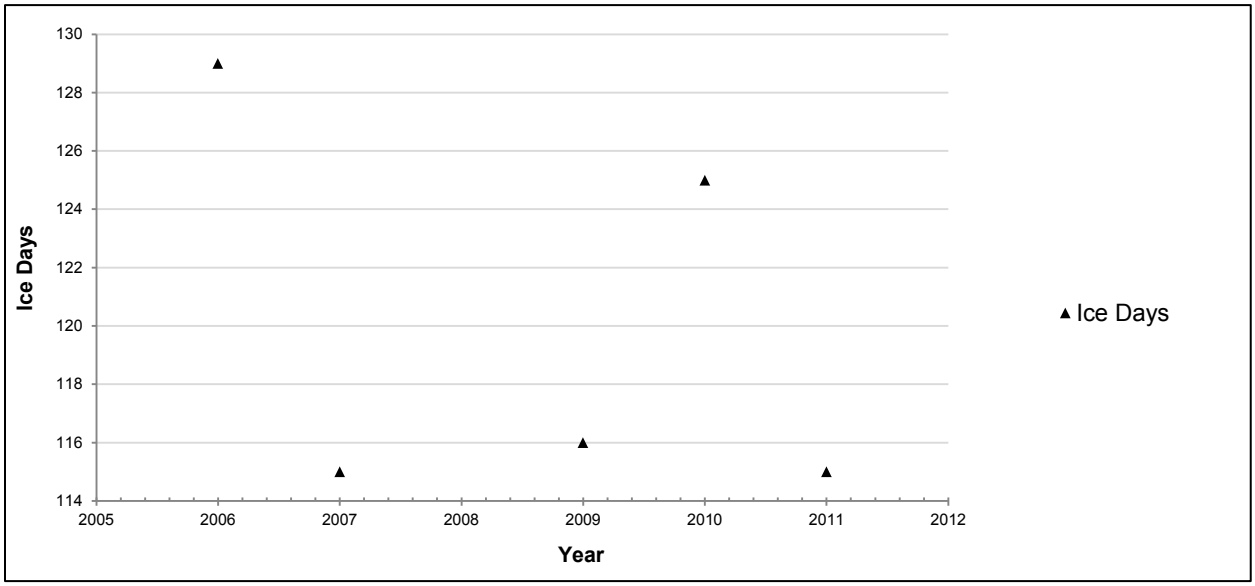


Figure 84. Yearly ice days at Telaquana Lake. Calculated using RClimDex toolset.

Yearly Growing Season Length (GSL) at the Telaquana Lake station averaged 143.8 days (n=5) from 2006 to 2011. GSL ranged from 134 days (2011) to 160 days (2006) (Figure 85).

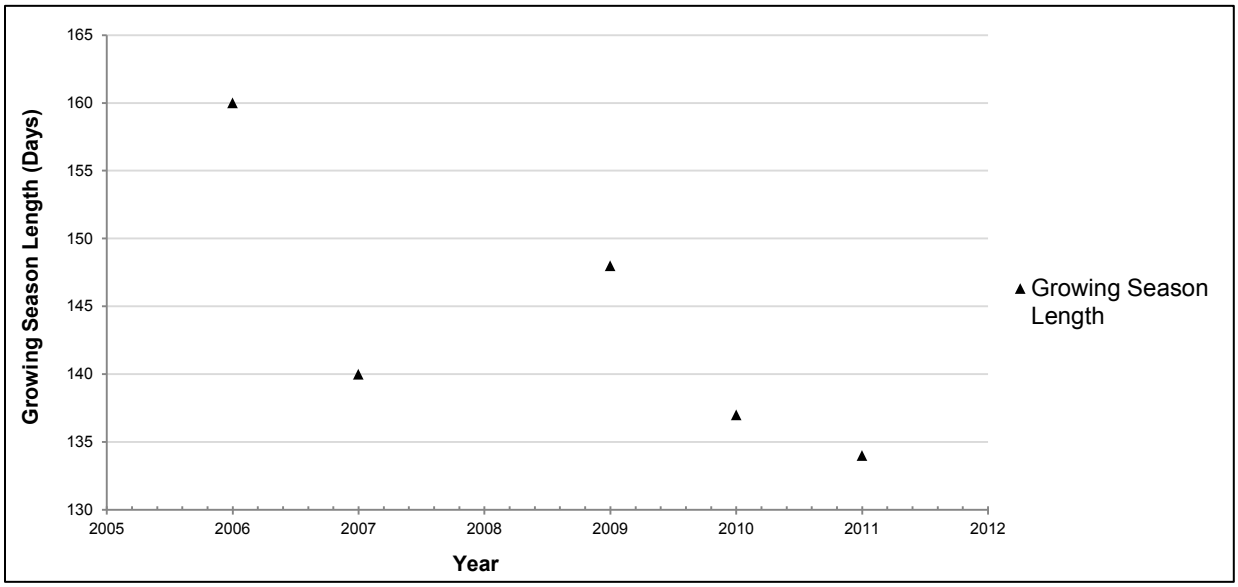


Figure 85. Yearly growing season length days at Telaquana Lake. Calculated using RClimDex toolset.

Yearly percent warm minimum temperatures at the Telaquana Lake station averaged 4.2% (n=5) from 2006 to 2011. The minimum percentage of warm minimum temperatures was 2.2% (2010) and the maximum was 6.6% (2007) (Figure 86).

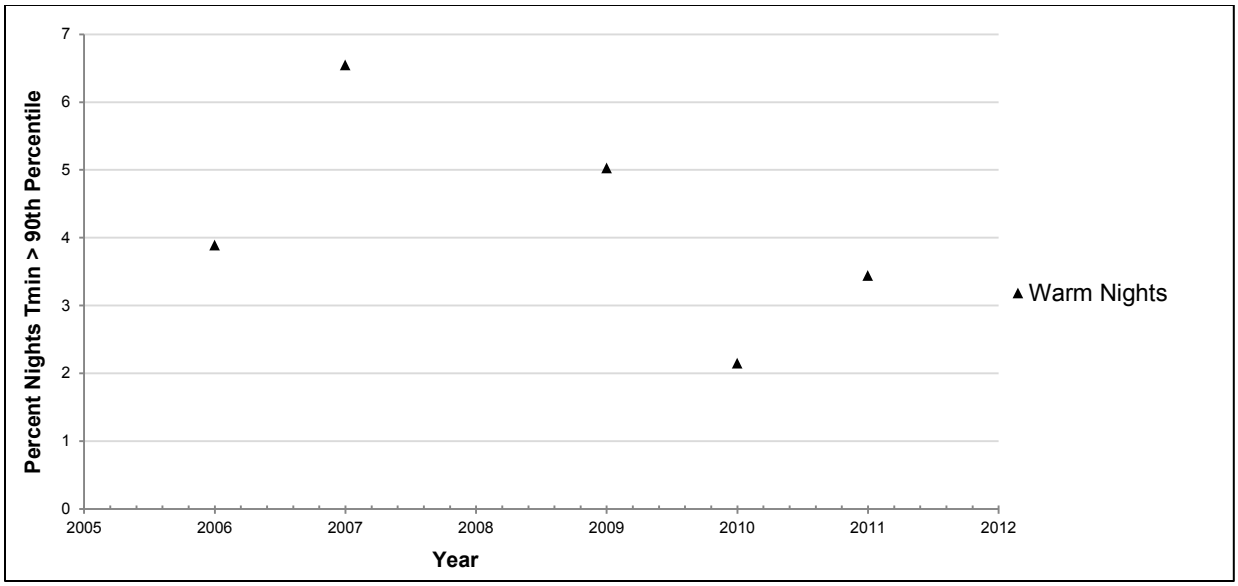


Figure 86. Yearly percent warm minimum temperatures at Telaquana Lake. Calculated using RClimDex toolset.

Yearly percent cool maximum temperatures at the Telaquana Lake station averaged 4.8% (n=5) from 2006 to 2011. The minimum percentage of cool maximum temperatures was 3.9% (2010) and the maximum was 5.4% (2011) (Figure 87).

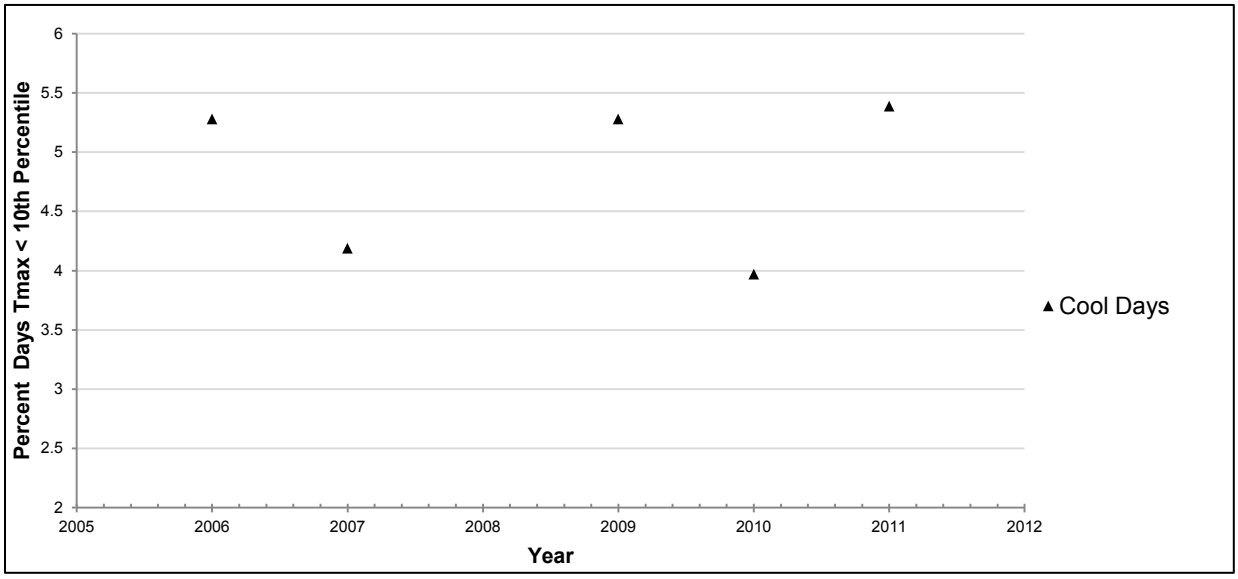


Figure 87. Yearly cool maximum temperatures at Telaquana Lake. Calculated using RClimDex toolset.

Yearly total precipitation at the Telaquana Lake station averaged 499.5 mm (n=5) from 2006 to 2011. Total precipitation ranged from 367.1 mm (2007) to 658.4 mm (2009) (Figure 88).

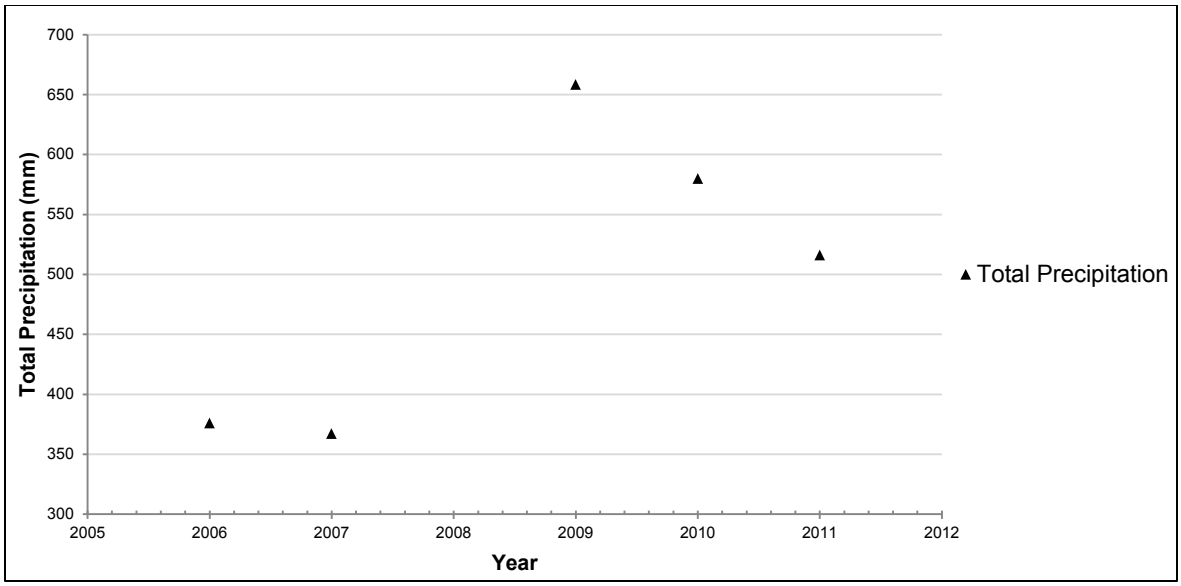


Figure 88. Yearly precipitation (mm) at Telaquana Lake. Calculated using RClimDex toolset.

Threats and Stressor Factors

There is a scientific consensus that human activities, particularly those that produce greenhouse gasses (e.g., fossil fuel burning), have contributed to a general warming trend in global climate (IPCC 2010). Climate models predict that change will be greatest at higher latitudes, like in Alaska (NPS 2011). In the LACL region, temperatures are projected to increase approximately 0.6°C (1°F) per decade over the next century (SNAP et al. 2009). Winter temperatures may change more dramatically, increasing by about 6°C (10°F) by 2080 (SNAP et al. 2009). Precipitation is predicted to increase, yet increased evapotranspiration due to warmer temperatures and a longer growing season will likely lead to an overall drier climate (SNAP et al. 2009). Potential impacts of these changes in southwest Alaska parks include reduced snowpack and a longer growing season, which could affect plant phenology and productivity, wildlife distribution and mating cycles, water availability, and recreational and subsistence activities (e.g., hunting, fishing) (SNAP et al. 2009, NPS 2011). Warmer temperatures would likely impact snow depth and could impact lake ice depth. Warmer winters could change the amount of precipitation that falls as rain versus snow.

Data Needs/Gaps

To better understand the climate of the LACL area, it will be important to continue gathering data from the three recently established RAWS stations and the four long-term stations. Data collecting from Telaquana Lake station should start to occur consistently throughout each month of the year. Consistent, monthly snow course monitoring at Port Alsworth is also needed to better assess snow depth. This information will help identify the range of climate variability within the park and if any changes are occurring over time. Implementing a more accurate method for measuring wintertime precipitation would also be helpful. Further studies may be needed to explore how changes in climate will impact other park resources (e.g., vegetation and wildlife, water regime, etc.).

Overall Condition

Temperature

The project team defined the *Significance Level* for temperature as a 3. WRCC (2014) displayed a slightly declining trend in temperature between 2009 and 2012. All three stations showed a slight increase in 2013 after four years of decreasing temperatures. WRCC (2014) data are limited as a result of only having records for a short period of time. It is difficult to say if this represents an actual trend or just natural variation. One of the four long term stations had increasing trends in temperature, one station displayed a stable trend, and two stations had declining trends. Iliamna Airport displayed an increasing trend in temperature over 71 years (GHCN 2014). The Telaquana Lake station displayed a stable trend over six years (Lindsay, written communication, 11 April 2014). The Port Alsworth station showed a decreasing trend over 47 years; however, temperatures seemed to stabilize between 1990 and 2010. The Stoney River station displayed a decreasing trend in temperature over 12 years (WRCC 2014). A significant warming trend through time is punctuated during the late 1970s. The climate shift of 1976 - 1977 can be clearly seen in all of the figures for the Iliamna station (e.g., increase in temperatures, decrease in frost and ice days, increase in growing season length, increase in warm minimum temperatures, and decrease in cool maximum days). Warming effects are more pronounced during the winter months than summer months (Lindsay, written communication, 11 April 2014); warming winter temperatures may result in major changes such as in the amount and type of precipitation (snow vs. rain). As a result of the cumulative data, this measure was assigned a *Condition Level* of 3, or high concern.

Precipitation

The project team defined the *Significance Level* for precipitation as a 2. The Iliamna Airport station precipitation showed a relatively stable 10-period moving average, only ranging between 550 mm and 750 mm between 1950 and 2013. Port Alsworth station precipitation decreased from 710 mm (1961) to 150.2 mm (1992), but then started to increase to approximately 450 mm in the mid-2000s (GHCN 2014). At Stoney River, precipitation appeared to increase from 2001 to 2006 and then was variable through 2011 (RAWS 2014). Telaquana Lake's annual precipitation increased between 2007 and 2009 but then decreased the next 2 years (Lindsay, written communication, 11 April 2014). The precipitation data are only decent at the long term stations, and unfortunately the records at Port Alsworth are inconsistent. One complete month of data is frequently missing every year. As a result, a *Condition Level* was not assigned to this measure.

Snow Depth/ Ice Thickness and Water Equivalent

The project team defined the *Significance Level* for snow depth and SWE as a 1. NOAA (2013) recorded an overall declining trend in lake ice and snow depth. The 10-period moving average for maximum ice thickness decreased from approximately 1,050 mm in the mid-1970s to approximately 550 mm in the late 1980s, and it remained low (<700 mm). Most records indicated that ice appeared around the 1st of November, thickened over several months, and then dissolved by the 31st of May. In 1976, the ice was present at the normal time; however, it remained less than 5 mm thick until March of 1977 and only reached a thickness of 13 mm. after 1980, several late winter records (December, January, February) had ice thickness of 0 mm. The overall average maximum lake ice thickness between 1961 and 2002 was 756.1 mm. The average maximum lake ice thickness in the

1960s was 996.2 mm, but it declined to 924.6 mm in the 1970s. By the 1980s the average maximum was 508 mm, and 701.7 mm in the 1990s. Yearly maximum snow depth also displayed a declining trend. The overall maximum snow depth was recorded in 1961 (609.6 mm). Most years after 1961 had maximum snow depths below 400 mm with the exception of 1966 (406.4 mm), 1970 (508 mm), and 1981 (406.4 mm). NRCS (2014) yearly average snow depths and SWE decreased at Telaquana Lake, Fishtrap Lake, and Upper Twin Lake stations. At Port Alsworth, the snow depth had increased slightly by 2013. WRCC (2014) recorded increasing snow depths at all stations between 2009 and 2012; however, all of the stations also had a slight decrease in snow depth in 2013. WRCC (2014) data are limited as a result of only having records for a short period of time. It is difficult to say if this represents an actual trend or just natural variation. Overall, the snow depth and ice thickness had been decreasing over the years until it has recently increased slightly. As a result, this measure was assigned a *Condition Level* of 2, or moderate concern.

Weighted Condition Score (WCS)

Climate in LACL has been assigned a *WCS* of 0.92, indicating that the component is of high concern. The long-term climate data have displayed a climate shift and warming trends, which suggests a declining trend; a medium confidence level was determined for the assessment.

Climate			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.92**
Temperature	3	3	
Precipitation	2	n/a	
Snow Depth/Ice Thickness & SWE	1	2	

4.13.6 Sources of Expertise

Chuck Lindsay, SWAN Physical Scientist

4.13.7 Literature Cited

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4.14 Glaciers

4.14.1 Description

Glaciers are large persistent bodies of ice that flow under the influence of gravity (Photo 23; Marshak 2005). The formation of a glacier requires three conditions: abundant snowfall, cool summer temperatures, and the gravitational flow of ice (NPS 2010). LACL is included among the three parks within SWAN considered to have a significant glacial coverage (Giffen and Lindsay 2011). According to Arendt et al. (2014) glacier ice covers 2,339 km^2 (903 mi^2) of LACL, forming an estimated 14.3% of the total park area.

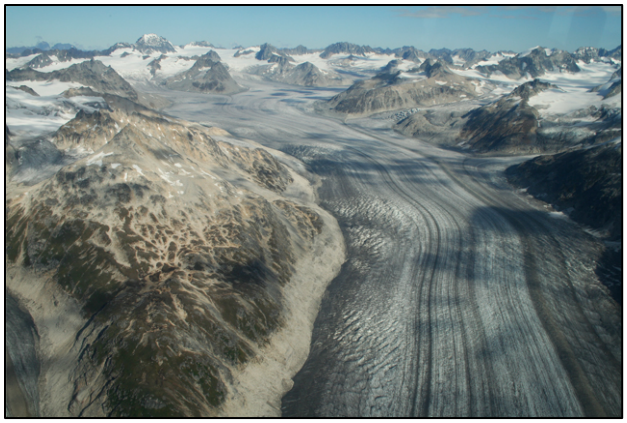


Photo 23. Tanaina Glacier located in Lake Clark Pass, Neacola Mountains (NPS photo).

Glaciation begins with the accumulation of fresh, loosely packed snow containing 90% air, due to the space created by its hexagonal crystals (Marshak 2005). As new layers of snow accumulate on top of the old snow, pressure increases from the weight, squeezing out air pockets and, over time, transforming the snow into a packed granular material called firn, which contains only 25% air (Marshak 2005). As melting occurs, water recrystallizes in the spaces between grains until the firn is transformed into a solid mass of glacial ice containing only 20% air (Marshak 2005).

Glacier mass balance studies determine the annual difference between accumulation and ablation (all processes that remove mass, i.e., sublimation, melting, and calving) (NPS 2010, Cogley et al. 2011). Mass balance is commonly reported using the water year following the assumption that accumulation begins, and ablation ends, on October 1. In reality, the end of the mass balance year is elevation dependent – it may occur earlier at higher elevations and later at lower elevations (Mayo et al. 1972).

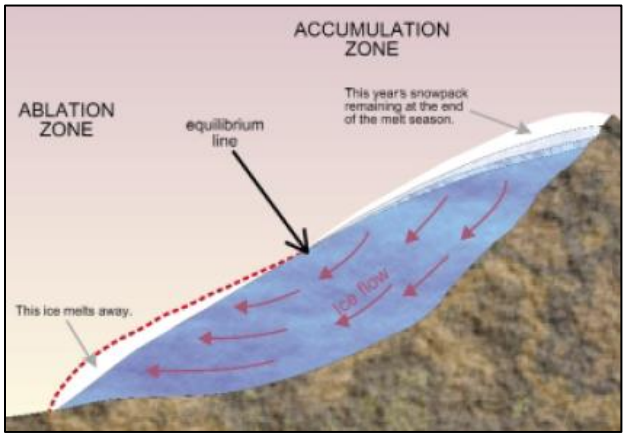


Figure 89. Illustration of a glacier showing the accumulation zone, ablation zone, and equilibrium line (Valentine et al. 2004).

If the rate of accumulation is higher than that of ablation, the glacier will thicken and / or advance. However, if the rate of ablation is higher than that of the accumulation, the glacier will thin, retreat, or both (Marshak 2005). The accumulation zone is the area on a glacier where more mass is gained than lost, whereas the area where more mass is lost than gained is known as the ablation zone (Figure 89; Cogley et al. 2011). The accumulation area ratio (AAR) represents the ratio of the accumulation zone to the area of the glacier at the end of a mass balance year (Cogley et al. 2011). Mass balance studies can provide information on the stability of glaciers, runoff predictions, and a

measurement of climatic variation and trends (Muirhead 1978).

Glacier snow lines define the boundary between the melting ablation zone and the snow-covered accumulation zone. Late summer is the end of the ablation season, and during this time, the late summer snow line reaches its highest elevation, called the annual snow line. The annual snow line is closely related to the equilibrium line, which separates the accumulation zone from the ablation zone (Figure 89; Muirhead 1978). The equilibrium line altitude (ELA) is the spatially averaged altitude of the equilibrium line at the end of a mass balance year (Cogley et al. 2011). The position of the snow line varies depending on the season. During winter, snow covers the entire glacier. As spring thaw occurs, the snow line moves up the glacier. The amount of accumulation and the ablation rate together determine how far the snow line will move up the glacier before the cycle repeats (Muirhead 1978).

Climatic extremes and significant weather events are characteristic of the LACL region. Of all the parks within the SWAN, weather stations within LACL recorded the lowest maximum temperature (62˚F Chigmit Mountains, LACL), lowest minimum temperature (-45˚F Stoney, LACL), greatest number of frost days (261 Chigmit Mountains, LACL), and the greatest number of ice days (207 Chigmit Mountains, LACL) during the 2010 calendar year (Lindsay 2011). An ice day occurs when the maximum air temperature does not rise above 32 ˚F while a frost day is characterized by the air temperature falling below 32 ˚F during some portion of the day (Lindsay 2011). The propensity for both to occur within LACL in addition to the geographic features of the mountain ranges provides a canvas suitable to support and form glaciated areas.

4.14.2 Measures

- Area
- Rate of terminus retreat
- Mass balance (surface elevation)

4.14.3 Reference Conditions/Values

Comprehensive data on glacial extent and the current condition of glaciers is lacking within LACL. A recent study (Arendt et al. 2014) was undertaken as a multi-year effort to map and document the glacial resources of the Alaskan parks. Arendt et al. (2014) utilized satellite imagery from 2006-2010 to compare to map data from 1954-1957 (map date 1957).

4.14.4 Data and Methods

Giffen and Lindsay (2011) provide a detailed description of methods used to quantify glacier extent from satellite imagery. Glacier mapping of this nature is scheduled to be repeated every ten years according to the glacial extent protocol.

Arendt et al. (2014) provides the glacier numbers, glacial extent, and volume data for LACL glaciers based on the interpolation of topographic maps between 1954 and 1957 (map date 1957) and satellite imagery from 2006 to 2010 (satellite date 2008). Map date and satellite date were defined by the

median years of the topographic maps and satellite imagery sources utilized. Mass balance data was also collected for eight glaciers within LACL over two time periods between 1996 and 2008.

Aerial obliques were taken over the glacial extent of LACL in 1997 and 2000 by Matthew Sturm, in 2004 by Bruce Giffen, and in 2007 by Bruce Giffen and Chuck Lindsay. Photos taken from a fixed winged aircraft were centered on capturing individual glaciers both named and unnamed in an attempt to capture extent changes of individual glaciers overtime. The large majority of the glaciated area within LACL has been captured in these photo datasets.

4.14.5 Current Condition and Trend

Area

Glaciers are prominent land features within LACL, covering about 259,800 ha (641,977 ac) or 14.3% of the total park area (Arendt et al. 2014). LACL is located at the convergence point of the Aleutian Range and the Alaskan Range; both are considered major mountain ranges within Alaska (Plate 30). These mountain ranges boast terrain reaching over 3,048 m (10,000 ft) in elevation and provide the ideal terrain for hundreds of glaciers and small icefields within LACL; many of the glaciers found within LACL reside in the Chigmit Mountains. Arendt et al. (2014) utilized satellite imagery from 2006-2010 (satellite date 2008) to determine that 1,740 glaciers could be found within LACL compared to 1,501 glaciers utilizing map data from 1954-1957 (map date 1957) (Table 114). Generally, these glaciers are large or small valley glaciers terminating on land, however, some glaciers do terminate in lakes (Giffen and Lindsay 2011). The greater number of glaciers recorded in 2009 is generally attributed to be a product of map/imagery quality inconsistencies across study years and the new occurrences of smaller ice masses from once larger glaciers which are now breaking up.

Table 114. Summary statistics for glaciers in LACL (Arendt et al. 2014).

Time Period	Number of Glaciers	Total Glacier Area (km^2)	Mean Glacier Size (km^2)	Max Glacier Size (km^2)
Map Date (1957)	1501	2955.5	2.0	168.2
Satellite Date (2008)	1740	2598.2	1.5	158.2
Absolute Change	239	-357.3	-0.5	-10.0
Percent Change	**16%**	**-12%**	**-24%**	**-6%**

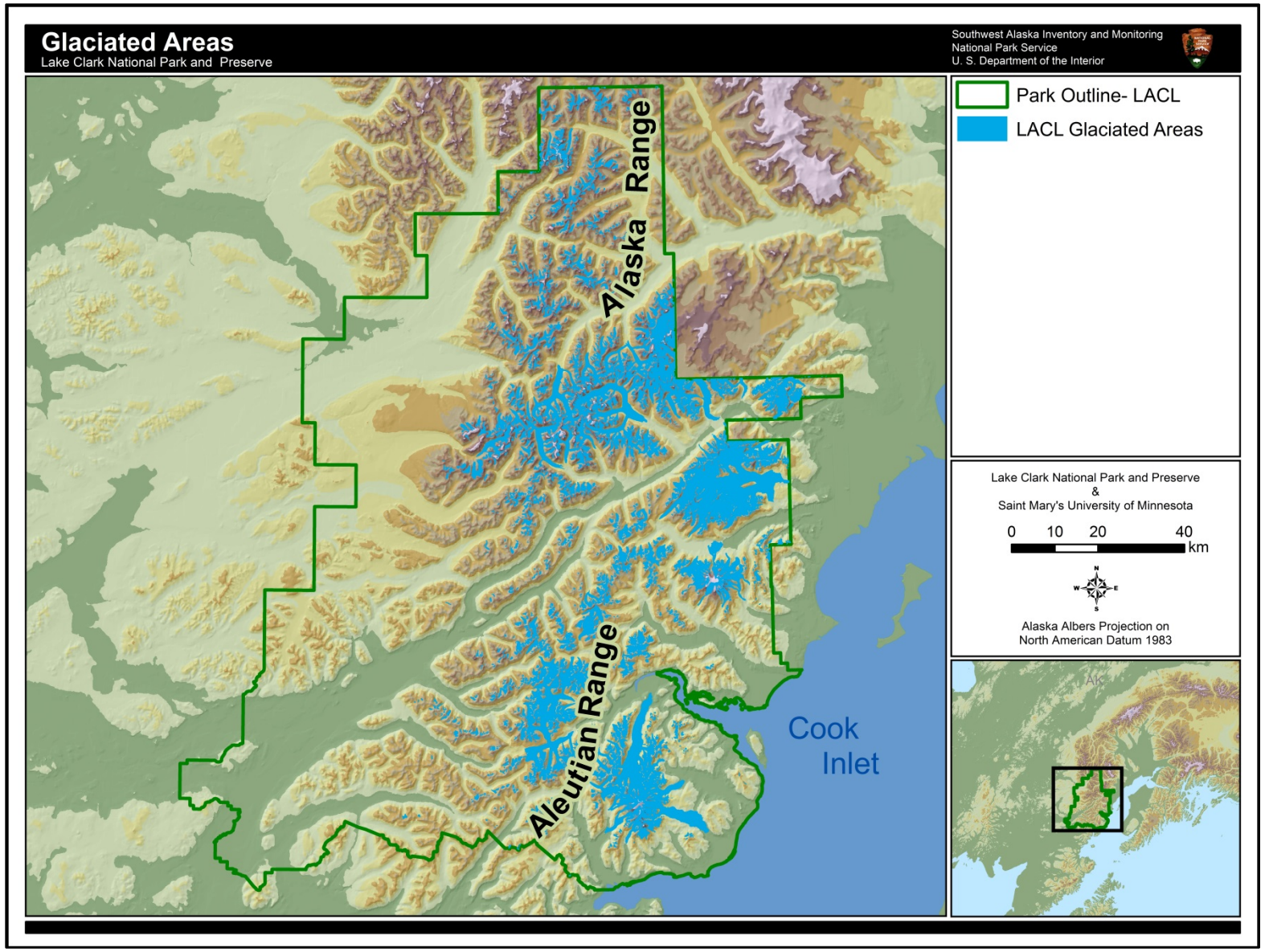


Plate 30. Satellite date (2008) glaciated extent and prominent mountain ranges within LACL (Arendt and Rich 2011).

Despite a 16% increase in the number of glaciers over this time period the total glaciated area within LACL decreased by 12% or approximately 357.3 km^2 (137.9 mi^2). The increase in the number of glaciers within LACL was reflected in the number of small and medium sized varieties, the frequency of large glaciers remained unchanged (Arendt et al. 2014). It should be noted that Arendt et al. (2014) attribute isolated advances of glaciers within LACL to be nothing more than cartographic inconsistencies across study years. Besides one isolated advance of a glacier near Mount Redoubt, an active volcano, other advances are not explained by the insolating properties of volcanic ash fallout and remain undetermined (Arendt et al. 2014). Glacial advance or retreat was found to be highly correlated with elevation within LACL. Generally, portions of each individual glacier at the highest elevation showed little or no change in area, however, the same could not be said for individual glacier extents at lower elevations. Arendt et al. (2014) reported glacial ice loss above 1,750 m (5,741 ft) to be minimal and concluded that a majority of glacial ice loss within LACL occurs below this elevation (Figure 90, Plate 31, Plate 32).

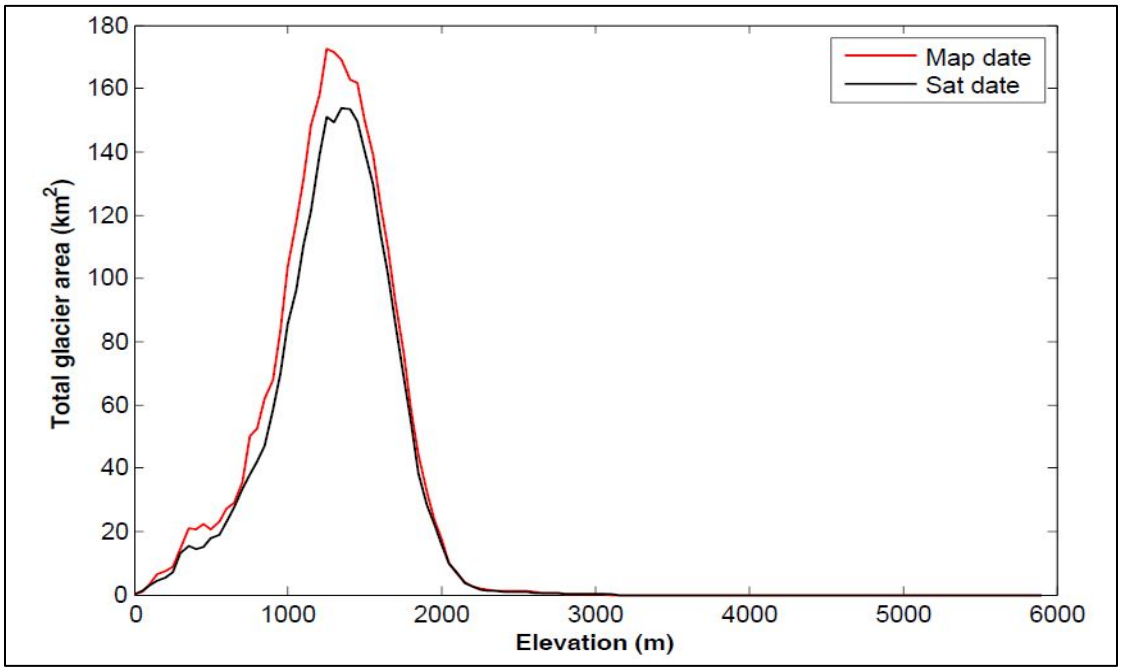


Figure 90. Total glacier covered area in LACL by elevation from 1957 (map date) to 2008 (satellite date) (Arendt et al. 2014).

Since the turn of the century the extent of glaciers within Alaska has been receding at rates never before documented in history. Glacial recession in some cases is so rapid that noticeable differences can be observed in merely a decade. Aerial obliques taken of LACL glaciers in 1997, 2000, and 2007 may be a valuable tool to visually determine extent changes in larger glaciers or the complete disappearance of smaller glaciers (Photo 24). If aerial obliques of LACL glaciers are shot in the future this dataset will supply glacial experts with a valuable resource to observe glacial extent changes within LACL over a time frame known for rapid glacial changes. Glacial photos will be sent to and archived with the National Snow and Ice Data Center (NSIDC) in accordance with the format for photo submissions outlined by the NSIDC.

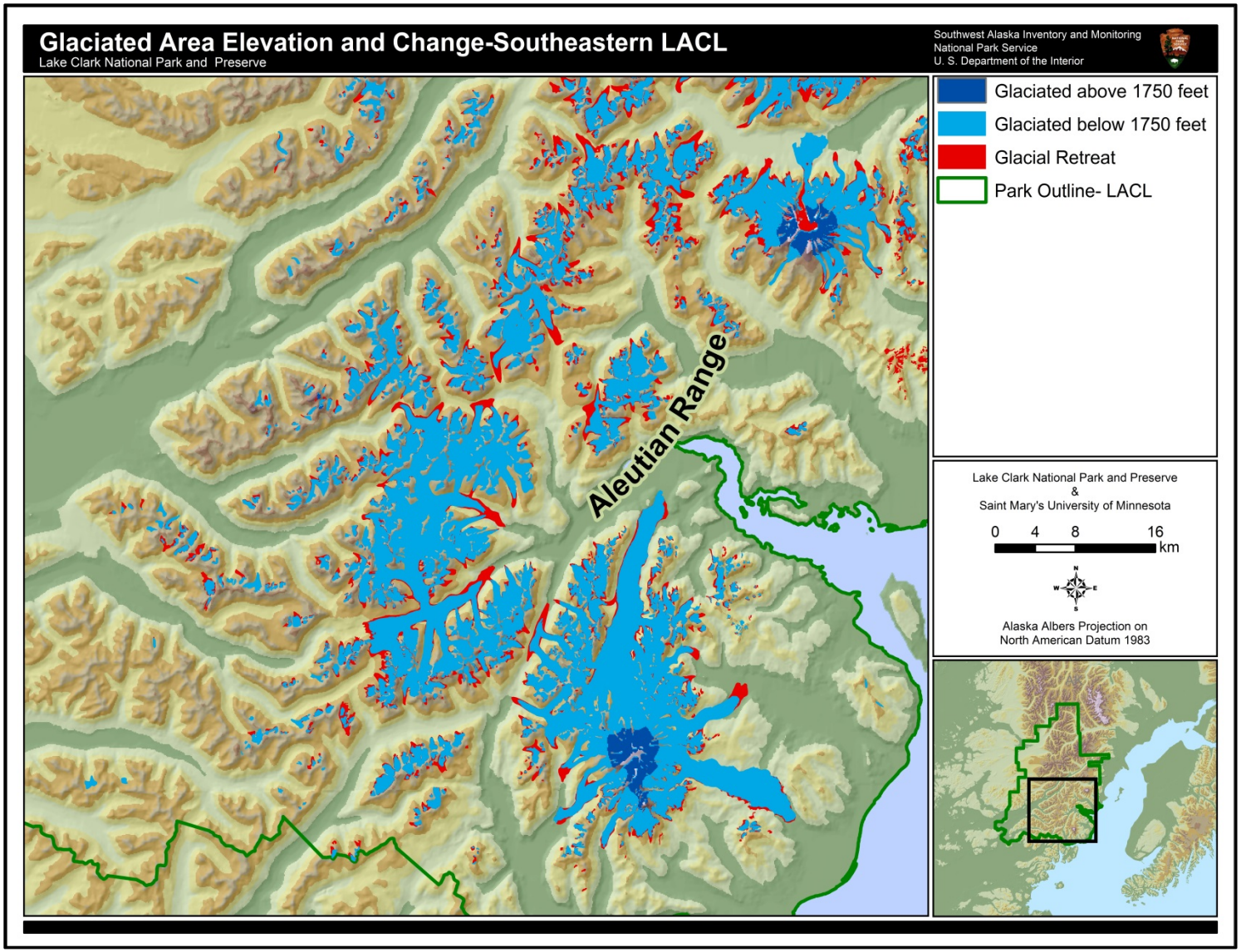


Plate 31. Extent of glacial ice in Southeastern LACL above and below 1,750 feet and glacial recession areas (red) from comparisons of glacial extent mapping from map date (1957) and satellite date (2008). Glacial thinnning and retreat was most prominent in glacial ice below 1,750 feet Arendt et al. (2014), glacial ice below this elevation and at the greatest risk of extripation is represented in moorea blue (Arendt and Rich 2011).

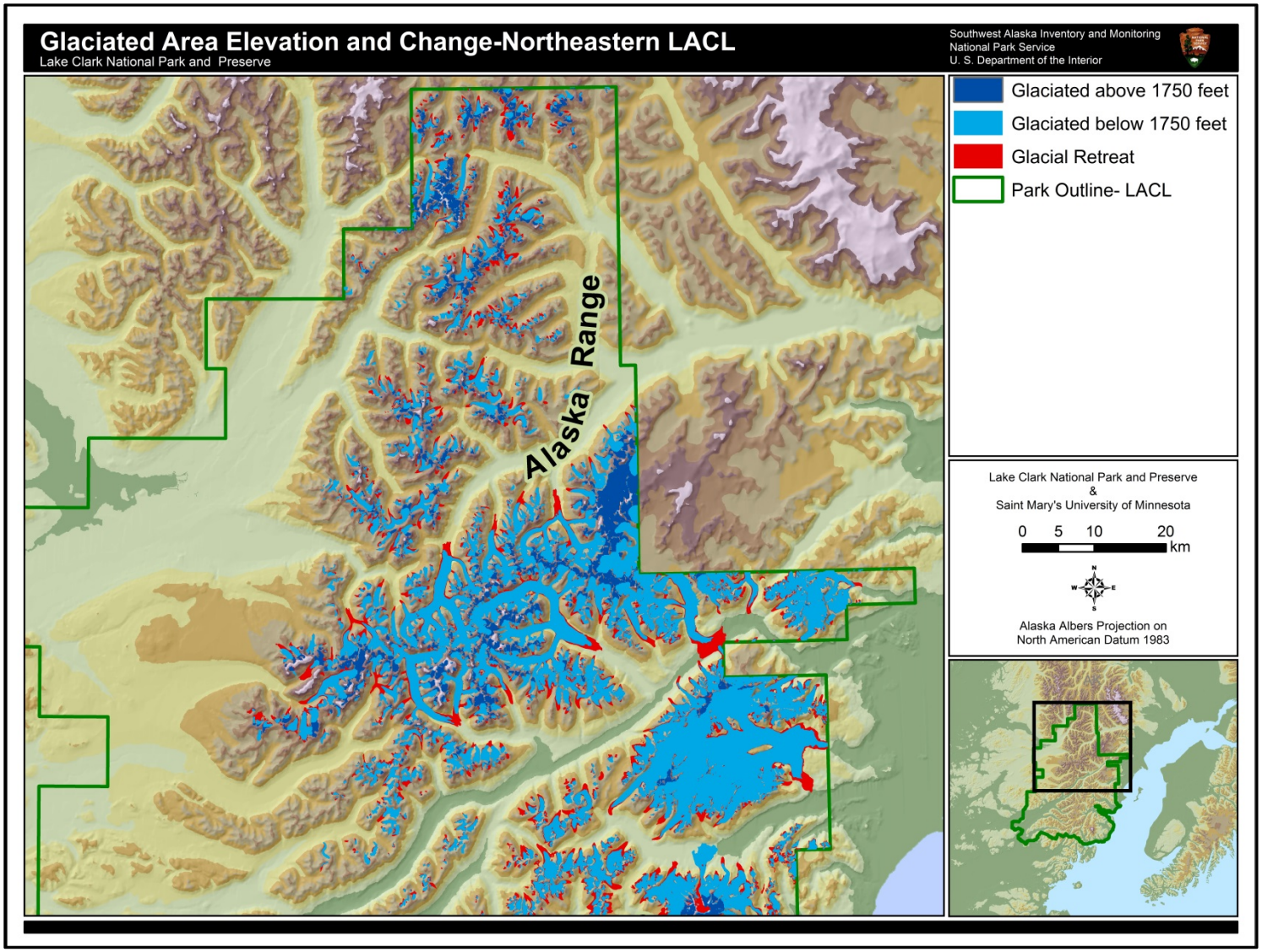


Plate 32. Extent of glacial ice in Northeastern LACL above and below 1,750 feet and glacial recession areas (red) from comparisons of glacial extent mapping from map date (1957) and satellite date (2008). Glacial thinning and retreat was most prominent in glacial ice below 1,750 feet Arendt et al. (2014), glacial ice below this elevation and at the greatest risk of extirpation is represented in moorea blue (Arendt and Rich 2011).

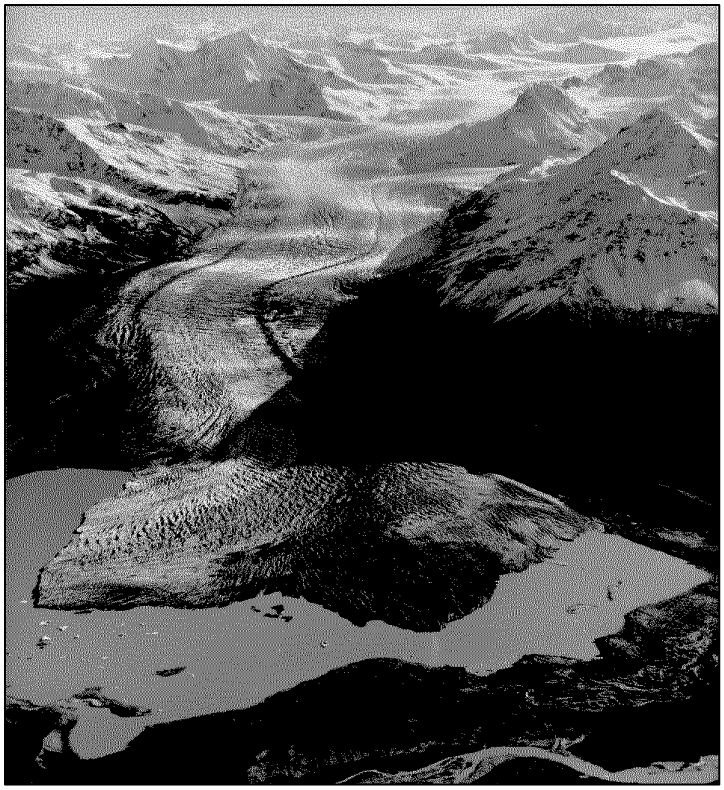


Photo 24. Aerial oblique taken of shamrock glacier in 2000 (Photo by Matthew Sturm).

Rate of Terminus Retreat

Terminus retreat is considered to be the most prevalent type of glacial change within LACL from 1957 to 2008. Plate 31 and Plate 32 represent the satellite date (2008) glacial extent within LACL along with areas that have shown glacial recession from mapdate (1957) glacial extents (Arendt et al. 2014, NPS 2011). Glacial terminus retreat accounts for much of the observed area change of LACL glaciers over time. Data from 1955 to 2007 indicate the average terminus retreat across all glaciated regions of LACL to be -1092 m (Table 115, Giffen 2011). The largest mean change over the aforementioned time period was reported in the Neocola Mountains region with a mean glacial terminus change of -1395 m translating to a mean annual change of -27 m/yr (Table 115, Giffen 2011). The mean annual rate of terminus change across LACL regions from 1955 to 2007 (a period of 52 years) and 1986 to 2007 (a period of 21 years) indicate that the mean annual rate of terminus retreat over the most recent time period has increased. All LACL regions reflect this statement excluding the double glacier region (Table 115). Photo 25 displays unnamed glaciers in LACL showing significant terminus retreat.



Photo 25. Unnamed glaciers in LACL showing significant terminus retreat from the Little Ice Age glacier positions (Giffen and Lindsay 2011).

Table 115. Glacial terminus change within LACL (Giffen 2011).

	Change from 1955 to 2007		Change from 1955 to 1986		Change from 1986-2007		
LACL Glacial Regions	**Mean Change (m)**	**Mean Annual Rate of Change (m/yr)**	**Mean Change (m)**	**Mean Annual Rate of Change (m/yr)**	**Mean Change (m)**	**Mean Annual Rate of Change (m/yr)**	**Number of Glaciers Measured**
All Regions	-1092	-21	-602	-19	-490	-23	87
Merrill Pass	-818	-16	-470	-15	-347	-17	9
Neocola Mountains	-1395	-27	-754	-24	-642	-31	22
Double Glacier	-1097	-21	-757	-24	-340	-16	5
Iliamna Volcano	-1296	-25	-759	-24	-538	-26	6
Chigmit Moutains	-1000	-19	-515	-17	-484	-23	22

Mass Balance (Surface Elevation)

Mass balance studies focus on documenting change in a glacier's volume (mass) over time by analyzing volume, area, and elevation change. Glacial mass balance studies provide information that can indicate changes in regional climates. Corresponding with the loss of glacial area, the total volume of LACL glaciers was also estimated to decrease by 17%, 61.3 km^3 between 1957 and 2008 (Table 116; Arendt et al. 2014).

Table 116. Summary statistics for glaciers in LACL (Arendt et al. 2014).

Time Period	Number of Glaciers	Estimated Volume (km^3)*
Map Date (1957)	1501	358.8
Modern (2008)	1740	297.6
Absolute Change	239	-61.3
Percent Change	16%	-17%

* - Volumes and volume changes are preliminary and subject to change. They are derived from the area/volume scaling (Bahr 1997) using coefficient/exponent values of 0.2055/1.375 from Radic and Hock (2010).

Arendt et al. (2014) conducted a mass balance study of eight glaciers within LACL from 1996 to 2008 including Double North, Double South, Shamrock, Tanaina, Tlikakila Glacier Fork, Tlikakila North Fork, Turquoise, and Tuxedni glaciers (Table 117). This time frame was broken into two time intervals, one from 1996 to 2001 and the later from 2001 to 2008 (Arendt et al. 2014). All but one of the glaciers (Turquoise) studied during the first time interval reported a positive mass balance rate. An inverse trend was observed over the second time interval as all eight glaciers within LACL reported a negative mass balance ratio from 2001 to 2008 (Figure 91; Arendt et al. 2014). From 2001 to 2008, Tlikakila North Glacier was observed to have the most negative mass balance rate of -1.4 m/yr. Glaciers displaying the least change in mass balance rate between the two studied time intervals were Shamrock and Tanaina.

Table 117. Mass balance and mass change of glaciers in Lake Clark NP&P inferred from laser altimetry at discrete time intervals, MB+, MB, MC+, and MC- give positive and negative 95% confidence intervals for mass balance and mass change, respectively (Arendt et al. 2014).

Glacier	Type	Size (km^2)	Mean Elev (m)	Start Date	End Date	Mass Balance (m/yr)	MB+	MB-	Mass Change (gt/yr)	MC+	MC-
Double all	(L/LK)	202	1230	5/14/96	5/13/01	0.21	0.14	0.13	0.04	0.03	0.03
Double all	(L/LK)	202	1230	5/13/01	5/26/08	-0.83	0.39	0.30	-0.17	0.06	0.06
Double N	(LK)	135	1260	5/14/96	5/13/01	0.23	0.14	0.20	0.03	0.03	0.03
Double N	(LK)	135	1260	5/13/01	5/26/08	-0.95	0.25	0.18	-0.13	0.02	0.02
Double S	(L)	67	1150	5/14/96	5/13/01	0.30	0.40	0.10	0.02	0.01	0.01
Double S	(L)	67	1150	5/13/01	5/26/08	-0.74	0.49	0.41	-0.05	0.03	0.03
Shamrock	(LK)	123	1620	5/14/96	5/13/01	0.25	0.12	0.13	0.03	0.02	0.02
Shamrock	(LK)	123	1620	5/13/01	5/21/08	-0.51	0.19	0.13	-0.06	0.02	0.02
Tanaina	(L)	156	1520	5/14/96	5/13/01	0.20	0.20	0.10	0.03	0.01	0.01
Tanaina	(L)	156	1520	5/13/01	5/21/08	-0.63	0.27	0.13	-0.10	0.02	0.02
Tlikakila GF	(L)	107	1350	5/13/01	5/21/08	-1.05	0.18	0.25	-0.11	0.03	0.03
Tlikakila NF	(L)	31	1320	5/13/01	5/21/08	-1.40	0.32	0.48	-0.04	0.01	0.01
Turquoise	(L)	16	1630	5/16/96	5/13/01	-0.70	0.10	0.09	-0.01	0.00	0.00
Turquoise	(L)	16	1630	5/13/01	5/26/08	-1.16	0.28	0.22	-0.02	0.00	0.00
Tuxedni	(S)	92	870	5/13/96	5/13/01	0.54	0.45	0.37	0.05	0.03	0.03
Tuxedni	(S)	92	870	5/13/01	5/26/08	-1.02	0.45	0.47	-0.09	0.04	0.04

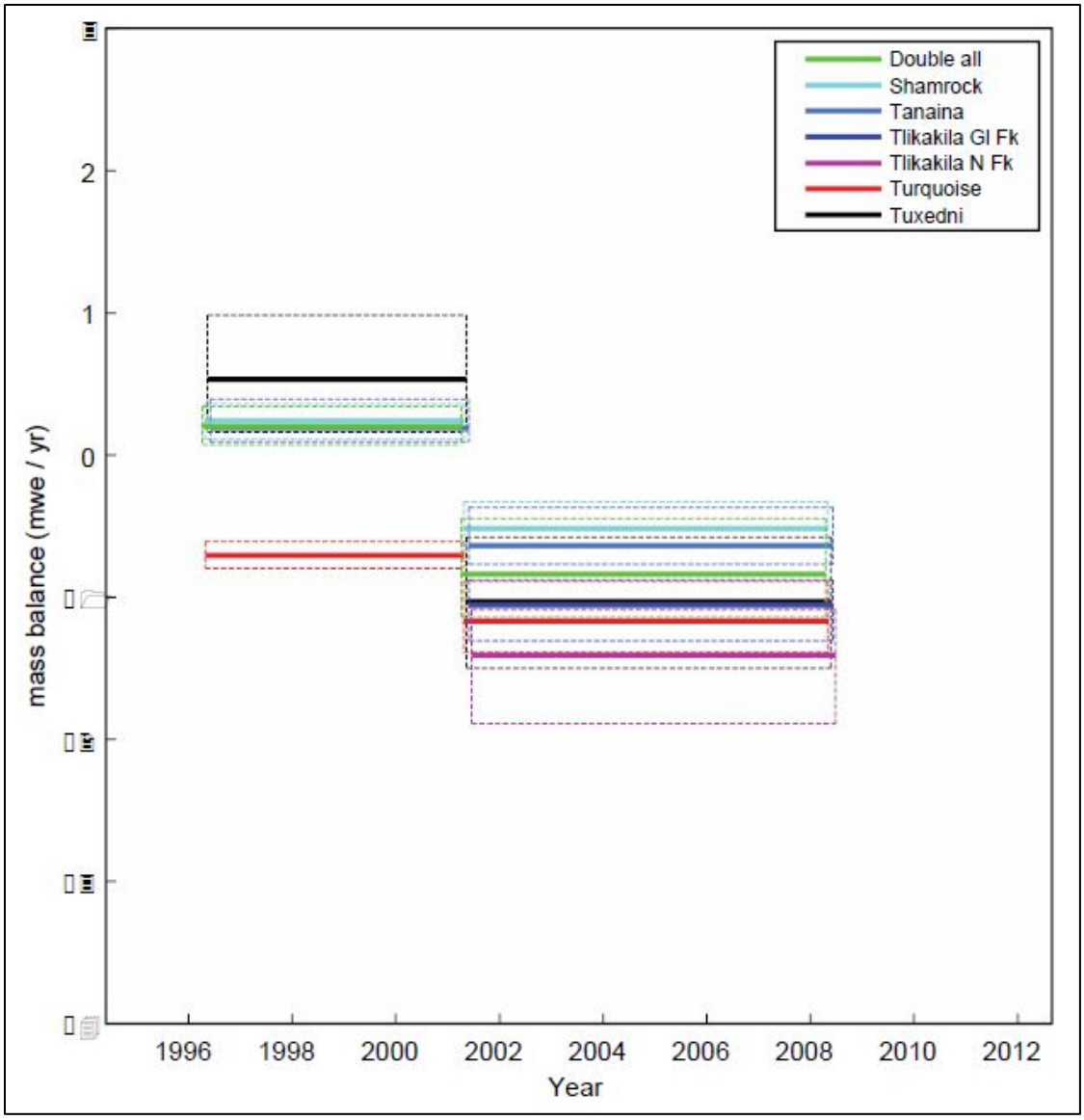


Figure 91. Mass balance of select glaciers in Lake Clark National Park and Preserve. Thick solid lines are mass balances; upper and lower dashed lines reflect confidence intervals for each time period. For clarity, some lines have been shifted a few pixels left or right to minimize overlap.

Threats and Stressor Factors

Climate Change

Climate is one of the most important factors influencing ecosystems. In Alaska, climate is constantly fluctuating on multiple temporal scales, including several natural cycles. One climate fluctuation of particular importance in Alaska is the Pacific Decadal Oscillation (PDO) (Lindsay 2011). Mantua et al. (1997) formally identified this pattern of climate variability in a study relating climate oscillation to salmon production. The PDO, which is related to sea surface temperatures in the northern Pacific Ocean, affects atmospheric circulation patterns and alternates between positive and negative phases (Wendler and Shulski 2009). A positive phase is associated with a relatively strong low pressure center over the Aleutian Islands, which moves warmer air into the state, particularly during the

winter (Wendler and Shulski 2009). Some of the variation in Alaska's climate over time can be explained by major shifts in the PDO which occurred in 1925 (negative to positive), 1947 (positive to negative), and 1977 (negative to positive) (Mantua et al. 1997). Hartmann and Wendler (2005) found that much of the warming that occurred in Alaska during the last half of the twentieth century was likely due to the PDO shift in 1976-77.

Over the time period of 1949 to 2008 an increase of summer and winter temperatures was reported from two different long-term climate stations located in SWAN park regions (Lindsay 2011). The mean annual temperature over this time period increased by 1.9°C (3.4°F) at weather stations in both King Salmon and Homer, Alaska (Lindsay 2013). The LACL region average annual temperatures are estimated to increase by about 0.6°C (1°F) per decade (SNAP et al. 2009). According to Arendt et al. (2014), glacial ice below 533 m (1,750 ft) is at the greatest risk of thinning or receding from the effects of climate change (Plate 31, Plate 32).

Data Needs/Gaps

Rate of terminus movement defines the behavior of the glaciers in a particular region. Terminus movement data helps quantitatively define the implications of climate change on the glaciers of a region. No data regarding rate of terminus movement for glaciers within LACL has been published since 2007.

Overall Condition

Area

A *Significance Level* of 3 was assigned to the area measure. A 16% increase in the number of glaciers within LACL between 1957 and 2008 was reflected in the number of small and medium sized varieties, the frequency of large glaciers remained unchanged (Arendt et al. 2014). This increase in the number of glaciers within LACL did not correspond with an increase in total glaciated area as this value decreased by 12% or 357.3 km^2 (138 mi^2). These data along with Figure 90 suggest that the glaciers at higher elevations may be increasing in total glaciated area or have remained unchanged. However, glaciers at lower elevations have decreased in area from 1957 to 2008, often in the form of terminus retreat, at a faster rate than the accumulation of new glaciated areas at higher elevations. As a result, glaciated area was assigned a *Condition Level* of 3, or of high concern.

Rate of Terminus Retreat

A *Significance Level* of 3 was assigned to the rate of terminus retreat. The Arendt et al. (2014) Alaskan National Park Glaciers Status and Trends document states that terminus retreat was the leading cause for an observed decrease in the area of LACL glaciers between 1957 and 2008. Giffen (2011) noted that the mean annual rate of terminus change across LACL regions from 1955 to 2007 (a period of 52 years) and 1986 to 2007 (a period of 21 years) indicate that the mean annual rate of terminus retreat over the most recent time period has increased. The *Condition Level* for this measure is 3, indicating high concern.

Mass Balance (surface elevation)
Mass balance (surface elevation) was assigned a *Significance Level* of 3. Glacial mass balance rates were calculated for eight glaciers within LACL during two time intervals. One glacier between 1996 and 2001 reported a negative mass balance rate, however, between 2001 and 2008 all eight glaciers reported negative mass balance rates. Such a shift occurring over a very small time frame is a cause for great concern regarding the longevity of glaciers within LACL. A *Condition Level* of 3 was assigned based on this concern.

Weighted Condition Score (WCS)
The *WCS* (see Chapter 3 for methodology) for glaciers in LACL was 1.0. A *WCS* of 1.0 represents an overall condition of the highest concern. Overall, the trend of this resource is considered decreasing.

Glaciers			
Measures	**Significance Level**	**Condition Level**	**WCS = 1.0**
Area	3	3	
Rate of Terminus Retreat	3	3	
Mass Balance	3	3	

4.14.6 Sources of Expertise
Chuck Lindsay, SWAN Physical Scientist

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Chapter 5 Discussion

Chapter 5 provides an opportunity to summarize assessment findings and discuss the overarching themes or common threads that have emerged for the featured components. The data gaps and needs identified for each component are summarized and the role these play in the designation of current condition is discussed. Also addressed is how condition analysis relates to the overall natural resource management issues of the park.

5.1 Component Data Gaps

The identification of key data and information gaps is an important objective of NRCAs. Data gaps or needs are those pieces of information that are currently unavailable, but would help to inform the status or overall condition of a key resource component in the park or would allow the park to develop a more thorough understanding of the topic in order to inform possible management decisions. Data gaps exist for most resource components assessed in this NRCA. Table 118 provides a detailed list of the data gaps identified in this assessment by component. Each data gap or need is discussed in further detail in the individual component assessments (Chapter 4).

Table 118. Identified data gaps or needs for the featured components.

Component	Data Gaps/Needs
Salt Marsh Communities	➢ This is a non-traditional component. As such data needs and gaps were not identified for this component
Brown Bear	➢ Quantitative data on intermixing of coastal and interior populations ➢ Implement plan to define travel extents of interior LACL brown bears ➢ Data gaps in coastal bear survey dataset in regards to bear counts in 2006, 2007, and 2010. ➢ Data gaps in subsistence harvest summaries from 2001 to 2004. ➢ Future research on female survival in the park
Caribou	➢ Research on recruitment rates by cohort for the Mulchatna Herd ➢ Establishment of annual study on adult cow survival rates for the Mulchatna Herd ➢ Continued annual caribou surveys to evaluate long-term trends in population dynamics for the Mulchatna Herd
Black Bear	➢ Need for consistent bear survey data, data gaps in 2006, 2007, and 2010. ➢ Quantitative data defining population size and density, recruitment, sex-ratios, and female survival.
Dall's Sheep	➢ Need for more consistent surveys (every 3-4 yrs) as identified in goals ➢ Only six surveys between 1978 and 2012 cover the entire extent of the Dall's sheep range in the park
Moose	➢ Lack of moose survey data after 2008 ➢ Consistent monitoring of moose populations for each GMU that intersects with the park ➢ Current data on adult cow survival rates ➢ Establishment of moose surveys within park concurrent to GMU surveys

Table 118 (continued). Identified data gaps or needs for the featured components.

Component	Data Gaps/Needs
Bald Eagles	➢ Data gaps related to current and potential threats in the park ➢ Conduct a contaminant analysis on eagle population in park ➢ Conduct a dietary study of bald eagles ➢ Expanded research on climate variation and bald eagle nesting success ➢ Research interaction of interior and coastal bald eagle populations
Salmon	➢ To be addressed in a future addendum.
Resident Fish	➢ To be addressed in a future addendum.
Air Quality	➢ Establishment of a monitoring station in the park that collects data on wet / dry deposition as well as ozone ➢ Continued monitoring of visibility at the Silver Salmon Creek station ➢ Continued monitoring at the IMPROVE station ➢ Establishment of baseline data
Water Quality	➢ Continued long-term monitoring of core water quality parameters in select water bodies in the park ➢ Establishment of baseline data ➢ Continued use of quality control protocol
Water Quantity	➢ Data gap in Newhalen River discharge values for years 1968 through 1981 ➢ Establishment of baseline data regarding water quantity parameters of select water bodies in the park ➢ Establishment of consistent readings of lake elevation, discharge, and out flow
Climate	➢ Continued monitoring of recently established RAWS stations in the park ➢ Continued monitoring of the four GHCN long-term stations in the park ➢ Consistent data collection at Telaquana Lake station ➢ Consistent monthly snow course monitoring at Port Alsworth ➢ Implementing a more accurate method for measuring wintertime precipitation
Glaciers	➢ No published data in regards to rate of terminus movement after 2007 ➢ Continued work on rate of terminus movement

Many of the park's data needs involve the challenge of determining ways to effectively sample and monitor biological phenomena in order to increase statistical confidence and to ensure long-term monitoring techniques are possible. To increase statistical confidence, sampling techniques of existing survey efforts could be strengthened and improved, or in some cases, designing entirely different approaches in terms of long-term data collection. Some statistical confidence will increase by simply consistently repeating the existing surveys to increase the total number of samples (e.g., years), as some sampling methods have only been repeated for a few consecutive years.

The sampling and monitoring efforts in LACL, as with many Alaskan park lands, are complicated given the remote location of the park, as well as potentially extreme environmental conditions.

Techniques for large animal surveys (aerial) often require ideal weather during the survey as well as for optimal sighting conditions. Moose surveys are frequently impacted by a lack of snow cover, inadequate snow depth and less than optimal flying conditions. Weather and sampling conditions also impact other population surveys in LACL including salmon and bear. A consistent but opportunistic and flexible approach to population surveys is necessary to gather data and improve analyses.

5.2 Park-wide Component Observations

Table 119 displays the conditions assigned to each resource component presented in Chapter 4 (definitions of condition graphics are located in Figure 92 following Table 119). It is important to remember that the graphics represented are simple symbols for the overall condition and trend assigned to each component. Because the assigned condition of a component (as represented by the symbols in Table 119) is based on a number of factors and an assessment of multiple literature and data sources, it is strongly recommended that the reader refer back to each specific component assessment in Chapter 4 for a detailed explanation and justification of the assigned condition. Condition designations for some components are supported by existing datasets and monitoring information and/or the expertise of NPS staff, while other components lack historic data, a clear understanding of reference conditions (i.e., what is considered desirable or natural), or even current information.

Condition assessments were not considered appropriate for four of the 15 components: salt marsh communities, air quality, water quality, and water quantity. Condition could also not be determined for two of the 14 selected components; black bear and resident fish.

For featured components with available data and fewer data gaps, assigned conditions varied. Four components are considered to be of low concern: brown bear, Dall's sheep, bald eagles, and salmon. Just one component (moose) is of moderate concern and three components were of high concern: caribou, climate, and glaciers.

Table 119. Summary of current condition and condition trend for featured NRCA components.

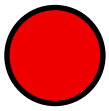
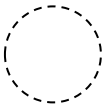
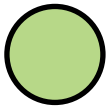
Component	WCS	Condition
Biotic Composition		
Ecological Communities		
Salt Marsh Communities	N/A	N/A
Mammals		
Brown Bear	0.00	
Caribou	0.67	
Black Bear	N/A	
Dall's Sheep	0.33	
Moose	0.47	
Birds		
Bald Eagles	0.33	
Fish		
Salmon	Future Addendum	N/A
Resident Fish	Future Addendum	N/A
Environmental Quality		
Air Quality	N/A	N/A
Water Quality	N/A	N/A
Water Quantity	N/A	N/A

Table 119 (continued). Summary of current condition and condition trend for featured NRCA components.

Component	WCS	Condition
Physical Characteristics		
Geologic & Hydrologic		
Climate	0.92	
Glaciers	1.00	

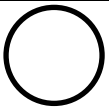
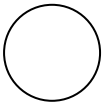
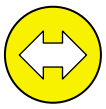
Condition Status		Trend in Condition		Confidence in Assessment	
	Resource is in Good Condition		Condition is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Medium
	Warrants Significant Concern		Condition is Deteriorating		Low

Figure 92. Description of symbology used for individual component assessments.

Examples of how the symbols should be interpreted:



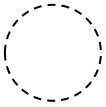
Resource is in good condition; its condition is improving; high confidence in the assessment.



Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.



Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.



Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment.

5.3 Park-wide Condition Observations

Despite the great variety in vegetation and physical features within LACL's boundaries, many of the resources discussed in this report are interrelated and share similar management concerns (e.g., data gaps, threats from outside the park).

5.3.1 Biological Composition

Ecological Communities

Salt Marsh Communities

Despite salt marsh communities occupying less than one percent of the total land area of LACL, they are considered to have great importance to the park's ecosystems (NPS 2014a). Salt marshes are among the most productive ecosystems in the world and provide habitat and food for a variety of the park's species including coastal brown bears, salmon, and resident and migratory birds (NPS 2014a).

Photo interpretation was used to better understand and identify the changes that have occurred over periods of time within the salt marshes of LACL. By utilizing imagery from 1940, 1980, and 2010 we delineated vegetation, mudflat, and other features of the salt marshes at a point in time as a reference point. This reference point was then compared throughout the periods to give us an indication of the change that has occurred.

The salt marsh community component of this NRCA is a non-traditional component type. As such data needs/gaps were not identified and a condition assessment or *Weighted Condition Score* was not created for this component.

Mammals

Brown Bear

The brown bear is a prominent mammal species in LACL (Olson and Putera 2007). The species utilizes much of LACL, with larger concentrations in coastal and lake ecosystems. The Alaskan Peninsula as a whole, and specifically the region within and around LACL, is world-renowned for its high bear densities (Olson and Putera 2007).

LACL, ecologically similar KATM (80 km [50 mi] away), and the McNeil River State Game Sanctuary (MRSGS, northeast of KATM) provide refuge for one of the world's most dense brown bear populations. The brown bear population within national parks and the MRSGS in unit 09 alone is estimated to be between 2,000 and 2,500 individuals (Butler 2009). The large protected coastal brown bear population of southeastern LACL provides visitors the opportunity to view bears in a natural setting. The establishment of a bear viewing camp in 1997 increased the visitation to one coastal salt marsh in LACL from 30 people in 1995 to over 500 people by the mid-2000s. Bear viewing also occurs at in-land Crescent Lake (Olson and Putera 2007).

All the measures reported for brown bear, excluding female survival, met or exceeded the standard for the reference condition for this resource and may be judged to be in excellent condition. The condition level for female survival was defined as N/A due to the lack of information regarding this measure within LACL.

Caribou

Caribou were once a prominent species in LACL. Today, they occasionally utilize the west and southwest portions of the park. LACL caribou are part of the Mulchatna Caribou Herd (MCH), one of the 32 designated herds in Alaska. Herds may intermix at wintering grounds but calving grounds are separate and historically remain in the same general area. The traditional calving grounds of the MCH have been the upper reaches of the Mulchatna River and the Bonzna Hills that are located southwest and west of LACL, respectively. Lesser used areas include Jack Rabbit Hills, Koktulil Hills, Mosquito River, and Kilbuck Mountains (Woolington 2009b, 2011b). The traditional calving grounds have been used sparingly since 1988. Calving now occurs most commonly between Kemuk Mountain and the Nushagak River; some calving also occurs west of LACL, between the Stoney River and Hoholitna River (Woolington 2009b, 2011b).

Mulchatna Caribou Herd population estimates and observations within LACL and the surrounding region indicate that the population has been declining since 1998. According to Woolington (2012), the peak in population size occurred in 1996 with an estimated 200,000 caribou with the most recent population estimate taken in 2008 being 30,000 caribou. The decline of the MCH could be attributed to several factors including poor weather conditions, low recruitment levels, cow survival, or predation.

Black Bear

Black bear utilize LACL resources year round for foraging, reproduction, and denning. The species is widely dispersed throughout the forested areas of the park during much of the year although concentrations around coastal, riverine, and lake ecosystems sometimes occur. Minimal data exist regarding the population size and densities of black bears in the LACL region.

Quantitative data defining population size and density, recruitment, sex-ratios, and female survival that would enable explicit conclusions regarding condition of these measures do not exist for this component; the *Significance Level* for all measures was identified as a 3 or of high importance. Lack of sufficient data regarding this resource prevents an accurate assignment of *Condition Levels* to the preceding measures. However, the absence of literature expressing concern for the resource and anecdotal observations from park staff indicate that black bears are currently stable within LACL.

Dall's Sheep

Dall's sheep inhabit mountain ranges farther north than all members of the closely related bighorn sheep, and are a prominent mammal species in LACL. The protection of Dall's sheep and the unique habitat in which they reside was part of the grounds for the establishment of LACL: "… to protect habitats for and populations of fish and wildlife, including, but not limited to caribou, Dall's sheep, brown/grizzly bears, bald eagles, and peregrine falcons" (Haertel 1984, p. 2).

Within LACL, Dall's sheep frequent open alpine areas, steep slopes with rugged "escape" terrain, and high meadows (Olson 2008). The entire population of Dall's sheep in LACL occurs on the western side of the mountain divide; coastal climate influence on the eastern slopes, primarily in the form of heavier winter snows, is the most likely cause for this distribution (Bennett and Terenzi 1997). Dall's sheep within LACL represent the southwestern most population of sheep in Alaska.

Natural fluctuations (20-25%) in sheep numbers between subsequent years is not uncommon. These fluctuations make assessing the current condition of population size in LACL difficult. Annual surveys have not been completed in LACL, and data from the available surveys are of varying extents and methods. Park-wide population estimates were completed for six years between 1978-79 and 2012, reporting an average Dall's sheep population within LACL of 771 sheep during these survey years. The most recent park-wide survey was conducted in 2012 and estimated 1,010 sheep, a value similar to the highest park-wide population estimation ever recorded.

Moose

Moose are found in the lowlands of LACL. They occupy boreal forests as well as areas of shrub/scrub near the rivers and lake riparian zones (Rausch et al. 2008). Moose have historically been associated with northern forests and subarctic climates typical of southwestern Alaska.

There are little available moose data after 2008. From 1992-2003 and 2003-2013, the NPS surveyed two similar areas in three-year cycles. As a result, survey data are somewhat limited. Current data for cow survival are not available. The most recent cow survival data are at least 10 years old (Mangipane and Putera 2000), and therefore may not be helpful in making an accurate assessment for the present moose population in LACL. ADF&G (2010) lacks the most recent data. The data in the survey are five years old, and are not consistent among the LACL GMUs. For example, the only population estimates in unit 9 were from a 1983 census and unit 19 B does not have a population estimate recorded. NPS (2011) has current data; however, the survey only covers 45 percent of moose habitat in the park. This lack of data coverage makes it difficult to make an accurate assessment of current population dynamics.

The ADF&G tracks moose parameters such as population density, population composition, habitat, and harvest for selected species in each Game Management Unit (GMU). Portions of five individual GMUs extend over LACL, including units 09A, 09B, 16B south, 17B, and 19B. All five of these units have different ADF&G-defined moose population management goals and objectives. Population size, density, and calf:cow ratio estimates have declined over the years; however, three of four moose survey units seem to be stabilizing. This does not necessarily indicate good population health; but a break in the previous declining trend.

Birds

Bald Eagle

LACL is home to the northern subspecies of bald eagle (Stalmaster 1987). This subspecies is slightly larger than the southern subspecies, and is the only subspecies that has a breeding range in Alaska (Stalmaster 1987). Bald eagles serve an important ecological role in freshwater and marine coastal ecosystems within SWAN, and monitoring of their populations across the region, including LACL, is important to understanding the overall ecological health of the area.

The unique geography of LACL isolates two specific regions of bald eagle nesting habitat: the interior of the park (shoreline habitat surrounding Lake Clark and the associated drainages), and the coastal region of the park (Cook Inlet coastline and the associated drainages). Eagle populations in the two regions of the park are highly variable, and no clear pattern or relationship was visible when

looking at the data. It appears that the populations are self-sustaining and are meeting all reference conditions, but with yearly fluctuations it is difficult to ascertain current trends accurately.

The *Weighted Condition Score* for bald eagles was 0.33, indicating a component in good condition. This WCS is at the upper limit of the good condition designation (nearing moderate concern), and the component should continue to be monitored annually to observe any potential trends or signs of degradation. A trend arrow was not assigned to this measure, not because of a lack of data, but rather because of the highly variable data that exist for both measures. Fluctuations above and below the reference condition for these two measures happened frequently, sometimes on a yearly basis. Furthermore, the two distinct regions of nesting eagles make assigning a single trend graphic difficult.

5.3.2 Environmental Quality

Air Quality

The Clean Air Act of 1977 defines two distinct categories of protection for natural areas, Class I and Class II airsheds. Class I airsheds receive the highest level of air quality protection as offered through the CAA; only a small amount of additional air pollution is permitted in the airshed above baseline levels. For Class II airsheds, the increment ceilings for additional air pollution above baseline levels are slightly greater than for Class I areas and allows for moderate development (EPA 2013). LACL is classified as a Class II air quality area (Bennett et al. 2006).

Potential impacts to the air quality in LACL include anthropogenic fugitive dust from resource development, the release of natural gases and coal dust into the air, oil and gas development, and the long-range transport of air pollutants as well as particulates from natural sources such as wildfire smoke, pollen, and airborne glacial silt. Fugitive dust is a type of particulate matter created from open air industrial operations and is not filtered. Sources of fugitive dust include unpaved roads/runways, mining, transportation of uncovered mineral materials, blasting, gravel operations, and construction operations (ADEQ 2011).

Wet and dry deposition and ozone monitoring programs are needed in order to more confidently report on the condition of air quality within the park. As a high precipitation region, it is more susceptible to wet deposition. More information regarding visibility at Tuxedni would be useful. Tuxedni reported lower concentrations of particulate matter compared to the EPA standards for human health. The IMPROVE dataset is the longest air quality dataset for LACL and could provide useful baseline air quality information for comparison to future monitoring results.

Water Quality

Aquatic systems within SWAN parks are remote and pristine, providing researchers with an opportunity to examine the effects of climate change and atmospheric pollutants on intact systems. LACL is considered to have one of the most diverse collections of water resources of any SWAN park. LACL includes over 9,656 km (6,000 mi) of rivers and streams that flow through a variety of environments including glacial, volcanic, coastal, and freshwater ecosystems (Weeks 2003).

The implementation of a long-term monitoring program nationally within the NPS resulted in a shift away from project-driven data collection to a strategic approach to examine resource trends. SWAN has developed a long-term water quality protocol to examine trends in various parameters across a tiered system of lakes (Shearer et al. 2015a, b). Additionally, focused studies by the USGS (Brabets 2002, Brabets and Ourso 2006) have allowed managers to establish baseline water quality and hydrologic conditions. Future project funding will be used to target additional water resources where baseline data are needed, such as on-going work by the USGS on the Chulitna River.

Wilson and Moore (2013) reported quality control concerns with previous collection methods in both field collection protocols and data collection efficiency. Significant differences were found in collected samples after changes regarding calibration, sonde transportation technique, and equilibration methods were established. Changes outlined in Wilson and Moore (2013) and Shearer et al. (2015) have been implemented to increase data integrity, stream line sampling efforts, reduce cost of sampling, and increase efficiency.

Water Quantity

Monitoring the annual, seasonal, and weather-event specific hydrology fluctuations of lakes, rivers, and streams within LACL is important for explaining variations in water quality parameters such as dissolved oxygen, temperature, conductivity, etc. (Bennett 2005). Peak discharges and gage heights of Alaskan water bodies generally occur during mid to late summer; average daily air temperatures peak during this time, causing the most rapid melt of glacial ice and snow.

Lake Clark lake elevation, and discharge/out flow readings are measured manually using tape height. Due to a lack of automation, readings are not recorded consistently through the year or between years. This inconsistency, along with gaps in the data for certain days on which no readings were reported, makes comparative analysis between years difficult.

The general lack of baseline data regarding water quantity parameters for the water bodies presented in this document and all water bodies within Lake Clark make identifying trends and deciding on management actions difficult. Any evaluation of water quantity condition based on data regarding this resource would not be appropriate at this time due to lack of reference condition and the limited data.

5.3.3 Physical Characteristics

Climate

Climate is widely recognized as one of the most fundamental drivers of ecological condition and ecological change, particularly in Alaska (NPS 2011a). As a primary driver of many other ecosystem components (vegetation, wildlife, disturbance regime, etc.), climate also has numerous management consequences and implications. Climate was selected by the SWAN I&M program as a high-priority Vital Sign for southwest Alaska parks (Bennett et al. 2006). The climate in LACL can be described as boreal, continental, and maritime; the climate to the west of the mountain range is boreal and continental, but the climate to the east of the mountain range, located along the coast, is maritime (Lindsay 2011). The mountains also influence the wide range in annual temperatures and precipitation levels.

To better understand the climate of the LACL area, it will be important to continue gathering data from the three recently established RAWS stations and the four long-term stations. Data collecting from Telaquana Lake station should start to occur consistently throughout each month of the year. Consistent, monthly snow course monitoring at Port Alsworth is also needed to better assess snow depth. This information will help identify the range of climate variability within the park and if any changes are occurring over time. Implementing a more accurate method for measuring wintertime precipitation would also be helpful. Further studies are needed to explore how changes in climate will impact other park resources (e.g., vegetation and wildlife, water regime, etc.). Climate change is of paramount concern for LACL.

Glaciers

LACL is included among the three parks within SWAN considered to have a significant glacial coverage (Giffen and Lindsay 2011). According to Arendt et al. (2014) glacier ice covers 2,339 km^2 (903 mi^2) of LACL, forming an estimated 14.3% of the total park area.

Comprehensive data on glacial extent and the current condition of glaciers is lacking within LACL. A recent study (Arendt et al. 2014) was undertaken as a multi-year effort to map and document the glacial resources of the Alaskan parks. Arendt et al. (2014) utilized satellite imagery from 2006-2010 to compare to map data from 1954-1957 (map date 1957).

Rate of terminus movement defines the behavior of the glaciers in a particular region. Terminus movement data helps quantitatively define the implications of climate change on the glaciers of a region. No data regarding rate of terminus movement for glaciers within LACL has been published since 2007, therefore the benefits in which these data can provide are also absent.

5.3.4 Park-wide Threats and Stressors

Anthropogenic impacts from climate change to tourism potentially impact LACL and their resources. Arguably the most relevant, long-term threat to LACL is climate change. Alaska already experiences cyclical shifts in weather and climate because of the PDO. Depending on the phase of the PDO, warmer or cooler air pushes into the northern latitudes for extended periods of time, causing shifts in temperature and precipitation regimes.

If a global warming trend persists, glacial melt and shifts in wave regimes would change the dynamic of LACL. From 1950-2005, the recession of glaciers resulted in exposure of new shoreline, streams, and revegetation of once-covered bare ground. Places in higher latitudes, such as LACL, are anticipated to experience greater rates of change and higher variability.

For biological resources analyzed in this assessment many concerns also stem from climate change (warming). Salmon may experience decreased survival of eggs and fry, slowed growth, premature smolting, and shifts in onsets of runs (Alderice and Velsen 1978), Other potential impacts of a warmer climate include reduced snowpack and a longer growing season, which could affect plant phenology and productivity, wildlife distribution and mating cycles, water availability, and recreational and subsistence activities (e.g., hunting, fishing) (SNAP et al. 2009, NPS 2011a).

Human use in LACL, including hunting and fishing, is also considered a stressor. Salmon, bear, and moose can be harvested in the preserve. These species face increased harvest risk if/when they travel outside LACL boundaries.

Another threat to resources in LACL is human caused disasters such as oil spills. The Exxon Valdez oil spill in spring of 1989 was one of the most environmentally devastating (human-caused) events to affect Prince William Sound, Resurrection Bay, Cook Inlet and adjacent parks (NPS 1990, as cited by Nagorski et al. 2007). The shoreline of LACL received minor impacts compared to Kenai Fjords and Katmai National Parks (NPS 1990, as cited by Nagorski et al. 2007). Continued oil and gas exploration and industrial shipping in Cook Inlet continue today as a potential source for future impacts.

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Appendices

Appendix A. Types of physiographic change from 1950 to 1980 in Silver Salmon Creek salt marsh areas.

Physiography 1950	Physiography 1980	Area (ha)	Percent Area
Coastal Mid Marsh	Coastal Mid Marsh	58.13	31.76%
Upland	Upland	28.61	15.63%
Barren	Barren	23.16	12.66%
Upland	Barren	11.51	6.29%
Coastal Low & Mid Marsh	Coastal Mid Marsh	10.07	5.50%
Barren	Coastal Mid Marsh	8.91	4.87%
Ocean	Ocean	6.84	3.74%
Barren	Upland	5.77	3.15%
Barren	Coastal Low Marsh	5.68	3.10%
Coastal Mid Marsh	Upland	3.81	2.08%
Coastal Low Marsh	Coastal Mid Marsh	3.69	2.02%
Coastal Low Marsh	Coastal Low Marsh	3.33	1.82%
Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	3.08	1.68%
Ocean	Barren	2.66	1.46%
Barren	Ocean	2.09	1.14%
Barren	Coastal Low & Mid Marsh	1.21	0.66%
Upland	Coastal Mid Marsh	1.01	0.56%
Upland	Coastal Low Marsh	0.85	0.47%
Ocean	Coastal Low & Mid Marsh	0.75	0.41%
Coastal Low Marsh	Barren	0.71	0.39%
Ocean	Coastal Mid Marsh	0.41	0.22%
Ocean	Coastal Low Marsh	0.36	0.20%
Coastal Low Marsh	Ocean	0.28	0.15%
Upland	Ocean	0.06	0.04%

Appendix B. Types of physiographic change from 1980 to 2010 in Silver Salmon Creek salt marsh areas.

Physiography 1980	Physiography 2010	Area (ha)	Percent Area
Coastal Mid Marsh	Coastal Mid Marsh	74.87	40.90%
Upland	Upland	32.48	17.75%
Barren	Barren	28.13	15.37%
Ocean	Barren	7.75	4.24%
Coastal Low Marsh	Barren	5.62	3.07%
Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	4.83	2.64%
Upland	Barren	4.52	2.47%
Barren	Upland	4.34	2.38%
Barren	Coastal Low Marsh	2.58	1.41%
Coastal Mid Marsh	Coastal Low & Mid Marsh	2.56	1.40%
Coastal Low Marsh	Coastal Low Marsh	2.33	1.27%
Barren	Ocean	2.26	1.24%
Coastal Mid Marsh	Coastal Low Marsh	2.03	1.11%
Coastal Mid Marsh	Upland	1.45	0.79%
Coastal Low Marsh	Coastal Mid Marsh	1.42	0.78%
Coastal Mid Marsh	Barren	1.31	0.72%
Ocean	Ocean	1.08	0.59%
Upland	Ocean	0.86	0.47%
Barren	Coastal Mid Marsh	0.73	0.40%
Coastal Low Marsh	Upland	0.33	0.18%
Ocean	Coastal Low Marsh	0.32	0.18%
Upland	Coastal Mid Marsh	0.31	0.17%
Coastal Low Marsh	Coastal Low & Mid Marsh	0.27	0.15%
Coastal Low Marsh	Ocean	0.24	0.13%
Coastal Low & Mid Marsh	Barren	0.21	0.12%
Ocean	Coastal Mid Marsh	0.11	0.06%

Appendix C. Types of physiographic change for all three year classes 1950, 1980, and 2010 in Silver Salmon Creek salt marsh areas.

Physiography 1950	Physiography 1980	Physiography 2010	Area (ha)	Percent Area
Coastal Mid Marsh	Coastal Mid Marsh	Coastal Mid Marsh	56.12	30.66%
Upland	Upland	Upland	23.21	12.68%
Barren	Barren	Barren	18.95	10.36%
Coastal Low & Mid Marsh	Coastal Mid Marsh	Coastal Mid Marsh	10.07	5.50%
Upland	Barren	Barren	6.12	3.35%
Barren	Coastal Mid Marsh	Coastal Mid Marsh	5.94	3.25%
Ocean	Ocean	Barren	5.85	3.20%
Barren	Upland	Upland	5.77	3.15%
Upland	Upland	Barren	4.52	2.47%
Upland	Barren	Upland	4.34	2.38%
Coastal Mid Marsh	Upland	Upland	3.51	1.91%
Barren	Coastal Low Marsh	Barren	3.22	1.76%
Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	3.08	1.68%
Barren	Barren	Coastal Low Marsh	2.49	1.36%
Ocean	Barren	Barren	2.33	1.28%
Coastal Low Marsh	Coastal Low Marsh	Barren	2.12	1.16%
Barren	Coastal Low Marsh	Coastal Low Marsh	1.71	0.94%
Coastal Low Marsh	Coastal Mid Marsh	Coastal Mid Marsh	1.71	0.93%
Barren	Barren	Ocean	1.56	0.86%
Barren	Ocean	Barren	1.55	0.85%
Barren	Coastal Mid Marsh	Coastal Low Marsh	1.52	0.83%
Coastal Low Marsh	Coastal Mid Marsh	Coastal Low & Mid Marsh	1.47	0.81%
Coastal Mid Marsh	Coastal Mid Marsh	Upland	1.45	0.79%
Upland	Coastal Mid Marsh	Coastal Mid Marsh	1.01	0.56%
Barren	Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	0.99	0.54%
Barren	Coastal Mid Marsh	Barren	0.91	0.49%
Upland	Upland	Ocean	0.86	0.47%

Appendix C (continued). Types of physiographic change for all three year classes 1950, 1980, and 2010 in Silver Salmon Creek salt marsh areas.

Physiography 1950	Physiography 1980	Physiography 2010	Area (ha)	Percent Area
Ocean	Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	0.75	0.41%
Ocean	Ocean	Ocean	0.65	0.36%
Coastal Low Marsh	Coastal Low Marsh	Coastal Low Marsh	0.61	0.33%
Upland	Coastal Low Marsh	Coastal Mid Marsh	0.61	0.33%
Upland	Barren	Ocean	0.57	0.32%
Coastal Mid Marsh	Coastal Mid Marsh	Coastal Low & Mid Marsh	0.55	0.31%
Barren	Coastal Mid Marsh	Coastal Low & Mid Marsh	0.53	0.29%
Coastal Low Marsh	Coastal Mid Marsh	Coastal Low Marsh	0.51	0.28%
Upland	Barren	Coastal Mid Marsh	0.46	0.25%
Barren	Ocean	Ocean	0.42	0.23%
Ocean	Coastal Mid Marsh	Barren	0.41	0.22%
Barren	Coastal Low Marsh	Coastal Mid Marsh	0.38	0.21%
Coastal Low Marsh	Coastal Low Marsh	Coastal Mid Marsh	0.35	0.19%
Coastal Mid Marsh	Upland	Coastal Mid Marsh	0.31	0.17%
Coastal Low Marsh	Ocean	Barren	0.28	0.15%
Barren	Coastal Low Marsh	Coastal Low & Mid Marsh	0.27	0.15%
Ocean	Coastal Low Marsh	Barren	0.27	0.15%
Upland	Coastal Low Marsh	Upland	0.25	0.14%
Coastal Low Marsh	Coastal Low Marsh	Ocean	0.24	0.13%
Barren	Coastal Low & Mid Marsh	Barren	0.21	0.12%
Ocean	Ocean	Coastal Low Marsh	0.21	0.12%
Barren	Barren	Coastal Mid Marsh	0.14	0.08%
Ocean	Barren	Ocean	0.12	0.07%
Ocean	Barren	Coastal Mid Marsh	0.12	0.07%
Ocean	Ocean	Coastal Mid Marsh	0.11	0.06%
Barren	Ocean	Coastal Low Marsh	0.11	0.06%
Ocean	Coastal Low Marsh	Coastal Mid Marsh	0.08	0.05%
Ocean	Barren	Coastal Low Marsh	0.08	0.05%
Barren	Coastal Low Marsh	Upland	0.07	0.04%
Upland	Ocean	Barren	0.06	0.04%

Appendix D. Summary of physiographic area per year for 2010 in Silver Salmon Creek salt marsh areas.

	1950		1980		2010	
Physiography	**Area (ha)**	**Percent Area**	**Area (ha)**	**Percent Area**	**Area (ha)**	**Percent Area**
Coastal Mid Marsh	61.94	33.84%	82.23	44.92%	77.46	42.31%
Barren	46.34	25.31%	38.06	20.79%	47.57	25.99%
Upland	42.05	22.97%	38.18	20.86%	38.61	21.10%
Coastal Low & Mid Marsh	13.15	7.19%	5.04	2.76%	7.67	4.19%
Coastal Low Marsh	8.02	4.38%	10.23	5.59%	7.27	3.97%
Ocean	11.03	6.03%	9.28	5.07%	4.45	2.44%
Coastal High Marsh	0.49	0.27%	--	--	--	--

-- no data, not applicable

Appendix E. Types of landscape formation change from 1950 to 1980 in Silver Salmon Creek salt marsh areas.

Landscape Formation 1950	Landscape Formation 1980	Area (ha)	Percent Area
Meadow	Meadow	31.35	17.13%
Upland	Upland	28.60	15.63%
Mudflat	Mudflat	23.05	12.59%
Interlevee Basin Meadow	Interlevee Basin Meadow	20.56	11.23%
Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	13.16	7.19%
Upland	Mudflat	11.51	6.29%
Mudflat	Interlevee Basin Meadow	10.12	5.53%
Open Water	Open Water	6.85	3.74%
Meadow	Interlevee Ponded Basin	5.59	3.06%
Mudflat	Upland	5.39	2.95%
Mudflat	Mudflat and Panne	5.23	2.86%
Interlevee Basin Meadow	Upland	3.50	1.91%
Mudflat and Panne	Mudflat and Panne	3.34	1.82%
Open Water	Mudflat	2.67	1.46%
Mudflat and Panne	Eroding Levee Meadow	2.42	1.32%
Mudflat	Open Water	2.09	1.14%
Mudflat and Panne	Interlevee Basin Meadow	1.27	0.69%
Upland	Interlevee Basin Meadow	1.02	0.56%
Upland	Mudflat and Panne	0.86	0.47%
Meadow	Upland	0.80	0.44%
Open Water	Interlevee Basin&Channel Basin	0.75	0.41%
Mudflat and Panne	Mudflat	0.72	0.39%
Interlevee Ponded Basin	Interlevee Ponded Basin	0.64	0.35%
Mudflat	Meadow	0.45	0.24%
Open Water	Interlevee Basin Meadow	0.41	0.22%
Open Water	Mudflat and Panne	0.36	0.20%
Mudflat and Panne	Open Water	0.28	0.15%
Upland	Open Water	0.07	0.04%

Appendix F. Types of landscape formation change from 1980 to 2010 in Silver Salmon Creek salt marsh areas.

Landscape Formation 1980	Landscape Formation 2010	Area (ha)	Percent Area
Upland	Upland	32.49	17.75%
Interlevee Basin Meadow	Interlevee Basin Meadow	28.84	15.75%
Mudflat	Mudflat	28.13	15.37%
Meadow	Meadow	26.29	14.36%
Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	13.91	7.60%
Open Water	Mudflat	7.76	4.24%
Interlevee Ponded Basin	Interlevee Ponded Basin	5.87	3.21%
Mudflat and Panne	Mudflat	5.62	3.07%
Upland	Mudflat	4.53	2.47%
Mudflat	Upland	4.35	2.38%
Meadow	Interlevee Ponded Basin	4.05	2.21%
Mudflat	Mudflat and Panne	2.58	1.41%
Mudflat	Open Water	2.15	1.18%
Interlevee Basin Meadow	Mudflat and Panne	2.03	1.11%
Mudflat and Panne	Mudflat and Panne	1.88	1.03%
Interlevee Basin Meadow	Mudflat	1.53	0.84%
Eroding Levee Meadow	Eroding Levee Meadow	1.47	0.81%
Meadow	Upland	1.45	0.79%
Mudflat and Panne	Interlevee Basin Meadow	1.35	0.74%
Open Water	Open Water	1.09	0.59%
Upland	Open Water	0.98	0.53%
Eroding Levee Meadow	Interlevee Basin Meadow	0.95	0.52%
Mudflat	Interlevee Basin Meadow	0.73	0.40%
Interlevee Basin Meadow	Eroding Levee Meadow	0.55	0.30%
Interlevee Basin Meadow	Interlevee Ponded Basin	0.42	0.23%
Interlevee Ponded Basin	Meadow	0.36	0.19%
Mudflat and Panne	Meadow	0.36	0.19%
Mudflat and Panne	Upland	0.33	0.18%

Appendix F (continued). Types of landscape formation change from 1980 to 2010 in Silver Salmon Creek salt marsh areas.

Landscape Formation 1980	Landscape Formation 2010	Area (ha)	Percent Area
Open Water	Mudflat and Panne	0.33	0.18%
Upland	Meadow	0.31	0.17%
Mudflat and Panne	Open Water	0.24	0.13%
Open Water	Interlevee Basin Meadow	0.12	0.06%

Appendix G. Types of landscape formation change from 1950, 1980 and 2010 in Silver Salmon Creek salt marsh areas.

Landscape Formation 50	Landscape Formation 80	Landscape Formation 10	Area (ha)	Percent Area
Meadow	Meadow	Meadow	26.29	14.36%
Upland	Upland	Upland	23.21	12.68%
Interlevee Basin Meadow	Interlevee Basin Meadow	Interlevee Basin Meadow	20.13	11.00%
Mudflat	Mudflat	Mudflat	18.96	10.36%
Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	13.16	7.19%
Mudflat	Interlevee Basin Meadow	Interlevee Basin Meadow	6.93	3.78%
Upland	Mudflat	Mudflat	6.12	3.35%
Open Water	Open Water	Mudflat	5.86	3.20%
Mudflat	Upland	Upland	5.28	2.88%
Meadow	Interlevee Ponded Basin	Interlevee Ponded Basin	5.24	2.86%
Upland	Upland	Mudflat	4.53	2.47%
Upland	Mudflat	Upland	4.35	2.38%
Meadow	Meadow	Interlevee Ponded Basin	3.61	1.97%
Interlevee Basin Meadow	Upland	Upland	3.50	1.91%
Mudflat	Mudflat and Panne	Mudflat	3.22	1.76%
Mudflat	Mudflat	Mudflat and Panne	2.50	1.36%
Open Water	Mudflat	Mudflat	2.34	1.28%
Mudflat and Panne	Mudflat and Panne	Mudflat	2.13	1.16%
Mudflat	Open Water	Mudflat	1.55	0.85%

Appendix G (continued). Types of landscape formation change from 1950, 1980 and 2010 in Silver Salmon Creek salt marsh areas.

Landscape Formation 50	Landscape Formation 80	Landscape Formation 10	Area (ha)	Percent Area
Mudflat	Interlevee Basin Meadow	Mudflat and Panne	1.52	0.83%
Mudflat and Panne	Eroding Levee Meadow	Eroding Levee Meadow	1.47	0.81%
Meadow	Meadow	Upland	1.45	0.79%
Mudflat	Mudflat	Open Water	1.45	0.79%
Mudflat	Mudflat and Panne	Mudflat and Panne	1.27	0.70%
Mudflat	Interlevee Basin Meadow	Mudflat	1.12	0.61%
Upland	Interlevee Basin Meadow	Interlevee Basin Meadow	1.02	0.56%
Mudflat and Panne	Eroding Levee Meadow	Interlevee Basin Meadow	0.95	0.52%
Upland	Upland	Open Water	0.86	0.47%
Mudflat and Panne	Interlevee Basin Meadow	Interlevee Basin Meadow	0.76	0.41%
Open Water	Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	0.75	0.41%
Mudflat and Panne	Mudflat	Mudflat	0.72	0.39%
Mudflat	Mudflat and Panne	Interlevee Basin Meadow	0.66	0.36%
Open Water	Open Water	Open Water	0.66	0.36%
Interlevee Ponded Basin	Interlevee Ponded Basin	Interlevee Ponded Basin	0.64	0.35%
Mudflat and Panne	Mudflat and Panne	Mudflat and Panne	0.61	0.33%
Upland	Mudflat and Panne	Interlevee Basin Meadow	0.60	0.33%
Upland	Mudflat	Open Water	0.58	0.32%
Mudflat	Interlevee Basin Meadow	Eroding Levee Meadow	0.55	0.30%
Mudflat and Panne	Interlevee Basin Meadow	Mudflat and Panne	0.51	0.28%

Appendix G (continued). Types of landscape formation change from 1950, 1980 and 2010 in Silver Salmon Creek salt marsh areas.

Landscape Formation 50	Landscape Formation 80	Landscape Formation 10	Area (ha)	Percent Area
Meadow	Upland	Upland	0.49	0.27%
Upland	Mudflat	Interlevee Basin Meadow	0.46	0.25%
Mudflat	Meadow	Interlevee Ponded Basin	0.45	0.24%
Mudflat	Open Water	Open Water	0.43	0.23%
Interlevee Basin Meadow	Interlevee Basin Meadow	Interlevee Ponded Basin	0.42	0.23%
Open Water	Interlevee Basin Meadow	Mudflat	0.41	0.22%
Meadow	Interlevee Ponded Basin	Meadow	0.36	0.19%
Mudflat and Panne	Mudflat and Panne	Meadow	0.36	0.19%
Meadow	Upland	Meadow	0.31	0.17%
Mudflat and Panne	Open Water	Mudflat	0.28	0.15%
Open Water	Mudflat and Panne	Mudflat	0.27	0.15%
Upland	Mudflat and Panne	Upland	0.26	0.14%
Mudflat and Panne	Mudflat and Panne	Open Water	0.24	0.13%
Open Water	Open Water	Mudflat and Panne	0.21	0.12%
Mudflat	Mudflat	Interlevee Basin Meadow	0.15	0.08%
Open Water	Mudflat	Open Water	0.12	0.07%
Open Water	Mudflat	Interlevee Basin Meadow	0.12	0.07%
Open Water	Open Water	Interlevee Basin Meadow	0.12	0.06%
Mudflat	Upland	Open Water	0.11	0.06%
Mudflat	Open Water	Mudflat and Panne	0.11	0.06%

Appendix G (continued). Types of landscape formation change from 1950, 1980 and 2010 in Silver Salmon Creek salt marsh areas.

Landscape Formation 50	Landscape Formation 80	Landscape Formation 10	Area (ha)	Percent Area
Open Water	Mudflat and Panne	Interlevee Basin Meadow	0.09	0.05%
Open Water	Mudflat	Mudflat and Panne	0.08	0.05%
Mudflat	Mudflat and Panne	Upland	0.07	0.04%
Upland	Open Water	Mudflat	0.07	0.04%

Appendix H. Summary of landscape formation area per year for 2010 in Silver Salmon Creek salt marsh areas.

	1950		1980		2010	
Landscape Formation	**Area (ha)**	**Percent Area**	**Area (ha)**	**Percent Area**	**Area (ha)**	**Percent Area**
Mudflat	46.34	25.31%	37.95	20.73%	47.57	25.99%
Upland	42.06	22.97%	38.30	20.92%	38.62	21.10%
Interlevee Basin Meadow	24.06	13.14%	33.37	18.23%	31.99	17.48%
Meadow	37.74	20.62%	31.79	17.37%	27.31	14.92%
Interlevee Basin&Channel Basin	13.16	7.19%	13.91	7.60%	13.91	7.60%
Interlevee Ponded Basin	0.64	0.35%	6.23	3.40%	10.35	5.65%
Mudflat and Panne	8.03	4.38%	9.79	5.35%	6.82	3.73%
Open Water	11.04	6.03%	9.29	5.07%	4.46	2.44%
Eroding Levee Meadow	--	--	2.42	1.32%	2.03	1.11%

-- no data, not applicable

Appendix I. Types of land change from 1950, 1980, and 2010 in Silver Salmon Creek salt marsh areas.

Change Code from 1950 to 1980	Change Code from 1980 to 2010	Area (ha)	Percent Area
No Change	No Change	109.68	59.92%
Vegetation Development/Expansion in Intertidal Area	No Change	18.60	10.16%
Vegetation Loss/Decrease in Intertidal Area	No Change	6.84	3.74%
No Change	Vegetation Loss/Decrease in Intertidal Area	6.66	3.64%
Vegetation Loss/Decrease in Intertidal Area	Vegetation Development/Expansion in Intertidal Area	5.44	2.97%
Wetland Creation	No Change	5.24	2.86%
No Change	Vegetation Development/Expansion in Intertidal Area	4.45	2.43%
No Change	Mixed Forest Establishment	4.24	2.31%
No Change	Wetland Creation	3.61	1.97%
Vegetation Development/Expansion in Intertidal Area	Vegetation Loss/Decrease in Intertidal Area	3.49	1.91%
Channel Abandonment	No Change	3.26	1.78%
No Change	Channel Formation	2.56	1.40%
Channel Formation	Channel Abandonment	2.01	1.10%
No Change	Channel Abandonment	1.95	1.07%
Vegetation Development/Expansion in Intertidal Area	Vegetation Development/Expansion in Intertidal Area	1.69	0.92%
Vegetation Loss/Decrease in Intertidal Area	Channel Formation	0.58	0.32%
Channel Abandonment	Vegetation Loss/Decrease in Intertidal Area	0.51	0.28%
Spruce Establishment/Expansion	No Change	0.49	0.27%
Vegetation Development/Expansion in Intertidal Area	Wetland Creation	0.45	0.24%

Appendix I (continued). Types of land change from 1950, 1980, and 2010 in Silver Salmon Creek salt marsh areas.

Change Code from 1950 to 1980	Change Code from 1980 to 2010	Area (ha)	Percent Area
Channel Formation	No Change	0.43	0.23%
Wetland Creation	Vegetation Development/Expansion in Intertidal Area	0.36	0.19%
Channel Abandonment	Vegetation Development/Expansion in Intertidal Area	0.29	0.16%
Channel Abandonment	Channel Formation	0.12	0.07%
Vegetation Development/Expansion in Intertidal Area	Channel Formation	0.11	0.06%

Appendix J. Summary of land change from 1950 to 1980 and from 1980 to 2010 in Silver Salmon Creek salt marsh areas.

	1950 - 1980		1980 - 2010	
Change Code	**Area (ha)**	**Percent Area**	**Area (ha)**	**Percent Area**
No Change	133.15	72.73%	144.54	78.96%
Vegetation Development/Expansion in Intertidal Area	24.34	13.29%	12.24	6.68%
Vegetation Loss/Decrease in Intertidal Area	12.86	7.03%	10.65	5.82%
Mixed Forest Establishment	-	-	4.24	2.31%
Wetland Creation	5.59	3.06%	4.05	2.21%
Channel Abandonment	4.19	2.29%	3.97	2.17%
Channel Formation	2.44	1.33%	3.37	1.84%
Spruce Establishment/Expansion	0.49	0.27%	--	--

-- no data, not applicable

Appendix K. Types of physiographic change from 1950 to 1980 in Chinitna Bay South West salt marsh areas.

Physiography 1950	Physiography 1980	Area (ha)	Percent Area
Coastal High Marsh	Coastal High Marsh	363.47	41.98%
Barren	Barren	145.10	16.76%
Barren	Coastal Low Marsh	107.32	12.40%
Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	93.33	10.78%
Coastal Mid Marsh	Coastal Mid Marsh	56.39	6.51%
Costal Low Marsh	Costal Low Marsh	50.4	5.82%
Upland	Upland	24.28	2.80%
Barren	Coastal Low & Mid Marsh	13.14	1.52%
Ocean	Ocean	4.93	0.57%
Coastal Low & Mid Marsh	Coastal Mid Marsh	4.13	0.48%
Coastal High Marsh	Barren	3.27	0.30%

Appendix L. Types of physiographic change from 1980 to 2010 in Chinitna Bay South West salt marsh areas.

Physiography 1980	Physiography 2010	Area (ha)	Percent Area
Coastal High Marsh	Coastal High Marsh	350.21	40.45%
Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	106.47	12.30%
Coastal Low Marsh	Coastal Low & Mid Marsh	93.23	10.77%
Barren	Barren	71.97	8.31%
Barren	Coastal Low & Mid Marsh	64.93	7.50%
Coastal Low Marsh	Coastal Low Marsh	60.90	7.03%
Coastal Mid Marsh	Coastal Mid Marsh	57.79	6.68%
Upland	Upland	24.28	2.80%
Coastal High Marsh	Barren	10.64	1.23%
Barren	Coastal Low Marsh	8.19	0.90%
Ocean	Ocean	4.93	0.57%
Coastal Mid Marsh	Coastal High Marsh	3.72	0.43%
Coastal Low Marsh	Coastal Mid Marsh	3.59	0.42%
Barren	Coastal High Marsh	3.27	0.38%
Coastal High Marsh	Upland	2.62	0.30%

Appendix M. Types of physiographic change for all three year classes 1950, 1980, and 2010 in Chinitna Bay South West salt marsh areas.

Physiography 1950	Physiography 1980	Physiography 2010	Area (ha)	Percent Area
Coastal High Marsh	Coastal High Marsh	Coastal High Marsh	350.21	40.45%
Coastal Low & Mid Basin	Coastal Low & Mid Basin	Coastal Low & Mid Marsh	93.33	10.63%
Barren	Coastal Low Marsh	Coastal Low & Mid Marsh	78.87	9.11%
Barren	Barren	Barren	71.97	8.31%
Barren	Barren	Coastal Low & Mid Marsh	64.93	7.23%
Coastal Mid Marsh	Coastal Mid Marsh	Coastal High Marsh	56.39	6.51%
Coastal Low Marsh	Coastal Low Marsh	Coastal Low Marsh	36.05	4.16%
Barren	Coastal Low Marsh	Coastal Low Marsh	24.85	2.87%
Upland	Upland	Upland	24.28	2.80%
Coastal Low Marsh	Coastal Low Marsh	Coastal Low & Mid Marsh	14.35	1.66%
Barren	Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	13.14	1.49%
Coastal High Marsh	Coastal High Marsh	Barren	10.64	1.23%
Barren	Barren	Coastal Low Marsh	8.19	0.95%
Coastal Low & Mid Marsh	Coastal Mid Marsh	Coastal Mid Marsh	4.13	0.48%
Barren	Coastal Low Marsh	Coastal Mid Marsh	3.59	0.46%
Coastal High Marsh	Barren	Coastal High Marsh	3.27	0.38%
Coastal High Marsh	Coastal High Marsh	Upland	2.62	0.30%
Ocean	Ocean	Ocean	4.93	0.30%

Appendix N. Summary of physiographic area per year for 1950, 1980, and 2010 in Chinitna Bay South West salt marsh areas.

	1950		1980		2010	
Physiography	**Area (ha)**	**Percent Area**	**Area (ha)**	**Percent Area**	**Area (ha)**	**Percent Area**
Coastal High Marsh	366.75	42.36%	363.47	41.98%	357.21	41.26%
Coastal Low & Mid Marsh	97.47	11.26%	106.47	12.30%	264.64	30.57%
Barren	265.57	30.67%	148.37	17.14%	82.61	9.54%
Coastal Low Marsh	50.41	5.82%	157.73	18.22%	69.11	7.98%
Coastal Mid Marsh	56.39	6.51%	60.53	6.99%	60.41	6.98%
Upland	24.28	2.80%	24.28	2.80%	26.91	3.11%
Ocean	4.93	0.57%	4.93	0.57%	4.93	0.57%

Appendix O. Types of physiographic change from 1950 to 1980 in Chinitna Bay North East salt marsh areas.

Physiography 1950	Physiography 1980	Area (ha)	Percent Area
Coastal High Marsh	Coastal High Marsh	47.6	39.62%
Barren	Barren	19.3	16.06%
Barren	Coastal Low Marsh	11.07	9.22%
Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	9.71	8.09%
Coastal Mid Marsh	Coastal Mid Marsh	8.26	6.88%
Ocean	Ocean	5.27	4.39%
Coastal Low Marsh	Coastal Low & Mid Marsh	4.53	3.77%
Barren	Coastal Low & Mid Marsh	4.41	3.66%
Upland	Upland	3.71	3.09%
Coastal Low Marsh	Coastal Low Marsh	1.82	1.48%
Coastal Low Marsh	Ocean	1.27	1.02%
Barren	Ocean	1.35	0.84%
Barren	Coastal Mid Marsh	0.46	0.39%
Coastal Low Marsh	Barren	0.39	0.33%
Coastal Low Marsh	Coastal Mid Marsh	0.34	0.29%
Coastal Low Marsh	Coastal High Marsh	0.15	0.13%
Coastal High Marsh	Barren	0.16	0.11%
Barren	Coastal High Marsh	0.13	0.11%
Coastal High Marsh	Coastal Mid Marsh	0.09	0.08%
Coastal Low & Mid Marsh	Barren	0.03	0.03%

Appendix P. Types of physiographic change from 1980 to 2010 in Chinitna Bay North East salt marsh areas.

Physiography 1980	Physiography 2010	Area (ha)	Percent Area
Coastal High Marsh	Coastal High Marsh	42.11	35.04%
Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	17.19	14.31%
Barren	Barren	11.81	9.83%
Coastal Low Marsh	Coastal Low Marsh	11.76	9.79%
Coastal High Marsh	Upland	5.69	4.74%
Coastal Mid Marsh	Coastal High Marsh	5.62	4.68%
Ocean	Ocean	5.27	4.39%
Upland	Upland	3.71	3.09%
Coastal Mid Marsh	Upland	3.21	2.67%
Barren	Coastal Low Marsh	3.13	2.61%
Barren	Coastal Low & Mid Marsh	2.81	2.34%
Ocean	Barren	1.61	1.33%
Barren	Ocean	1.27	1.06%
Coastal Low & Mid Marsh	Barren	1.23	1.02%
Coastal Low Marsh	Barren	1.13	0.95%
Ocean	Coastal Low & Mid Marsh	0.81	0.68%
Barren	Coastal Low Marsh	0.44	0.37%
Barren	Upland	0.43	0.36%
Coastal Mid Marsh	Barren	0.34	0.29%
Coastal Low & Mid Marsh	Coastal Low Marsh	0.22	0.19%
Ocean	Coastal Low Marsh	0.21	0.17%
Coastal High Marsh	Coastal Mid Marsh	0.09	0.08%

Appendix Q. Types of physiographic change for all three year classes 1950, 1980, and 2010 in Chinitna Bay North East salt marsh areas.

Physiography 1950	Physiography 1980	Physiography 2010	Area (ha)	Percent Area
Coastal High Marsh	Coastal High Marsh	Coastal High Marsh	41.81	34.80%
Barren	Barren	Barren	11.67	9.72%
Barren	Coastal Low Marsh	Coastal Low Marsh	11.07	9.22%
Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	9.71	8.09%
Coastal High Marsh	Coastal High Marsh	Upland	5.69	4.74%
Ocean	Ocean	Ocean	5.27	4.39%
Coastal Mid Marsh	Coastal Mid Marsh	Coastal Mid Marsh	5.03	4.19%
Barren	Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	4.08	3.40%
Upland	Upland	Upland	3.71	3.09%
Barren	Barren	Coastal Low Marsh	3.58	2.98%
Coastal Low Marsh	Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	3.39	2.83%
Coastal Mid Marsh	Coastal Mid Marsh	Upland	2.85	2.38%
Barren	Barren	Coastal Low & Mid Marsh	2.77	2.31%
Barren	Ocean	Barren	1.35	1.13%
Barren	Barren	Ocean	1.27	1.06%
Coastal Low Marsh	Coastal Low & Mid Marsh	Barren	1.14	0.95%
Coastal Low Marsh	Coastal Low Marsh	Barren	1.13	0.95%
Coastal Low Marsh	Ocean	Coastal Low & Mid Marsh	0.81	0.68%
Coastal Low Marsh	Coastal Low Marsh	Coastal Low Marsh	0.69	0.58%

Appendix Q (continued). Types of physiographic change for all three year classes 1950, 1980, and 2010 in Chinitna Bay North East salt marsh areas.

Physiography 1950	Physiography 1980	Physiography 2010	Area (ha)	Percent Area
Barren	Coastal Mid Marsh	Coastal Mid Marsh	0.46	0.39%
Coastal Low Marsh	Barren	Upland	0.39	0.33%
Coastal Low Marsh	Coastal Mid Marsh	Upland	0.34	0.29%
Coastal Mid Marsh	Coastal Mid Marsh	Barren	0.34	0.29%
Coastal Low Marsh	Ocean	Barren	0.24	0.21%
Barren	Coastal Low & Mid Marsh	Coastal Low Marsh	0.22	0.19%
Coastal Low Marsh	Ocean	Coastal Low Marsh	0.21	0.17%
Coastal Low Marsh	Coastal High Marsh	Coastal High Marsh	0.15	0.13%
Coastal High Marsh	Barren	Barren	0.13	0.11%
Barren	Coastal High Marsh	Coastal High Marsh	0.13	0.11%
Coastal High Marsh	Coastal Mid Marsh	Coastal Mid Marsh	0.09	0.08%
Coastal High Marsh	Coastal High Marsh	Coastal Mid Marsh	0.09	0.08%
Barren	Coastal Low & Mid Marsh	Barren	0.09	0.08%
Coastal Low & Mid Marsh	Barren	Coastal Low & Mid Marsh	0.03	0.03%
Coastal High Marsh	Barren	Upland	0.03	0.03%
Coastal Mid Marsh	Coastal Mid Marsh	Coastal High Marsh	0.02	0.02%

Appendix R. Summary of physiographic area per year for 1950, 1980, and 2010 in Chinitna Bay North East salt marsh areas.

	1950		1980		2010	
Physiography	**Area (ha)**	**Percent Area**	**Area (ha)**	**Percent Area**	**Area (ha)**	**Percent Area**
Coastal High Marsh	47.87	39.85%	47.89	39.86%	42.12	35.06%
Coastal Low & Mid Marsh	9.75	8.12%	18.65	15.52%	20.82	17.33%
Barren	36.73	30.57%	19.91	16.57%	16.13	13.43%
Coastal Low Marsh	7.64	6.36%	12.89	10.74%	14.45	12.02%
Upland	3.71	3.09%	3.71	3.09%	13.04	10.86%
Coastal Mid Marsh	9.16	7.63%	9.17	7.64%	7.03	5.86%
Ocean	5.27	4.39%	7.89	6.57%	6.54	5.44%

Appendix S. Types of landscape formation change from 1950 to 1980 in Chinitna Bay South West salt marsh areas.

Landscape Formation 1950	Landscape Formation 1980	Area (ha)	Percent Area
Meadow	Meadow	222.19	25.66%
Mudflat	Mudflat	145.10	16.76%
Interlevee Ponded Basin	Interlevee Ponded Basin	117.45	13.57%
Mudflat	Mudflat and Panne	107.33	12.40%
Levee Meadow	Levee Meadow	93.80	10.83%
Pond or Lake	Pond or Lake	28.78	3.32%
Unconsolidated Shore	Unconsolidated Shore	28.56	3.30%
Interlevee Ponded Basin	Meadow	26.05	3.01%
Upland	Upland	24.28	2.80%
Unconsolidated Shore	Mudflat and Panne	21.84	2.52%
Meadow	Interlevee Ponded Basin	16.22	1.87%
Mudflat	Interlevee Ponded Basin	13.14	1.52%
Open Water	Open Water	4.94	0.57%
Meadow	Pond or Lake	4.74	0.55%
Interlevee Pond	Interlevee Pond	3.49	0.40%
Pond or Lake	Mudflat	3.28	0.38%
Interlevee Ponded Basin	Pond or Lake	2.50	0.29%
Meadow	Levee Meadow	2.14	0.25%

Appendix T. Types of landscape formation change from 1980 to 2010 in Chinitna Bay South West salt marsh areas.

Landscape Formation 1980	Landscape Formation 2010	Area (ha)	Percent Area
Meadow	Meadow	233.09	26.92%
Interlevee Ponded Basin	Interlevee Ponded Basin	111.75	12.91%
Levee Meadow	Levee Meadow	92.27	10.66%
Mudflat	Mudflat	71.97	8.31%
Mudflat	Interlevee Ponded Basin	68.21	7.88%
Mudflat and Panne	Interlevee Ponded Basin	65.14	7.52%
Mudflat and Panne	Mudflat and Panne	39.20	4.53%
Interlevee Ponded Basin	Meadow	33.23	3.84%
Upland	Upland	24.28	2.80%
Mudflat and Panne	Meadow	21.23	2.45%
Pond or Lake	Pond or Lake	17.76	2.05%
Unconsolidated Shore	Mudflat and Panne	13.89	1.60%
Meadow	Levee Meadow	12.99	1.50%
Pond or Lake	Mudflat	10.65	1.23%
Mudflat	Mudflat and Panne	8.20	0.95%
Unconsolidated Shore	Unconsolidated Shore	7.82	0.90%
Pond or Lake	Meadow	7.61	0.88%
Unconsolidated Shore	Interlevee Ponded Basin	6.86	0.79%
Open Water	Open Water	4.94	0.57%
Mudflat and Panne	Levee Meadow	3.60	0.42%
Interlevee Pond	Interlevee Pond	3.04	0.35%
Levee Meadow	Upland	2.62	0.30%
Interlevee Ponded Basin	Pond or Lake	1.50	0.17%
Meadow	Interlevee Ponded Basin	1.15	0.13%
Levee Meadow	Meadow	1.04	0.12%
Meadow	Pond or Lake	0.90	0.10%
Interlevee Pond	Interlevee Ponded Basin	0.45	0.05%
Interlevee Ponded Basin	Interlevee Pond	0.33	0.04%
Meadow	Interlevee Pond	0.11	0.01%

Appendix U. Types of landscape formation change from 1950, 1980 and 2010 in Chinitna Bay South West salt marsh areas.

Landscape Formation 1950	Landscape Formation 1980	Landscape Formation 2010	Area (ha)	Percent Area
Meadow	Meadow	Meadow	207.04	23.91%
Interlevee Ponded Basin	Interlevee Ponded Basin	Interlevee Ponded Basin	90.29	10.43%
Levee Meadow	Levee Meadow	Levee Meadow	90.14	10.41%
Mudflat	Mudflat	Mudflat	71.97	8.31%
Mudflat	Mudflat and Panne	Interlevee Ponded Basin	65.14	7.52%
Mudflat	Mudflat	Interlevee Ponded Basin	64.93	7.50%
Interlevee Ponded Basin	Interlevee Ponded Basin	Meadow	26.22	3.03%
Interlevee Ponded Basin	Meadow	Meadow	26.05	3.01%
Mudflat	Mudflat and Panne	Mudflat and Panne	24.85	2.87%
Upland	Upland	Upland	24.28	2.80%
Meadow	Interlevee Ponded Basin	Interlevee Ponded Basin	15.01	1.73%
Unconsolidated Shore	Mudflat and Panne	Mudflat and Panne	14.35	1.66%
Unconsolidated Shore	Unconsolidated Shore	Mudflat and Panne	13.89	1.60%
Mudflat	Mudflat and Panne	Meadow	13.74	1.59%
Meadow	Meadow	Levee Meadow	12.99	1.50%
Pond or Lake	Pond or Lake	Pond or Lake	10.84	1.25%
Pond or Lake	Pond or Lake	Mudflat	10.65	1.23%
Mudflat	Mudflat	Mudflat and Panne	8.20	0.95%
Unconsolidated Shore	Unconsolidated Shore	Unconsolidated Shore	7.82	0.90%

Appendix U (continued). Types of landscape formation change from 1950, 1980 and 2010 in Chinitna Bay South West salt marsh areas.

Landscape Formation 1950	Landscape Formation 1980	Landscape Formation 2010	Area (ha)	Percent Area
Unconsolidated Shore	Mudflat and Panne	Meadow	7.49	0.86%
Pond or Lake	Pond or Lake	Meadow	7.29	0.84%
Unconsolidated Shore	Unconsolidated Shore	Interlevee Ponded Basin	6.86	0.79%
Mudflat	Interlevee Ponded Basin	Meadow	6.69	0.77%
Mudflat	Interlevee Ponded Basin	Interlevee Ponded Basin	6.45	0.74%
Open Water	Open Water	Open Water	4.94	0.57%
Meadow	Pond or Lake	Pond or Lake	4.74	0.55%
Mudflat	Mudflat and Panne	Levee Meadow	3.60	0.42%
Pond or Lake	Mudflat	Interlevee Ponded Basin	3.28	0.38%
Interlevee Pond	Interlevee Pond	Interlevee Pond	3.04	0.35%
Levee Meadow	Levee Meadow	Upland	2.62	0.30%
Interlevee Ponded Basin	Pond or Lake	Pond or Lake	2.18	0.25%
Meadow	Levee Meadow	Levee Meadow	2.14	0.25%
Meadow	Meadow	Interlevee Ponded Basin	1.15	0.13%
Levee Meadow	Levee Meadow	Meadow	1.04	0.12%
Meadow	Meadow	Pond or Lake	0.90	0.10%
Meadow	Interlevee Ponded Basin	Pond or Lake	0.89	0.10%
Interlevee Ponded Basin	Interlevee Ponded Basin	Pond or Lake	0.61	0.07%
Interlevee Pond	Interlevee Pond	Interlevee Ponded Basin	0.45	0.05%
Interlevee Ponded Basin	Interlevee Ponded Basin	Interlevee Pond	0.33	0.04%

Appendix U (continued). Types of landscape formation change from 1950, 1980 and 2010 in Chinitna Bay South West salt marsh areas.

Landscape Formation 1950	Landscape Formation 1980	Landscape Formation 2010	Area (ha)	Percent Area
Meadow	Interlevee Ponded Basin	Meadow	0.32	0.04%
Interlevee Ponded Basin	Pond or Lake	Meadow	0.32	0.04%
Meadow	Meadow	Interlevee Pond	0.11	0.01%

Appendix V. Landscape formation area per year for 1950, 1980, and 2010 in Chinitna Bay South West salt marsh areas.

	1950		1980		2010	
Landscape Formation	**Area (ha)**	**Percent Area**	**Area (ha)**	**Percent Area**	**Area (ha)**	**Percent Area**
Meadow	245.28	28.33%	248.23	28.67%	296.19	34.21%
Interlevee Ponded Basin	146.00	16.86%	146.82	16.96%	253.56	29.29%
Levee Meadow	93.80	10.83%	95.93	11.08%	108.86	12.57%
Mudflat	265.57	30.67%	148.38	17.14%	82.62	9.54%
Mudflat and Panne	--	--	129.17	14.92%	61.28	7.08%
Upland	24.28	2.80%	24.28	2.80%	26.90	3.11%
Pond or Lake	32.06	3.70%	36.02	4.16%	20.17	2.33%
Unconsolidated Shore	50.40	5.82%	28.56	3.30%	7.82	0.90%
Open Water	4.94	0.57%	4.94	0.57%	4.94	0.57%
Interlevee Pond	3.49	0.40%	3.49	0.40%	3.48	0.40%

-- No data, not applicable

Appendix W. Types of landscape formation change from 1950 to 1980 in Chinitna Bay North East salt marsh areas.

Landscape Formation 1950	Landscape Formation 1980	Area (ha)	Percent Area
Levee Meadow	Levee Meadow	21.58	17.96%
Meadow	Meadow	20.36	16.95%
Mudflat	Mudflat	19.31	16.07%
Mudflat	Mudflat and Panne	11.08	9.22%
Interlevee Ponded Basin	Interlevee Ponded Basin	10.75	8.95%
Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	9.28	7.72%
Open Water	Open Water	5.27	4.39%
Mudflat	Interlevee Basin&Channel Basin	4.87	4.05%
Mudflat and Panne	Interlevee Basin&Channel Basin	4.69	3.90%
Upland	Upland	3.71	3.09%
Interlevee Ponded Basin	Interlevee Pond	2.22	1.85%
Mudflat	Open Water	1.36	1.13%
Mudflat and Panne	Open Water	1.27	1.06%
Mudflat and Panne	Mudflat and Panne	1.14	0.95%
Interlevee Basin Meadow	Interlevee Basin Meadow	0.87	0.72%
Interlevee Ponded Basin	Interlevee Basin&Channel Basin	0.87	0.72%
Mudflat and Panne	Mudflat	0.40	0.33%
Mudflat and Panne	Meadow	0.35	0.29%
Levee Meadow	Interlevee Pond	0.28	0.23%
Meadow	Mudflat	0.20	0.17%
Mudflat	Interlevee Ponded Basin	0.13	0.11%
Interlevee Basin&Channel Basin	Interlevee Pond	0.07	0.06%
Interlevee Basin&Channel Basin	Interlevee Basin Meadow	0.06	0.05%
Interlevee Basin&Channel Basin	Meadow	0.05	0.04%

Appendix X. Types of landscape formation changes from 1980 to 2010 in Chinitna Bay North East salt marsh areas.

Landscape Formation 1980	Landscape Formation 2010	Area (ha)	Percent Area
Levee Meadow	Levee Meadow	21.58	17.96%
Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	18.42	15.33%
Meadow	Meadow	12.33	10.26%
Mudflat	Mudflat	11.82	9.83%
Interlevee Ponded Basin	Interlevee Ponded Basin	7.92	6.59%
Meadow	Upland	7.82	6.51%
Mudflat and Panne	Interlevee Basin&Channel Basin	6.94	5.77%
Open Water	Open Water	5.27	4.39%
Mudflat	Interlevee Basin&Channel Basin	4.14	3.45%
Mudflat and Panne	Mudflat and Panne	4.14	3.44%
Upland	Upland	3.71	3.09%
Interlevee Ponded Basin	Interlevee Basin&Channel Basin	2.11	1.76%
Interlevee Pond	Interlevee Pond	1.81	1.51%
Open Water	Mudflat	1.60	1.33%
Mudflat	Levee Meadow	1.34	1.11%
Mudflat	Open Water	1.27	1.06%
Interlevee Basin&Channel Basin	Mudflat	1.23	1.02%
Mudflat and Panne	Mudflat	1.14	0.95%
Open Water	Interlevee Basin&Channel Basin	1.02	0.85%
Mudflat	Mudflat and Panne	0.91	0.76%
Interlevee Basin Meadow	Interlevee Basin Meadow	0.87	0.72%
Interlevee Ponded Basin	Levee Meadow	0.67	0.56%
Interlevee Pond	Interlevee Ponded Basin	0.48	0.40%
Mudflat	Upland	0.43	0.36%
Meadow	Mudflat	0.34	0.29%
Interlevee Pond	Interlevee Basin&Channel Basin	0.28	0.23%
Meadow	Interlevee Ponded Basin	0.26	0.22%
Interlevee Ponded Basin	Interlevee Pond	0.18	0.15%

Appendix X (continued). Types of landscape formation changes from 1980 to 2010 in Chinitna Bay North East salt marsh areas.

Landscape Formation 1980	Landscape Formation 2010	Area (ha)	Percent Area
Interlevee Basin Meadow	Meadow	0.06	0.05%
Interlevee Basin&Channel Basin	Interlevee Pond	0.06	0.05%

Appendix Y. Types of landscape formation change from 1950, 1980 and 2010 in Chinitna Bay North East salt marsh areas.

Landscape Formation 1950	Landscape Formation 1980	Landscape Formation 2010	Area (ha)	Percent Area
Levee Meadow	Levee Meadow	Levee Meadow	21.58	17.96%
Meadow	Meadow	Meadow	11.94	9.94%
Mudflat	Mudflat	Mudflat	11.68	9.72%
Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	9.23	7.68%
Meadow	Meadow	Upland	7.82	6.51%
Interlevee Ponded Basin	Interlevee Ponded Basin	Interlevee Ponded Basin	7.79	6.48%
Mudflat	Mudflat and Panne	Interlevee Basin&Channel Basin	6.94	5.77%
Open Water	Open Water	Open Water	5.27	4.39%
Mudflat	Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	4.78	3.97%
Mudflat	Mudflat and Panne	Mudflat and Panne	4.14	3.44%
Mudflat	Mudflat	Interlevee Basin&Channel Basin	4.11	3.42%
Upland	Upland	Upland	3.71	3.09%
Mudflat and Panne	Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	3.55	2.95%
Interlevee Ponded Basin	Interlevee Ponded Basin	Interlevee Basin&Channel Basin	2.11	1.76%
Interlevee Ponded Basin	Interlevee Pond	Interlevee Pond	1.57	1.31%
Mudflat	Open Water	Mudflat	1.36	1.13%
Mudflat	Mudflat	Levee Meadow	1.34	1.11%
Mudflat	Mudflat	Open Water	1.27	1.06%
Mudflat and Panne	Interlevee Basin&Channel Basin	Mudflat	1.14	0.95%

Appendix Y (continued). Types of landscape formation change from 1950, 1980 and 2010 in Chinitna Bay North East salt marsh areas.

Landscape Formation 1950	Landscape Formation 1980	Landscape Formation 2010	Area (ha)	Percent Area
Mudflat and Panne	Mudflat and Panne	Mudflat	1.14	0.95%
Mudflat and Panne	Open Water	Interlevee Basin&Channel Basin	1.02	0.85%
Mudflat	Mudflat	Mudflat and Panne	0.91	0.76%
Interlevee Basin Meadow	Interlevee Basin Meadow	Interlevee Basin Meadow	0.87	0.72%
Interlevee Ponded Basin	Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	0.87	0.72%
Interlevee Ponded Basin	Interlevee Ponded Basin	Levee Meadow	0.67	0.56%
Interlevee Ponded Basin	Interlevee Pond	Interlevee Ponded Basin	0.48	0.40%
Mudflat and Panne	Mudflat	Upland	0.40	0.33%
Mudflat and Panne	Meadow	Meadow	0.35	0.29%
Meadow	Meadow	Mudflat	0.34	0.29%
Meadow	Meadow	Interlevee Ponded Basin	0.26	0.22%
Mudflat and Panne	Open Water	Mudflat	0.25	0.21%
Levee Meadow	Interlevee Pond	Interlevee Pond	0.20	0.17%
Interlevee Ponded Basin	Interlevee Ponded Basin	Interlevee Pond	0.18	0.15%
Interlevee Ponded Basin	Interlevee Pond	Interlevee Basin&Channel Basin	0.17	0.15%
Meadow	Mudflat	Mudflat	0.14	0.11%
Mudflat	Interlevee Ponded Basin	Interlevee Ponded Basin	0.13	0.11%
Mudflat	Interlevee Basin&Channel Basin	Mudflat	0.09	0.08%
Levee Meadow	Interlevee Pond	Interlevee Basin&Channel Basin	0.08	0.06%
Interlevee Basin&Channel Basin	Interlevee Basin Meadow	Meadow	0.06	0.05%

Appendix Y (continued). Types of landscape formation change from 1950, 1980 and 2010 in Chinitna Bay North East salt marsh areas.

Landscape Formation 1950	Landscape Formation 1980	Landscape Formation 2010	Area (ha)	Percent Area
Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	Interlevee Pond	0.06	0.05%
Interlevee Basin&Channel Basin	Meadow	Meadow	0.05	0.04%
Interlevee Basin&Channel Basin	Interlevee Pond	Interlevee Pond	0.04	0.03%
Meadow	Mudflat	Interlevee Basin&Channel Basin	0.03	0.03%
Meadow	Mudflat	Upland	0.03	0.03%
Interlevee Basin&Channel Basin	Interlevee Pond	Interlevee Basin&Channel Basin	0.03	0.02%

Appendix Z. Landscape formation area per year for 1950, 1980, and 2010 in Chinitna Bay North East salt marsh areas.

	1950		1980		2010	
Landscape Formation	Area (ha)	Percent Area	Area (ha)	Percent Area	Area (ha)	Percent Area
Interlevee Basin&Channel Basin	9.46	7.87%	19.70	16.40%	32.91	27.39%
Levee Meadow	21.85	18.19%	21.58	17.96%	23.58	19.63%
Mudflat	36.74	30.57%	19.91	16.57%	16.14	13.43%
Meadow	20.57	17.12%	20.76	17.27%	12.39	10.31%
Upland	3.71	3.09%	3.71	3.09%	11.97	9.96%
Interlevee Ponded Basin	13.84	11.52%	10.88	9.06%	8.66	7.21%
Open Water	5.27	4.39%	7.90	6.57%	6.54	5.44%
Mudflat and Panne	7.85	6.53%	12.22	10.17%	5.05	4.20%
Interlevee Pond	--	--	2.57	2.14%	2.05	1.70%
Interlevee Basin Meadow	0.87	0.72%	0.93	0.77%	0.87	0.72%

-- No data, not applicable

Appendix AA. Types of land change from 1950 to 1980, and from 1980 to 2010 in Chinitna Bay South West.

Change Code from 1950 to 1980	Change Code from 1980 to 2010	Area (ha)	Percent Area
No Change	No Change	545.14	62.96%
No Change	Wetland Creation	66.08	7.63%
Vegetation Development/Expansion in Intertidal Area	Wetland Creation	65.14	7.52%
Vegetation Development/Expansion in Intertidal Area	No Change	42.80	4.94%
No Change	Vegetation Development/Expansion in Intertidal Area	29.31	3.39%
Wetland Loss	No Change	26.05	3.01%
Vegetation Development/Expansion in Intertidal Area	Vegetation Development/Expansion in Intertidal Area	21.23	2.45%
No Change	Pond Drying	19.64	2.27%
No Change	Wetland Loss	17.29	2.00%
Wetland Creation	No Change	16.85	1.95%
Pond/Lake Formation	No Change	6.92	0.80%
Pond Drying	Wetland Creation	3.28	0.38%
No Change	Spruce Establishment/Expansion	2.62	0.30%
No Change	Pond/Lake Formation	1.95	0.23%
Wetland Creation	Pond/Lake Formation	0.89	0.10%
Wetland Creation	Wetland Loss	0.32	0.04%
Pond/Lake Formation	Pond Drying	0.32	0.04%

Appendix BB. Summary of land change from 1950 to 1980 and from 1980 to 2010 in Chinitna Bay South West salt marsh areas.

	1950 - 1980		1980 - 2010	
Change Code	**Area (ha)**	**Percent Area**	**Area (ha)**	**Percent Area**
No Change	682.03	78.77%	637.75	73.66%
Vegetation Development/Expansion in Intertidal Area	129.17	14.92%	50.54	5.84%
Wetland Loss	26.05	3.01%	17.61	2.03%
Wetland Creation	18.07	2.09%	134.50	15.53%
Pond/Lake Formation	7.24	0.84%	2.84	0.33%
Pond Drying	3.28	0.38%	19.96	2.31%
Spruce Establishment/Expansion	--	--	2.62	0.30%

-- no data, not applicable

Appendix CC. Types of land change from 1950, 1980, and 2010 in Chinitna Bay North East.

Change Code from 1950 to19 80	Change Code from 1980 to 2010	Area (ha)	Percent Area
No Change	No Change	49.70	41.36%
No Change	Mixed Forest Establishment	26.51	22.06%
No Change	Vegetation Development/Expansion in Intertidal Area	11.50	9.57%
Vegetation Development/Expansion in Intertidal Area	No Change	10.46	8.71%
Mixed Forest Establishment	No Change	8.41	7.00%
Vegetation Development/Expansion in Intertidal Area	Vegetation Development/Expansion in Intertidal Area	7.28	6.06%
Vegetation Development/Expansion in Intertidal Area	Mixed Forest Establishment	3.23	2.69%
Mixed Forest Establishment	Mixed Forest Establishment	2.33	1.94%
Mixed Forest Establishment	Vegetation Development/Expansion in Intertidal Area	0.64	0.53%
Aquatic Bed Formation/Expansion in Palustrine Area	No Change	0.10	0.08%

Appendix DD. Summary of land change from 1950 to 1980 and from 1980 to 2010 in Chinitna Bay North East salt marsh areas.

	1950 - 1980		1980 - 2010	
Change Code	**Area (ha)**	**Percent Area**	**Area (ha)**	**Percent Area**
No Change	87.71	72.99%	68.67	57.15%
Vegetation Development/Expansion in Intertidal Area	20.98	17.46%	32.07	26.69%
Mixed Forest Establishment	11.37	9.46%	19.43	16.17%
Aquatic Bed Formation/Expansion in Palustrine Area	0.10	0.08%	--	--

-- no data, not applicable

Appendix EE. Types of physiographic change from 1950 to 1980 in Shelter Creek salt marsh areas.

Physiography 1950	Physiography 1980	Area (ha)	Percent Area
Upland	Upland	138.99	43.19%
Coastal Mid Marsh	Coastal Mid Marsh	66.81	20.76%
Coastal High Marsh	Coastal High Marsh	35.11	10.91%
Barren	Barren	23.68	7.34%
Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	15.27	4.75%
Ocean	Ocean	13.36	4.15%
Coastal Mid Marsh	Coastal Low & Mid Marsh	7.81	2.43%
Coastal High Marsh	Coastal Mid Marsh	4.01	1.25%
Coastal Mid Marsh	Coastal High Marsh	2.66	0.83%
Coastal High Marsh	Coastal Low & Mid Marsh	2.65	0.83%
Barren	Coastal Low Marsh	2.46	0.77%
Coastal High Marsh	Upland	1.42	0.44%
Barren	Coastal Low & Mid Marsh	1.42	0.44%
Barren	Ocean	1.41	0.44%
Coastal Low & Mid Marsh	Coastal Mid Marsh	0.96	0.30%
Coastal Mid Marsh	Upland	0.91	0.28%
Ocean	Barren	0.85	0.27%
Upland	Barren	0.77	0.24%
Ocean	Coastal Low & Mid Marsh	0.44	0.14%
Ocean	Coastal Mid Marsh	0.35	0.11%
Upland	Coastal Low & Mid Marsh	0.22	0.07%
Ocean	Coastal Low Marsh	0.11	0.03%
Coastal Low & Mid Marsh	Barren	0.07	0.02%
Coastal Low & Mid Marsh	Coastal Low Marsh	0.03	0.01%

Appendix FF. Types of physiographic changes from 1980 to 2010 in Shelter Creek salt marsh areas.

Physiography 1980	Physiography 2010	Area (ha)	Percent Area
Upland	Upland	140.71	43.72%
Coastal Mid Marsh	Coastal Mid Marsh	66.24	20.58%
Coastal High Marsh	Coastal High Marsh	33.47	10.40%
Barren	Barren	22.86	7.11%
Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	20.69	6.43%
Ocean	Ocean	9.64	3.00%
Coastal Mid Marsh	Upland	5.66	1.76%
Coastal Low & Mid Marsh	Coastal Mid Marsh	4.59	1.43%
Coastal High Marsh	Upland	4.11	1.28%
Ocean	Barren	2.64	0.82%
Barren	Coastal Low Marsh	1.77	0.55%
Ocean	Coastal Low Marsh	1.58	0.49%
Coastal Low Marsh	Coastal Low & Mid Marsh	1.34	0.42%
Coastal Low Marsh	Coastal Low Marsh	1.05	0.33%
Coastal Low & Mid Marsh	Ocean	1.03	0.32%
Coastal Low & Mid Marsh	Upland	0.91	0.28%
Ocean	Coastal Mid Marsh	0.88	0.27%
Barren	Ocean	0.83	0.26%
Coastal Low & Mid Marsh	Coastal High Marsh	0.61	0.19%
Upland	Upland	0.45	0.14%
Coastal Mid Marsh	Ocean	0.23	0.07%
Upland	Coastal High Marsh	0.16	0.05%
Coastal Low Marsh	Upland	0.16	0.05%
Coastal High Marsh	Coastal Low & Mid Marsh	0.11	0.03%
Coastal Low Marsh	Ocean	0.03	0.01%
Coastal Low Marsh	Coastal Mid Marsh	0.01	0.01%

Appendix GG. Types of physiographic change for year classes 1950, 1980, and 2010 in Shelter Creek.

Physiography 1950	Physiography 1980	Physiography 2010	Area (ha)	Percent Area
Upland	Upland	Upland	138.37	43.00%
Coastal Mid Marsh	Coastal Mid Marsh	Coastal Mid Marsh	60.91	18.92%
Coastal High Marsh	Coastal High Marsh	Coastal High Marsh	31.36	9.75%
Barren	Barren	Barren	21.91	6.81%
Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	11.52	3.58%
Ocean	Ocean	Ocean	8.24	2.56%
Coastal Mid Marsh	Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	7.43	2.31%
Coastal Mid Marsh	Coastal Mid Marsh	Upland	5.66	1.76%
Coastal High Marsh	Coastal Mid Marsh	Coastal Mid Marsh	4.01	1.25%
Coastal High Marsh	Coastal High Marsh	Upland	3.64	1.13%
Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	Coastal Mid Marsh	3.21	1.00%
Ocean	Ocean	Barren	2.64	0.82%
Coastal Mid Marsh	Coastal High Marsh	Coastal High Marsh	2.21	0.68%
Ocean	Ocean	Coastal Low Marsh	1.58	0.49%
Coastal High Marsh	Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	1.51	0.47%
Coastal High Marsh	Upland	Upland	1.42	0.44%
Barren	Ocean	Ocean	1.41	0.44%
Barren	Coastal Low Marsh	Coastal Low & Mid Marsh	1.25	0.39%
Barren	Coastal Low Marsh	Coastal Low Marsh	1.05	0.33%

Appendix GG (continued). Types of physiographic change for year classes 1950, 1980, and 2010 in Shelter Creek.

Physiography 1950	Physiography 1980	Physiography 2010	Area (ha)	Percent Area
Barren	Barren	Coastal Low Marsh	1.01	0.32%
Coastal Low & Mid Marsh	Coastal Mid Marsh	Coastal Mid Marsh	0.96	0.30%
Barren	Coastal Low & Mid Marsh	Upland	0.91	0.28%
Coastal Mid Marsh	Upland	Upland	0.91	0.28%
Ocean	Ocean	Coastal Mid Marsh	0.88	0.27%
Barren	Barren	Ocean	0.76	0.24%
Coastal High Marsh	Coastal Low & Mid Marsh	Coastal High Marsh	0.61	0.19%
Upland	Barren	Barren	0.61	0.19%
Ocean	Barren	Coastal Low Marsh	0.58	0.18%
Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	Ocean	0.54	0.17%
Coastal High Marsh	Coastal Low & Mid Marsh	Coastal Mid Marsh	0.54	0.17%
Barren	Coastal Low & Mid Marsh	Coastal Mid Marsh	0.51	0.16%
Coastal Mid Marsh	Coastal High Marsh	Upland	0.46	0.14%
Upland	Upland	Barren	0.45	0.14%
Ocean	Coastal Low & Mid Marsh	Ocean	0.44	0.14%
Ocean	Coastal Mid Marsh	Coastal Mid Marsh	0.35	0.11%
Coastal Mid Marsh	Coastal Low & Mid Marsh	Coastal Mid Marsh	0.32	0.10%
Ocean	Barren	Barren	0.26	0.08%
Coastal Mid Marsh	Coastal Mid Marsh	Ocean	0.23	0.07%
Upland	Coastal Low & Mid Marsh	Coastal Low & Mid Marsh	0.22	0.07%

Appendix GG (continued). Types of physiographic change for year classes 1950, 1980, and 2010 in Shelter Creek.

Physiography 1950	Physiography 1980	Physiography 2010	Area (ha)	Percent Area
Upland	Barren	Coastal Low Marsh	0.16	0.05%
Upland	Upland	Coastal High Marsh	0.16	0.05%
Barren	Coastal Low Marsh	Upland	0.16	0.05%
Coastal High Marsh	Coastal High Marsh	Coastal Low & Mid Marsh	0.10	0.03%
Ocean	Coastal Low Marsh	Coastal Low & Mid Marsh	0.09	0.03%
Coastal Low & Mid Marsh	Barren	Ocean	0.07	0.02%
Coastal Mid Marsh	Coastal Low & Mid Marsh	Ocean	0.03	0.01%
Coastal Low & Mid Marsh	Coastal Low Marsh	Ocean	0.03	0.01%
Ocean	Coastal Low Marsh	Coastal Mid Marsh	0.01	0.01%

Appendix HH. Summary of physiographic area per year for 1950, 1980, and 2010 in Shelter Creek.

	1950		1980		2010	
Physiography	**Area (ha)**	**Percent Area**	**Area (ha)**	**Percent Area**	**Area (ha)**	**Percent Area**
Upland	139.99	43.50%	141.32	43.91%	151.55	47.09%
Coastal Mid Marsh	78.17	24.29%	72.14	22.42%	71.41	22.19%
Coastal High Marsh	43.21	13.43%	37.68	11.71%	34.24	10.64%
Barren	28.96	9.00%	25.47	7.92%	26.28	8.17%
Coastal Low & Marsh	16.35	5.08%	27.83	8.65%	22.13	6.88%
Ocean	15.12	4.70%	14.76	4.59%	11.78	3.66%
Coastal Low Marsh	--	--	2.61	0.81%	4.41	1.37%

-- no data, not applicable

Appendix II. Types of landscape formation change from 1950 to 1980 in Shelter Creek salt marsh areas.

Landscape Formation 1950	Landscape Formation 1980	Area (ha)	Percent Area
Upland	Upland	138.99	43.19%
Meadow	Meadow	73.91	22.96%
Mudflat	Mudflat	23.68	7.36%
Interlevee Ponded Basin	Interlevee Ponded Basin	23.16	7.20%
Open Water	Open Water	13.36	4.15%
Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	7.95	2.47%
Levee Meadow	Levee Meadow	6.52	2.03%
Meadow	Interlevee Basin&Channel Basin	5.78	1.80%
Interlevee Ponded Basin	Interlevee Basin&Channel Basin	4.67	1.45%
Meadow	Interlevee Ponded Basin	2.45	0.76%
Interlevee Basin&Channel Basin	Interlevee Ponded Basin	2.45	0.76%
Interlevee Ponded Basin	Meadow	2.15	0.67%
Mudflat	Meadow	2.01	0.62%
Mudflat	Mudflat and Panne	1.88	0.58%
Meadow	Upland	1.51	0.47%
Mudflat	Open Water	1.40	0.44%
Interlevee Basin&Channel Basin	Interlevee Basin Meadow	1.17	0.36%
Interlevee Ponded Basin	Levee Meadow	1.10	0.34%
Interlevee Ponded Basin	Interlevee Pond	1.08	0.33%
Open Water	Mudflat	0.85	0.27%
Interlevee Ponded Basin	Interlevee Basin Meadow	0.84	0.26%
Levee Meadow	Interlevee Basin&Channel Basin	0.84	0.26%
Upland	Mudflat	0.77	0.24%
Open Water	Interlevee Basin Meadow	0.74	0.23%
Levee Meadow	Upland	0.53	0.16%
Pond or Lake	Pond or Lake	0.45	0.14%
Interlevee Basin&Channel Basin	Meadow	0.32	0.10%
Interlevee Ponded Basin	Upland	0.29	0.09%

Appendix II (continued). Types of landscape formation change from 1950 to 1980 in Shelter Creek salt marsh areas.

Landscape Formation 1950	Landscape Formation 1980	Area (ha)	Percent Area
Meadow	Interlevee Pond	0.23	0.07%
Upland	Interlevee Basin&Channel Basin	0.23	0.07%
Interlevee Ponded Basin	Pond or Lake	0.16	0.05%
Open Water	Mudflat and Panne	0.11	0.03%
Interlevee Basin&Channel Basin	Mudflat	0.07	0.02%
Open Water	Meadow	0.06	0.02%
Meadow	Pond or Lake	0.05	0.02%
Meadow	Interlevee Basin Meadow	0.04	0.01%
Interlevee Basin&Channel Basin	Mudflat and Panne	0.04	0.01%

Appendix JJ. Types of landscape formation change from 1980 to 2010 in Shelter Creek.

Landscape Formation 1980	Landscape Formation 2010	Area (ha)	Percent Area
Upland	Upland	140.70	43.72%
Meadow	Meadow	65.97	20.50%
Mudflat	Mudflat	22.77	7.08%
Interlevee Ponded Basin	Interlevee Ponded Basin	20.88	6.49%
Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	15.14	4.71%
Meadow	Upland	10.37	3.22%
Open Water	Open Water	9.65	3.00%
Levee Meadow	Levee Meadow	7.40	2.30%
Interlevee Ponded Basin	Interlevee Basin Meadow	4.72	1.47%
Open Water	Mudflat	2.65	0.82%
Interlevee Basin Meadow	Interlevee Basin Meadow	2.05	0.64%
Interlevee Basin&Channel Basin	Interlevee Basin Meadow	1.98	0.62%
Interlevee Ponded Basin	Meadow	1.59	0.49%
Open Water	Mudflat and Panne	1.50	0.47%
Meadow	Interlevee Ponded Basin	1.45	0.45%
Mudflat and Panne	Interlevee Basin Meadow	1.36	0.42%
Mudflat	Mudflat and Panne	1.15	0.36%
Interlevee Pond	Interlevee Pond	1.13	0.35%
Open Water	Interlevee Basin Meadow	0.88	0.27%
Mudflat	Open Water	0.84	0.26%
Pond or Lake	Pond or Lake	0.66	0.21%
Interlevee Basin&Channel Basin	Levee Meadow	0.65	0.20%
Mudflat and Panne	Meadow	0.63	0.19%
Interlevee Basin&Channel Basin	Meadow	0.61	0.19%
Interlevee Basin&Channel Basin	Interlevee Ponded Basin	0.57	0.18%
Interlevee Basin&Channel Basin	Open Water	0.48	0.15%
Interlevee Basin Meadow	Open Water	0.48	0.15%
Upland	Mudflat	0.45	0.14%

Appendix JJ (continued). Types of landscape formation change from 1980 to 2010 in Shelter Creek.

Landscape Formation 1980	Landscape Formation 2010	Area (ha)	Percent Area
Mudflat	Meadow	0.45	0.14%
Meadow	Pond or Lake	0.43	0.13%
Interlevee Ponded Basin	Interlevee Pond	0.31	0.10%
Interlevee Basin Meadow	Upland	0.27	0.08%
Interlevee Ponded Basin	Interlevee Basin&Channel Basin	0.24	0.07%
Meadow	Open Water	0.23	0.07%
Interlevee Ponded Basin	Upland	0.22	0.07%
Levee Meadow	Eroding Levee Meadow	0.21	0.07%
Interlevee Pond	Interlevee Ponded Basin	0.18	0.06%
Mudflat	Interlevee Basin Meadow	0.16	0.05%
Upland	Meadow	0.16	0.05%
Open Water	Meadow	0.09	0.03%
Interlevee Ponded Basin	Open Water	0.07	0.02%
Mudflat and Panne	Open Water	0.04	0.01%
Interlevee Ponded Basin	Pond or Lake	0.03	0.01%
Interlevee Basin&Channel Basin	Pond or Lake	0.02	0.01%

Appendix KK. Types of landscape formation change from 1950, 1980 and 2010 in Shelter Creek salt marsh areas.

Landscape Formation 50	Landscape Formation 80	Landscape Formation 10	Area (ha)	Percent Area
Upland	Upland	Upland	138.38	43.00%
Meadow	Meadow	Meadow	62.96	19.56%
Mudflat	Mudflat	Mudflat	21.90	6.81%
Interlevee Ponded Basin	Interlevee Ponded Basin	Interlevee Ponded Basin	17.75	5.51%
Meadow	Meadow	Upland	9.17	2.85%
Open Water	Open Water	Open Water	8.25	2.56%
Levee Meadow	Levee Meadow	Levee Meadow	6.31	1.96%
Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	5.34	1.66%
Meadow	Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	4.84	1.50%
Interlevee Ponded Basin	Interlevee Ponded Basin	Interlevee Basin Meadow	4.72	1.47%
Interlevee Ponded Basin	Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	4.44	1.38%
Open Water	Open Water	Mudflat	2.65	0.82%
Interlevee Basin&Channel Basin	Interlevee Ponded Basin	Interlevee Ponded Basin	2.24	0.70%
Interlevee Ponded Basin	Meadow	Meadow	1.74	0.54%
Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	Interlevee Basin Meadow	1.65	0.51%
Meadow	Upland	Upland	1.51	0.47%
Open Water	Open Water	Mudflat and Panne	1.50	0.47%
Mudflat	Open Water	Open Water	1.40	0.44%
Mudflat	Mudflat and Panne	Interlevee Basin Meadow	1.25	0.39%

Appendix KK (continued). Types of landscape formation change from 1950, 1980 and 2010 in Shelter Creek salt marsh areas.

Landscape Formation 50	Landscape Formation 80	Landscape Formation 10	Area (ha)	Percent Area
Meadow	Interlevee Ponded Basin	Meadow	1.23	0.38%
Interlevee Basin&Channel Basin	Interlevee Basin Meadow	Interlevee Basin Meadow	1.17	0.36%
Meadow	Meadow	Interlevee Ponded Basin	1.16	0.36%
Interlevee Ponded Basin	Levee Meadow	Levee Meadow	1.10	0.34%
Interlevee Ponded Basin	Interlevee Pond	Interlevee Pond	1.08	0.33%
Mudflat	Meadow	Upland	1.08	0.33%
Mudflat	Meadow	Meadow	0.93	0.29%
Meadow	Interlevee Ponded Basin	Interlevee Ponded Basin	0.89	0.28%
Open Water	Open Water	Interlevee Basin Meadow	0.88	0.27%
Mudflat	Mudflat	Open Water	0.76	0.24%
Mudflat	Mudflat and Panne	Meadow	0.63	0.19%
Meadow	Interlevee Basin&Channel Basin	Meadow	0.61	0.19%
Upland	Mudflat	Mudflat	0.61	0.19%
Open Water	Mudflat	Mudflat and Panne	0.59	0.18%
Interlevee Ponded Basin	Interlevee Basin Meadow	Interlevee Basin Meadow	0.57	0.18%
Mudflat	Mudflat	Mudflat and Panne	0.56	0.18%
Levee Meadow	Interlevee Basin&Channel Basin	Levee Meadow	0.55	0.17%
Levee Meadow	Upland	Upland	0.53	0.16%
Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	Open Water	0.48	0.15%
Upland	Upland	Mudflat	0.45	0.14%

Appendix KK (continued). Types of landscape formation change from 1950, 1980 and 2010 in Shelter Creek salt marsh areas.

Landscape Formation 50	Landscape Formation 80	Landscape Formation 10	Area (ha)	Percent Area
Mudflat	Mudflat	Meadow	0.45	0.14%
Pond or Lake	Pond or Lake	Pond or Lake	0.45	0.14%
Open Water	Interlevee Basin Meadow	Open Water	0.44	0.14%
Meadow	Meadow	Pond or Lake	0.39	0.12%
Interlevee Ponded Basin	Interlevee Ponded Basin	Meadow	0.36	0.11%
Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	Interlevee Ponded Basin	0.35	0.11%
Meadow	Interlevee Basin&Channel Basin	Interlevee Basin Meadow	0.33	0.10%
Interlevee Ponded Basin	Interlevee Ponded Basin	Interlevee Pond	0.31	0.10%
Open Water	Interlevee Basin Meadow	Interlevee Basin Meadow	0.30	0.09%
Interlevee Ponded Basin	Upland	Upland	0.29	0.09%
Levee Meadow	Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	0.29	0.09%
Interlevee Ponded Basin	Meadow	Interlevee Ponded Basin	0.28	0.09%
Interlevee Basin&Channel Basin	Meadow	Meadow	0.28	0.09%
Interlevee Ponded Basin	Interlevee Basin Meadow	Upland	0.27	0.08%
Open Water	Mudflat	Mudflat	0.26	0.08%
Meadow	Meadow	Open Water	0.23	0.07%
Upland	Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	0.23	0.07%
Interlevee Ponded Basin	Interlevee Basin&Channel Basin	Interlevee Ponded Basin	0.23	0.07%
Meadow	Interlevee Ponded Basin	Upland	0.22	0.07%
Levee Meadow	Levee Meadow	Eroding Levee Meadow	0.21	0.07%

Appendix KK (continued). Types of landscape formation change from 1950, 1980 and 2010 in Shelter Creek salt marsh areas.

Landscape Formation 50	Landscape Formation 80	Landscape Formation 10	Area (ha)	Percent Area
Meadow	Interlevee Pond	Interlevee Ponded Basin	0.18	0.06%
Upland	Mudflat	Interlevee Basin Meadow	0.16	0.05%
Upland	Upland	Meadow	0.16	0.05%
Interlevee Ponded Basin	Pond or Lake	Pond or Lake	0.16	0.05%
Interlevee Basin&Channel Basin	Interlevee Ponded Basin	Interlevee Basin&Channel Basin	0.14	0.04%
Interlevee Ponded Basin	Meadow	Upland	0.12	0.04%
Open Water	Mudflat and Panne	Interlevee Basin Meadow	0.11	0.03%
Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	Levee Meadow	0.11	0.03%
Meadow	Interlevee Ponded Basin	Interlevee Basin&Channel Basin	0.10	0.03%
Open Water	Open Water	Meadow	0.09	0.03%
Interlevee Basin&Channel Basin	Mudflat	Open Water	0.07	0.02%
Interlevee Basin&Channel Basin	Interlevee Ponded Basin	Open Water	0.07	0.02%
Meadow	Interlevee Pond	Interlevee Pond	0.06	0.02%
Open Water	Meadow	Meadow	0.06	0.02%
Meadow	Pond or Lake	Pond or Lake	0.05	0.02%
Interlevee Basin&Channel Basin	Meadow	Pond or Lake	0.04	0.01%
Meadow	Interlevee Basin Meadow	Open Water	0.04	0.01%
Interlevee Basin&Channel Basin	Mudflat and Panne	Open Water	0.04	0.01%
Interlevee Ponded Basin	Interlevee Ponded Basin	Pond or Lake	0.03	0.01%
Interlevee Basin&Channel Basin	Interlevee Basin&Channel Basin	Pond or Lake	0.02	0.01%

Appendix LL. Summary of landscape formation area per year for 1950, 1980, and 2010 in Shelter Creek.

	1950		1980		2010	
Landscape Formation 10	**Area (ha)**	**Percent Area**	**Area (ha)**	**Percent Area**	**Area (ha)**	**Percent Area**
Upland	139.99	43.50%	141.32	43.91%	151.56	47.09%
Meadow	83.97	26.09%	78.44	24.37%	69.49	21.59%
Mudflat	28.97	9.00%	25.38	7.89%	25.87	8.04%
Interlevee Ponded Basin	33.44	10.39%	28.06	8.72%	23.08	7.17%
Interlevee Basin&Channel Basin	12.00	3.73%	19.46	6.05%	15.38	4.78%
Open Water	15.13	4.70%	14.76	4.59%	11.79	3.66%
Interlevee Basin Meadow	--	--	2.79	0.87%	11.15	3.47%
Levee Meadow	7.88	2.45%	7.62	2.37%	8.06	2.50%
Mudflat and Panne	--	--	2.02	0.63%	2.65	0.82%
Interlevee Pond	--	--	1.31	0.41%	1.45	0.45%
Pond or Lake	0.45	0.14%	0.66	0.21%	1.14	0.35%
Eroding Levee Meadow	--	--	--	--	0.21	0.07%

-- no data, not applicable

Appendix MM. Types of land change from 1950, 1980, and 2010 in Shelter Creek salt marsh areas.

Change Code From 1950 to 1980	Change Code From 1980 to 2010	Area (ha)	Percent Area
No Change	No Change	274.23	85.21%
Channel Formation	No Change	9.99	3.10%
No Change	Vegetation Development/Expansion in Intertidal Area	6.10	1.90%
Vegetation Development/Expansion in Intertidal Area	No Change	5.07	1.58%
Vegetation Development/Expansion in Intertidal Area	Vegetation Development/Expansion in Intertidal Area	3.07	0.95%
No Change	Coastal Subsidence/Flooding	3.02	0.94%
No Change	Pond/Lake Formation	2.26	0.70%
No Change	Aquatic Bed Formation/Expansion in Palustrine Area	1.74	0.54%
Open Water Formation/Marine Intrusion	No Change	1.72	0.53%
No Change	Channel Abandonment	1.59	0.49%
No Change	Open Water Formation/Marine Intrusion	1.52	0.47%
Channel Formation	Channel Abandonment	1.38	0.43%
No Change	Wetland Creation	1.29	0.40%
Wetland Creation	Wetland Loss	1.23	0.38%
No Change	Pond Drying	1.13	0.35%
Pond Drying	No Change	0.94	0.29%
Pond/Lake Formation	No Change	0.75	0.23%
Coastal Subsidence/Flooding	Vegetation Development/Expansion in Intertidal Area	0.70	0.22%
Mass Wasting	No Change	0.61	0.19%

Appendix MM (continued). Types of land change from 1950, 1980, and 2010 in Shelter Creek salt marsh areas.

Change Code From 1950 to 1980	Change Code From 1980 to 2010	Area (ha)	Percent Area
Pond/Lake Formation	Channel Formation	0.59	0.18%
No Change	Mass Wasting	0.45	0.14%
Wetland Creation	No Change	0.39	0.12%
Channel Abandonment	No Change	0.38	0.12%
Coastal Subsidence/Flooding	No Change	0.36	0.11%
Pond Drying	Pond/Lake Formation	0.28	0.09%
Pond Drying	Vegetation Development/Expansion in Intertidal Area	0.27	0.08%
Pond/Lake Formation	Vegetation Development/Expansion in Intertidal Area	0.22	0.07%
Open Water Formation/Marine Intrusion	Vegetation Development/Expansion in Intertidal Area	0.18	0.06%
Mass Wasting	Vegetation Development/Expansion in Intertidal Area	0.16	0.05%
Vegetation Loss/Decrease in Intertidal Area	Open Water Formation/Marine Intrusion	0.11	0.03%
Pond/Lake Formation	Open Water Formation/Marine Intrusion	0.07	0.02%
Channel Abandonment	Pond/Lake Formation	0.04	0.01%

Appendix NN. Summary of land change from 1950 to 1980 and from 1980 to 2010 in Shelter Creek.

	1950 - 1980		1980 - 2010	
Change Code	**Area (ha)**	**Percent Area**	**Area (ha)**	**Percent Area**
No Change	293.33	91.14%	294.43	91.48%
Vegetation Development/Expansion in Intertidal Area	8.15	2.53%	10.70	3.33%
Coastal Subsidence/Flooding	1.06	0.33%	3.02	0.94%
Channel Abandonment	0.42	0.13%	2.97	0.92%
Pond/Lake Formation	1.63	0.51%	2.58	0.80%
Aquatic Bed Formation/Expansion in Palustrine Area	--	--	1.74	0.54%
Open Water Formation/Marine Intrusion	1.90	0.59%	1.70	0.53%
Wetland Creation	1.62	0.50%	1.29	0.40%
Wetland Loss	--	--	1.23	0.38%
Pond Drying	1.49	0.46%	1.13	0.35%
Channel Formation	11.37	3.53%	0.59	0.18%
Mass Wasting	0.77	0.24%	0.45	0.14%
Vegetation Loss/Decrease in Intertidal Area	0.11	0.03%	--	--

-- no data, not applicable

Appendix OO. Summary of radio collared Mulchatna cows observed during May surveys, 2000 – 2012 (retrieved from Woolington 2012a).

	Age – 2 yr old		Age – 3 yr old		Age – 4 yr old		Age – 5 + yrs old			
Year	No. Radios[A]	No. Pregnant	No. Radios[A]	No. Pregnant	Caribou located	No. Pregnant	No. Radios[A]	No. Pregnant	Total Caribou located	Age 3 yr old and greater Percent Pregnant
2000	5	0	0	0	0	0	22	21	27	95%
2001	6	0	4	3	0	0	11	8	21	73%
2002[B]	4	0	7	4	1	0	5	2	17	46%
2003	4	0	8	2	6	5	9	9	27	70%
2004	9	0	2	0	3	3	13	12	27	83%
2005	4	0	5	2	8	6	13	11	30	73%
2006	7	0	0	0	3	2	14	12	24	82%
2007	10	0	5	0	1	1	15	12	31	62%
2008	10	1	10	4	9	7	14	11	43	67%
2009	10	0	6	5	10	9	10	10	36	92%
2010	5	1	13	9	9	5	19	16	46	73%
2011	13	0	3	2	11	10	29	22	56	79%
2012	12	0	15	10	2	1	32	27	61	77%

A - Number of radio collared female caribou of that age found and observed during the study

B - Survey incomplete because of weather

Appendix PP. Mean concentrations (+/- 1 standard deviation) of eight major ions and pH of sample stations on Lake Clark from 1985 to 1987 (June-October). Ion concentrations are measured in µeq/L,pH in pH units, N is number of samples (Chamberlain 1988).

Location	N	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	NO_3	SO_4^{2}	CL	HCO3	pH
Station L2	18	307.3 (70.2)	55.6(6.2)	37.2(4.0)	20.9(2.0)	16.0(3.7)	75.9(9.2)	11.0(2.0)	298.9(40.6)	7.16(0.28)
Station L3	21	382.0 (52.9)	83.9(8.9)	52.1(6.3)	19.6(3.2)	14.1(8.7)	93.7(9.6)	18.4(8.9)	331.1(41.4)	7.26(0.27)
Station L4	20	396.9 (44.0)	88.3(7.3)	52.4(4.2)	18.6(1.9)	11.8(2.6)	94.0(10.3)	16.7(2.7)	337.8(36.8)	7.32(0.26)
Station L5	47	399.5 (38.6)	89.7(10.4)	53.9(4.1)	18.8(1.8)	11.5(2.5)	96.2(6.6)	17.4(2.6)	347.2(45.0)	7.30(0.21)
Station L6	14	385.9 (57.8)	92.3 (15.8)	53.0 (3.8)	21.2(7.3)	13.6(4.2)	97.4(6.7)	17.4(1.4)	323.0(27.4)	7.22(0.39)
Station L7	53	400.2 (48.7)	91.8 (16.6)	54.7(7.7)	18.8(8.8)	10.6 (3.2)	94.3(12.5)	17.3(8.5)	351.4(50.8)	7.34(0.40)
Station L8	21	393.8 (49.3)	92.2(12.7)	55.9 (3.4)	18.0(1.8)	11.5(1.9)	95.2(6.2)	15.9(2.6)	328.9(37.8)	7.25(0.33)
Station L9	11	386.0 (36.9)	80.4(14.9)	51.9(10.0)	17.2(3.9)	11.0(2.2)	90.8(15.8)	15.9(3.2)	383.4(61.3)	7.23(0.35)
Station L10	11	345.6 (42.9)	78.8(5.8)	56.1(2.4)	19.0(0.52)	12.4(0.91)	99.7(2.9)	19.6(6.5)	400.6(61.2)	6.90(0.27)
Station L11	50	397.6 (33.5)	90.7(10.5)	56.5(5.4)	18.1(1.7)	10.8(2.4)	93.3(5.3)	16.9(2.0)	352.0(47.4)	7.41(0.21)
Station PB1	21	403.2 (21.3)	90.4(8.1)	59.9(7.5)	16.6(4.7)	10.5(2.2)	93.7(4.7)	17.5(1.8)	353.0(51.6)	7.38(0.38)
Station PB2	17	407.9 (32.0)	91.5(11.1)	56.9(7.4)	17.6(3.8)	10.5(1.8)	94.4(2.5)	17.2(1.2)	356.9(44.0)	7.34(0.44)
Station L12	7	406.4 (20.7)	97.4(5.9)	55.4(3.5)	17.8(1.0)	10.4(2.1)	93.1(3.3)	16.4(1.1)	377.2(64.2)	7.47(0.15)
Station L13	3	305.6 (61.1)	76.6(6.0)	55.4(2.8)	19.2(0.70)	13.8(1.2)	100.1(1.0)	17.3(3.0)	377.2(23.2)	6.81(0.32)
Station L14	7	316.9 (53.4)	82.9(9.9)	57.0(5.3)	17.2(2.8)	11.8(2.1)	97.9(4.1)	19.7(3.5)	374.8(55.6)	7.02(0.40)
Station L15	9	353.6 (49.3)	80.4(7.5)	56.5(4.8)	16.3(1.9)	11.6(1.2)	90.7(8.0)	17.8(1.9)	309.8(48.0)	7.26(0.35)

Appendix QQ. Mean concentrations (+/- 1 standard deviation) of eight major ions, pH, and specific conductivity of sample stations on nine lakes within LACL from 1985 to 1987 (June-October). Ion concentrations are measured in µeq/L, pH in pH units and N is number of samples (Chamberlain 1988).

Station	N	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	NO_3	SO_4^{2}	CL	HCO_3^{-}	pH	Specific Conductivity
TZ1	19	169.8(37.0)	30.5(3.2)	40.2(8.3)	4.4(1.0)	12.4(2.9)	97.8(6.0)	16.9(3.6)	116.5(37.4)	6.86(0.40)	24.6(3.4)
TZ2	20	171.1(39.4)	32.0(4.7)	46.8(3.6)	4.4(0.9)	11.9(2.4)	78.5(4.3)	18.5(5.0)	141.4(36.4)	6.88(0.33)	25.0(4.4)
K	16	289.6(34.3)	62.2(5.5)	53.0(4.1)	8.3(1.1)	10.1(2.0)	129.4(12.6)	33.0(4.1)	199.9(53.6)	7.15(0.21)	25.0(4.4)
TU	19	360.4(48.7)	44.2(5.0)	37.0(1.7)	16.1(1.8)	1.0(1.2)	59.8(4.4)	8.1(2.9)	323.7(44.4)	7.37(0.34)	39.6(4.4)
K14	20	370.6(69.1)	66.4(15.3)	59.2(12.9)	9.2(3.0)	24.8(5.1)	103.3(17.0)	14.5(2.9)	306.8(42.0)	7.20(0.38)	43.6(4.4)
K13	26	373.8(72.5)	64.5(11.9)	56.5(9.4)	9.0(3.0)	25.3(5.0)	103.0(11.8)	14.5(2.9)	311.2(57.0)	7.18(0.34)	47.2(7.4)
TE	19	436.9(43.4)	66.7(8.8)	66.2(6.6)	29.8(3.5)	4.9(2.3)	205.2(19.0)	17.4(1.9)	293.9(37.1)	7.37(0.27)	56.5(4.6)
LB	18	484.9(117.9)	101.2(18.2)	59.3(8.6)	8.6(1.9)	3.8(2.5)	144.3(40.8)	12.4(3.6)	374.5(87.0)	7.33(0.26)	59.2(12.0)
TN	21	565.3(106.2)	98.6(9.3)	54.3(6.7)	17.0(2.4)	2.7(3.0)	152.4(23.0)	11.4(2.9)	470.9(68.2)	7.43(0.30)	67.7(8.9)
TW1	19	577.5(124.5)	91.3(10.4)	41.8(3.8)	27.3(2.4)	8.4(2.1)	186.1(24.1)	11.8(4.4)	424.2(49.0)	7.45(0.26)	69.6(11.0)

Appendix RR. Minimum, mean, and maximum concentrations of metals found in Lake Clark, three major tributaries (Currant Creek, Tlikakila River, Tanalian River), and eight sample lakes (Telaquana, Twin Lakes, Turquoise Lake, Kijik Lake, Tazimina Lake, Two Lakes, Kontra Kontrashibuna Lake, Lachbuna Lake) in LACL between 1986 and 1987 (Chamberlain 1988). Metal concentrations are in µg/L unless stated otherwise.

	Lake Clark			Major Tributaries			Sample Lakes		
Parameter	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**
Sodium (mg/L)	1.11	1.33	1.55	0.74	1.39	1.79	0.77	1.30	1.87
Potassium (mg/L)	0.00	1.01	2.22	0.00	0.84	1.73	0.00	0.58	2.01
Calcium (mg/L)	6.27	7.84	9.04	5.59	8.11	10.50	2.84	8.18	13.50
Magnesium (mg/L)	0.86	1.00	1.15	0.49	0.76	1.04	0.29	0.83	1.48
Phosphorus (mg/L)	0.00	0.29	0.78	0.00	0.50	1.03	0.00	0.39	1.24
Iron	8.00	46.88	135.00	0.00	45.38	104.00	0.00	19.23	269.00
Chromium	0.00	4.40	19.00	0.00	3.25	8.00	0.00	1.96	7.00
Copper	0.00	2.03	22.00	0.00	0.13	2.00	0.00	0.69	10.00
Manganese	0.00	1.23	6.00	0.00	4.63	11.00	0.00	1.27	18.00
Aluminum	0.00	78.10	631.00	0.00	110.31	261.00	0.00	69.57	742.00
Cadmium	0.00	10.90	100.00	0.00	22.63	157.00	0.00	13.03	99.00
Nickel	0.00	0.98	11.00	0.00	1.69	12.00	0.00	2.26	20.00
Beryllium	0.00	0.48	8.00	0.00	0.19	1.00	0.00	1.11	9.00
Vanadium	0.00	7.20	18.00	0.00	8.25	18.00	0.00	6.91	20.00

Appendix RR (continued). Minimum, mean, and maximum concentrations of metals found in Lake Clark, three major tributaries (Currant Creek, Tlikakila River, Tanalian River), and eight sample lakes (Telaquana, Twin Lakes, Turquoise Lake, Kijik Lake, Tazimina Lake, Two Lakes, Kontra Kontrashibuna Lake, Lachbuna Lake) in LACL between 1986 and 1987 (Chamberlain 1988). Metal concentrations are in µg/L unless stated otherwise.

	Lake Clark			Major Tributaries			Sample Lakes		
Parameter	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**
Tin	0.00	2.18	9.00	0.00	2.00	7.00	0.00	0.90	20.00
Zinc	0.00	7.78	39.00	0.00	8.56	30.00	0.00	8.20	111.00
Silver	0.00	2.25	12.00	0.00	1.00	5.00	0.00	1.51	12.00
Silicon (mg/L)	2.71	2.86	3.06	1.76	2.41	3.78	1.83	2.84	3.78
Boron	0.00	16.50	71.00	0.00	41.06	95.00	0.00	25.10	103.00
Cobalt	0.00	7.15	30.00	0.00	5.63	16.00	0.00	6.30	26.00
Molybdenum	10.00	67.38	179.00	17.00	75.56	169.00	0.00	65.24	194.00
Lithium	0.00	4.00	51.00	0.00	7.13	68.00	0.00	3.16	53.00
Strontium	40.00	42.65	46.00	26.00	41.19	67.00	15.00	34.86	61.00
Arsenic	0.00	21.93	77.00	0.00	35.94	85.00	0.00	19.10	88.00
Selenium	0.00	25.13	97.00	0.00	26.50	111.00	0.00	20.91	80.00
Lead	0.00	22.90	77.00	0.00	34.19	76.00	0.00	20.03	114.00
Barium	0.00	11.18	31.00	0.00	11.69	32.00	0.00	8.00	29.00

Appendix SS. Minimum, mean, and maximum temperatures (°C) at depths from 1 m to 190 m at the five stations in Lake Clark between June and August, 1999-2000 (Wilkens 2002).

Depth (m)	Station 1			Station 2			Station 3			Station 4			Station 5		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
1	7.50	8.75	10.59	8.33	9.36	10.79	7.11	10.32	12.44	6.11	9.84	12.30	7.82	10.16	11.93
2	7.22	8.53	10.58	7.73	9.17	10.77	7.08	10.11	12.15	5.65	9.61	11.88	7.51	9.96	11.62
3	6.99	8.40	10.58	7.50	9.09	10.61	7.01	9.94	12.04	5.13	9.21	11.30	7.51	9.87	11.22
4	6.66	8.20	10.57	7.42	8.95	10.60	7.03	9.84	11.76	5.04	8.68	10.92	6.78	9.62	11.06
5	6.63	8.13	10.57	7.03	8.79	10.60	6.99	9.62	11.16	5.04	8.41	10.70	5.96	9.38	10.86
10	6.32	7.61	10.36	6.38	8.52	10.59	5.19	8.66	10.79	4.93	7.62	10.63	5.68	8.33	10.33
20	5.11	5.83	9.32	5.36	6.88	8.37	4.11	6.80	8.34	4.29	6.12	9.98	4.61	6.44	9.17
30	4.51	4.93	6.30	4.45	5.54	7.55	3.81	5.46	7.36	4.01	4.90	7.12	4.20	5.19	7.38
40	4.34	4.50	4.95	4.00	4.70	6.38	3.77	4.77	6.20	3.90	4.29	5.79	4.06	4.54	5.84
50	4.16	4.32	4.60	3.73	4.24	5.54	3.78	4.27	5.47	3.87	4.08	5.09	3.95	4.31	5.37
70	3.95	4.08	4.20	3.71	3.96	4.20	3.73	3.99	4.75	3.77	3.92	4.41	3.79	4.12	4.67
90	3.79	3.93	4.05	--	--	--	3.70	3.88	4.32	3.71	3.83	4.17	3.75	4.06	4.43
110	3.76	3.86	3.93	--	--	--	3.68	3.83	4.13	3.68	3.78	3.98	3.67	4.00	4.24
130	--	--	--	--	--	--	3.68	3.79	4.06	3.65	3.73	3.91	3.65	3.94	4.20
150	--	--	--	--	--	--	3.67	3.76	4.02	3.62	3.70	3.88	3.71	3.95	4.45
170	--	--	--	--	--	--	3.66	3.73	3.92	3.59	3.67	3.81	3.82	4.05	4.72

Appendix SS (continued). Minimum, mean, and maximum temperatures (°C) at depths from 1 m to 190 m at the five stations in Lake Clark between June and August, 1999-2000 (Wilkens 2002).

Depth (m)	Station 1			Station 2			Station 3			Station 4			Station 5		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
190	--	--	--	--	--	--	3.64	3.70	3.88	--	--	--	--	--	--
Overall	**3.76**	**6.24**	**10.59**	**3.71**	**7.2**	**10.79**	**3.68**	**7.04**	**12.44**	**3.68**	**6.48**	**12.30**	**3.67**	**6.92**	**11.93**

-- no data, not applicable

Appendix TT. Minimum, mean, and maximum concentrations of trace elements collected from the Johnson River gaging station between 1999 and 2004 (USGS 2015).

	1999			2000			2001		
Parameter	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**
Mercury	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Hardness (mg/L) as CaCO3	14.900	21.600	32.000	16.800	27.240	42.500	15.200	23.18	38.700
Calcium (mg/L)	6.590	10.480	20.200	6.730	7.700	8.830	6.260	7.14	8.310
Magnesium (mg/L)	1.060	2.380	7.450	1.140	1.190	1.230	0.720	1.248	2.050
Sodium (mg/L)	0.830	1.290	2.580	0.860	0.990	1.210	0.650	1.095	1.520
Potassium (mg/L)	0.300	0.500	0.900	0.400	0.430	0.500	0.300	0.4	0.500
Bicarbonate (mg/L)	12.000	17.400	26.000	16.000	20.400	26.000	13.000	17.2	23.000
Alkalinity (mg/L) as CaCO3	13.000	15.600	21.000	12.000	16.400	22.000	12.000	14.6	20.000
Sulfate (mg/L)	3.730	7.990	13.500	5.630	11.110	17.900	5.330	9.37	17.800
Chloride (mg/L)	0.330	0.580	0.970	0.470	0.976	1.710	0.460	0.828	1.970
Fluoride (mg/L)	< 0.100	< 0.100	< 0.100	< 0.100	< 0.10	< 0.100	< 0.200	< 0.20	< 0.200
Silica (mg/L) as SiO2	1.820	2.870	4.360	2.00	3.428	5.560	2.050	3.002	4.670
Nitrite (mg/L)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Nitrate (mg/L)	0.013	0.081	0.299	0.030	0.114	0.301	0.023	0.077	0.181
Nitrate + Nitrite (mg/L)	0.014	0.082	0.300	0.030	0.114	0.302	0.024	0.077	0.181
Ammonia (mg/L)	0.002	0.004	0.007	0.004	0.024	0.056	0.002	0.002	0.002
Phosphorus (mg/L)	0.006	0.118	0.590	0.013	0.028	0.038	0.006	0.0272	0.059

Appendix TT (continued). Minimum, mean, and maximum concentrations of trace elements collected from the Johnson River gaging station between 1999 and 2004 (USGS 2015).

	1999			2000			2001		
Parameter	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**
Orthophosphate (mg/L)	0.003	0.008	0.025	0.006	0.008	0.009	< 0.021	< 0.021	< 0.021
Aluminum (µg/L)	230.000	5712.000	24400.000	1020.000	1730.000	2160.000	350.000	1925	4070.000
Antimony (µg/L)	< 1.000	< 1.000	< 1.000	< 1.000	< 1.000	< 1.000	--	--	--
Arsenic (µg/L)	1.000	2.800	7.000	E 1.000	E 1.500	E 2.000	E 1.000	E 1.0	E 1.000
Barium (µg/L)	13.800	27.800	76.300	13.000	14.600	15.700	10.000	15.7	27.000
Beryllium (µg/L)	< 4.000	--	< 5.000	< 5.000	< 5.000	< 5.000	< 2.500	< 2.50	< 2.500
Boron (µg/L)	--	--	--	17.000	25.600	43.000	16.000	27.8	54.000
Cadmium (µg/L)	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.1	< 0.100
Chromium (µg/L)	1.100	3.150	5.200	E 0.600	E 0.650	E 0.700	< 1.000	< 1.0	< 1.000
Cobalt (µg/L)	1.200	3.260	9.800	E 1.000	E 1.530	E 1.800	E 1.800	E 1.45	E 1.100
Copper (µg/L)	38.700	38.700	38.700	< 20.000	< 20.000	< 20.000	< 20.000	< 20.0	< 20.000
Iron (ug/L)	177.00	4166	16900.000	841.000	1443.000	1900.000	306.000	1649	3510.000
Lead (µg/L)	1.000	1.300	1.600	< 1.000	< 1.000	< 1.000	< 1.000	< 1.0	< 1.000
Lithium (µg/L)	E 6.120	--	< 12.000	< 7.000	< 7.000	< 7.000	< 7.000	< 7.00	< 7.000
Manganese (µg/L)	7.530	96.330	395.000	20.500	31.730	41.000	8.400	38.95	79.100
Molybdenum (µg/L)	1.000	1.000	1.000	1.000	1.000	1.000	E 1.000	--	< 2.000
Nickel (µg/L)	1.300	3.400	5.500	< 1.800	< 1.800	< 1.800	< 2.000	< 2.0	< 2.000
Selenium (µg/L)	< 1.000	--	< 3.000	< 3.000	--	< 7.000	< 3.000	< 3	< 3.000
Silver (µg/L)	< 1.000	< 1.000	< 1.000	< 1.000	< 1.000	< 1.000	< 0.400	< 0.4	< 0.400

Appendix TT (continued). Minimum, mean, and maximum concentrations of trace elements collected from the Johnson River gaging station between 1999 and 2004 (USGS 2015).

	1999			2000			2001		
Parameter	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**
Strontium (µg/L)	15.400	26.170	65.200	14.900	16.500	19.000	13.200	16	18.900
Thallium (µg/L)	--	--	--	< 0.900	< 0.900	< 0.900	< 0.040	< 0.040	< 0.040
Vanadium (µg/L)	--	--	--	< 1.00	< 1.000	< 1.000	0.500	0.55	0.600
Zinc (µg/L)	E 16.700	E 29.400	E 39.800	< 31.000	< 31.000	< 31.000	E 17.200	E 19.9	E 22.700
Uranium (natural) (µg/L)	< 1.000	< 1.000	< 1.000	< 1.000	< 1.000	< 1.000	0.041	0.041	0.041
Organic carbon (mg/L)	0.200	0.260	0.400	0.400	0.650	0.900	E 0.190	--	< 0.300

-- no data, not applicable

Appendix UU. Monthly temperature (°C) (minimum, mean, maximum) from the Chulitna River gaging station. Values for each day are an average of the temperature readings for 2010 and 2014 (USGS 2010, 2011, 2012 2013, 2014). It should be noted that the USGS 2014 data are unpublished and are still subject to revision.

Month	Calculation	2010	2011	2012	2013	2014
October	Min	---	0.0	---	---	1.4
	Mean	---	2.0	---	---	4.1
	Max	---	6.0	---	---	6.3
November	Min	0.0	0.0	---	---	-0.1
	Mean	0.0	0.0	---	---	0.7
	Max	0.0	0.0	---	---	3.6
December	Min	0.0	0.0	---	---	0.0
	Mean	0.0	0.0	---	---	0.0
	Max	0.0	0.0	---	---	0.0
January	Min	0.0	---	---	---	---
	Mean	0.0	---	---	---	---
	Max	0.0	---	---	---	---
February	Min	0.0	---	---	---	---
	Mean	0.0	---	---	---	---
	Max	0.0	---	---	---	---
March	Min	0.0	---	---	---	0.0
	Mean	0.0	---	---	---	0.1
	Max	0.0	---	---	---	0.1
April	Min	0.0	0.0	---	---	---
	Mean	0.0	0.0	---	---	---
	Max	0.0	0.0	---	---	---
May	Min	0.0	0.0	---	---	3.5
	Mean	5.4	5.5	---	---	10.2
	Max	13.5	11.0	---	---	15.2

--- no data, not applicable

Appendix UU (continued). Monthly temperature (°C) (minimum, mean, maximum) from the Chulitna River gaging station. Values for each day are an average of the temperature readings for 2010 and 2014 (USGS 2010, 2011, 2012 2013, 2014). It should be noted that the USGS 2014 data are unpublished and are still subject to revision.

Month	Calculation	2010	2011	2012	2013	2014
June	Min	7.5	7.0	---	8.3	4.4
	Mean	12.1	9.9	---	13.4	10.8
	Max	17.0	14.5	---	19.0	14.7
July	Min	8.5	10.0	---	8.0	11.2
	Mean	11.5	12.3	---	14.0	14.9
	Max	16.0	16.0	---	20.5	16.5
August	Min	8.5	8.5	---	10.2	9.4
	Mean	11.0	11.1	---	12.3	13.0
	Max	13.5	13.5	---	18.4	17.4
September	Min	2.0	4.0	---	2.6	---
	Mean	8.6	8.5	---	7.3	---
	Max	11.5	10.5	---	10.9	---

--- no data, not applicable

Appendix VV. Chulitna River gaging station water quality report for the 2010 – 2013 water years (USGS 2010, 2011, 2012, 2013).

	2010			2011			2012			2013		
Parameters	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**
Specific conductance (µS/cm)	57.0000	75.8000	114.0000	63.0000	77.4000	108.0000	29.0000	46.5000	64.0000	51.0000	64.5000	73.0000
pH	7.0000	7.3800	7.6000	6.9000	7.3000	7.5000	7.0000	7.2500	7.5000	7.2000	7.2500	7.4000
Water temperature (°C)	0.1000	7.0000	11.0000	0.0000	7.0400	10.2000	0.0000	5.1500	10.3000	4.5000	7.6500	12.6000
DO (mg/L)	10.7000	11.7000	12.4000	10.7000	11.5000	12.1000	9.9000	10.7000	11.5000	10.7000	12.3000	13.4000
Turbidity (FNU)	4.3000	6.1500	8.9000	1.5000	4.1700	8.5000	< 2.0000	--	7.0000	8.2000	13.6000	19.0000
Hardness (mg/L) as CaCO3	24.2000	31.8400	46.5000	27.4000	33.9400	49.2000	27.0000	38.9000	50.8000	21.5000	27.8000	32.2000
Calcium (mg/L)	7.3880	9.7660	14.5000	8.4300	10.3720	15.3000	8.2900	11.8950	15.5000	6.5000	8.4900	9.8600
Magnesium (mg/L)	1.3900	1.8000	2.4800	1.5400	1.9340	2.6500	1.5100	2.2150	2.9200	1.2700	1.5930	1.8900
Sodium (mg/L)	1.6100	1.9820	2.6600	1.7700	2.0620	2.7200	1.7600	2.2850	2.8100	1.2600	1.7330	1.9900
Potassium (mg/L)	0.3200	0.4730	0.6940	0.3180	0.4480	0.6320	0.3540	0.4705	0.5870	0.4120	0.5260	0.8190
Bicarbonate (mg/L)	25.0000	37.0000	56.0000	49.0000	49.0000	49.0000	29.0000	47.0000	64.0000	37.0000	37.5000	38.0000
Carbonate (mg/L)	< 2.0000	< 2.0000	< 2.0000	< 2.0000	< 2.0000	< 2	0.0000	0.0000	0.0000	< 2.0000	< 2.0000	< 2.0000
Alkalinity (mg/L) as CaCO3	21.0000	30.0000	46.0000	40.0000	40.0000	40.0000	24.0000	38.0000	52.0000	30.0000	30.5000	31.0000
Sulfate (mg/L)	4.2000	6.0080	8.4300	5.0800	6.1420	8.8000	4.9000	6.3850	7.8700	3.1000	4.1625	5.2100
Chloride (mg/L)	0.3450	0.5176	0.8080	0.3800	0.5336	0.7090	0.4870	0.6465	0.8060	0.4260	0.5202	0.6790
Fluoride (mg/L)	0.0800	0.0820	0.0840	0.0410	0.0538	0.0620	0.0750	0.0785	0.0820	0.0430	0.0575	0.0650
Silica (mg/L) as SiO2	6.3400	8.3080	12.0000	6.9100	8.8560	11.8000	6.6600	9.9800	13.3000	5.5900	7.1625	8.3300
Dissolved solids (mg/L)	46.0000	54.4000	66.0000	42.0000	55.20000	66.0000	44.0000	55.5000	67.0000	44.0000	48.7500	54.0000

-- no data, not applicable

Appendix VV (continued). Chulitna River gaging station water quality report for the 2010 – 2013 water years (USGS 2010, 2011, 2012, 2013).

	2010			2011			2012			2013		
Parameters	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**
Nitrite (mg/L)	E 0.0010	--	< 0.0020	0.0014	0.0014	0.0013	0.0010	0.0010	0.0010	< 0.0010	< 0.0010	< 0.0010
Nitrate + nitrite (mg/L)	0.0699	0.1033	0.1790	0.0440	0.1036	0.1760	0.1170	0.1435	0.1700	0.0510	0.0870	0.1160
Nitrate (mg/L)	E 0.0690	--	E 0.0950	0.0440	0.1034	0.1760	0.1170	0.1405	0.1640	0.0510	0.0870	0.1160
Ammonia (mg/L)	E .01600	--	E .0160	0.0155	0.0608	0.1060	0.0141	0.0165	0.0190	< 0.0100	< 0.0100	< 0.0100
Phosphorus (mg/L)	0.0088	0.0228	0.0298	0.0074	0.0155	0.0276	E 0.013	E 0.013	0.0137	0.0119	0.0298	0.0674
Orthophosphate (mg/L)	0.0086	0.0086	0.0086	0.0047	0.0054	0.0058	0.0070	0.0070	0.0070	< 0.0040	< 0.0040	< 0.0040
Aluminum (µg/L)	12.2000	23.1500	45.0000	3.8100	14.0000	19.6000	4.4300	7.1800	9.9300	13.2000	19.8800	27.5000
Antimony (µg/L)	0.0901	0.1397	0.1900	0.0844	0.1094	0.1430	0.0847	0.1069	0.1290	0.0761	0.1044	0.1710
Arsenic (µg/L)	1.2100	1.3200	1.5600	0.9400	1.2900	1.6800	1.1600	1.2400	1.3100	1.1100	1.3500	1.7000
Barium (µg/L)	3.7900	4.7120	7.0800	3.8700	4.4700	5.4700	3.6700	5.0650	6.4600	3.9800	4.2400	4.6200
Beryllium (µg/L)	E 0.0070	--	< 0.0120	< 0.0060	< 0.0060	< 0.006	< 0.0060	< 0.0060	< 0.006	< 0.0060	< 0.0060	< 0.0060
Boron (µg/L)	2.9400	3.2900	3.9500	3.70000	3.7000	3.7000	3.5000	3.6700	3.8300	3.4500	3.6600	3.8600
Cadmium (µg/L)	E 0.0130	E 0.0130	E 0.0130	< 0.0160	< 0.0160	< 0.016	< 0.016	< 0.0160	<0.016	0.0370	0.0370	0.0370
Chromium (µg/L)	0.1210	0.1375	0.1540	0.07200	0.1028	0.1370	0.0760	0.1895	0.3030	0.0850	0.1330	0.1850
Cobalt (µg/L)	0.1570	0.7922	1.6900	0.2000	0.6692	1.4800	0.0720	0.2370	0.4020	0.1910	0.3775	0.7470
Copper (µg/L)	E 0.6400	E 0.7800	E 0.9200	0.5100	0.5400	0.5600	< 0.8000	< 0.8000	< 0.8000	< 0.800	< 0.8000	< 0.8000
Iron (µg/L)	151000	245.4000	356.0000	162.0000	230.8000	363.0000	125.0000	217.5000	310.0000	170.0000	254.5000	368.0000
Lead (µg/L)	0.0449	0.0709	0.1220	0.0239	0.0472	0.0716	0.0251	0.0786	0.1320	0.0289	0.0568	0.0911
Lithium (µg/L)	0.5710	0.7408	1.3000	0.5730	0.7422	0.9420	0.5920	0.7685	0.9450	0.4640	0.6438	0.8000
Manganese (µg/L)	11.0000	20.6800	36.7000	10.0000	17.6600	30.2000	10.3000	36.2000	62.1000	12.1000	13.6750	16.1000
Molybdenum (µg/L)	0.2770	0.3104	0.3750	0.3190	0.3432	0.3570	0.3530	0.3735	0.3940	0.2240	0.2940	0.3510

-- no data, not applicable

Appendix VV (continued). Chulitna River gaging station water quality report for the 2010 – 2013 water years (USGS 2010, 2011, 2012, 2013).

	2010			2011			2012			2013		
Parameters	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**
Nickel (µg/L)	0.2390	0.3838	0.6410	0.2410	0.3972	0.5090	0.2020	0.2220	0.2420	0.2570	0.3173	0.3750
Selenium (µg/L)	0.0688	0.0971	0.1520	0.0900	0.1134	0.1450	0.1210	0.1210	0.1210	0.0520	0.0753	0.1010
Silver (µg/L)	E 0.0060	--	< 0.1000	< 0.0050	< 0.0050	< 0.005	< 0.0050	< 0.005	< 0.0050	< 0.0050	< 0.0050	< 0.0050
Strontium (µg/L)	39.4000	53.5200	76.4000	44.9000	56.3800	72.5000	47.4000	62.9500	78.5000	37.4000	47.5500	53.7000
Thallium (µg/L)	< 0.0200	< 0.0200	< 0.0200	< 0.0100	< 0.0100	< 0.010	0.0656	0.0656	0.0656	< 0.0100	< 0.0100	< 0.0100
Vanadium (µg/L)	0.2380	0.3583	0.5210	0.1560	0.2560	0.3070	0.1620	0.1910	0.2200	0.2360	0.3430	0.4920
Zinc (µg/L)	< 2.8000	< 2.8000	< 2.8000	< 1.4000	< 1.4000	< 1.4	< 1.4000	< 1.4	< 1.4000	< 1.4000	< 1.4000	< 1.4000
Uranium (natural) (µg/L)	0.0221	0.02540	0.0293	0.0170	0.02240	0.0257	0.0216	0.0252	0.0287	0.0202	0.0230	0.0250
Organic carbon (mg/L)	1.0100	3.4600	5.2600	1.1800	3.0500	4.4500	1.5900	2.0100	2.4200	3.3000	3.8700	4.2000
Suspended sediment (mg/L)	2.0000	13.2000	22.0000	2.0000	8.2000	20.0000	2.0000	5.5000	9.0000	4.0000	17.5000	44.0000

-- no data, not applicable

Appendix WW. Extent and timing of LACL Dall's sheep surveys from 1978 to 2004 (NPS 2004).

Year	Dates	Aircraft Class	Type	Notes	Units Surveyed
1978	July 10-14	Fixed Wing	Citabria	What became unit 5 was only partially completed	1-5
1979	July 19-20	Fixed Wing	PA-18	Small portion of unit 4 and covered 5 and 6	4*-6
1981	Aug 29-30, Sept 5-6	Helicopter	Bell 206		1-6
1984	Sept 16-17	Helicopter	Hughes 500	Surveyed units 1 and 4	1&4
1985	July 31-Aug 2	Helicopter	Bell 206	also little PA18	1,2,5,6
1987	July 5-28	Helicopter	Bell 206		1-6
1990	July 17	Helicopter		Unit 2 was a partial survey	1-2
1992	June 22-23	Helicopter	Bell 206	Sampled 21 of 44 sample subunits	1-6
1995	June 27-30	Helicopter	Bell 206	Sampled 16 of 44 sample subunits	1-6
2000	July 25	Helicopter	Bell 206	Only surveyed 3 subunits in Unit 4	4*
2003	June 13-20	Both	PA-18 and Hughes 500	unit 1 and 2	1&2
2003	Aug 2-3	Both	PA-18 and Hughes 500	unit 1 and 2	1&2
2003	Aug 3-4	Fixed Wing	PA-18	unit 3 and 4	3&4
2003	Sept 5	Fixed Wing	PA-18	Partial unit 1 and 2, 8 subunits with high/med density	1&2
2004	June 23-26	Both	PA-18 and R-44	unit 1 and 2	1&2
2004	July 31-Aug 3	Both	PA-18 and R-44	Partial unit 1 and 2, sampled 12 of 23 subunits	1&2

Appendix WW (continued). Extent and timing of LACL Dall's sheep surveys from 1978 to 2004 (NPS 2004). "Ewe-like" can include ewes, yearlings and rams with less than ½ curl horns.

Year	Dates	Est.Sheep	Total	Ewe	Ewe-Like	Yrlgs	Lambs	Lamb:Ewe	Rams	Ram:Ewe
1978	July 10-14		480		283		132	46.6	65	
1979	July 19-20		51		27		11		13	
1981	Aug 29-30, Sept 5-6		805	356		82	195	58.0	173	51.0
1984	Sept 16-17									
1985	July 31-Aug 2		235	91		28	34	37.4	82	90.1
1987	July 5-28		1088	367		120	281	76.6	303	82.6
1990	July 17		193	102		10	38	37.3	41	40.2
1992	June 22-23	520	392	192			69	36.0	106	55.0
1995	June 27-30	716	440		272		73	38.0	85	37.0
2000	July 25		125		69	7	18		28	
2003	June 13-20		295	156		10	23	33.1	72	45.0
2003	Aug 2-3		264	87	45	10	31	23.5	91	68.9
2003	Aug 3-4		277	126	21	4	64	43.5	60	40.8
2003	Sept 5		195	73	21	1	47	50.0	53	56.0
2004	June 23-26		273	105	43	21	33	22.0	70	47.0
2004	July 31-Aug 3		165	88		4	15		58	

Appendix XX. Sex and age composition of Dall's sheep in LACL (Singer and Lovaas 1981, Singer and Twitchell 1984).

Year/Unit	Unit	Total Sheep	Lambs:100 Ewes	Yearlings:100 Ewes	Rams:100 Ewes	Rams 1/4 Curl	Rams 1/2 Curl	Rams 3/4 Curl	Rams Full Curl
1981	1, 2		59	22	119				
1981	1	48				8	25	25	42
1981	2	56				8	13	31	48
1981	3	156	53	39	52	9	28	28	34
1981	4	333	56	21	27	18	30	30	22
1981	5	124	53	21	89	21	31	29	19
1981	6	88	57	23	54	10	32	26	32
1981 Total	**N/A**	**805**	**58**	**24**	**51**	**15**	**27**	**28**	**30**
1984	1	183	53	24	43	6	17	30	47
1984	4	339	53	14	36	12	10	46	32
1984 Total	**N/A**	**522**	**53**	**17**	**38**	**9**	**13**	**41**	**38**
1985	1	68	20	27	80	29	17	29	25
1985	2	79	44	31	69	19	23	27	31
1985	5	51	53	42	74	0	7	64	29
1985	6	37	45	27	164	6	17	44	33
1985 Total	**N/A**	**235**	**37**	**31**	**90**	**16**	**17**	**38**	**29**

Appendix YY. Dall's sheep population, sex, and age composition within survey units 1 and 2 of LACL (NPS 2004).

Unit	Year	Lamb	Ewe	Yearling	Ewe-like	Un-classified	Rams <1/4 curl	Rams 1/4 curl	Rams 1/2 curl	Rams 3/4 curl	Rams 4/4 curl
1	1978	11	0	0	26	0	0	0	3	6	2
	1984	44	83	20	0	0	0	2	6	4	17
	1985	6	30	8	0	0	0	7	4	7	6
	1987	36	41	11	0	1	7	3	6	7	12
	1990	14	20	0	0	0	0	4	0	4	1
	2003[A]	38	106	4	4	0	0	6	18	20	20
	2003[B]	23	53	7	45	0	0	6	9	18	17
	2004	23	67	13	43	0	0	5	15	14	15
2	1978	29	0	0	48	0	0	0	4	12	3
	1985	13	31	9	0	0	0	5	6	7	8
	1987	47	59	14	0	7	8	8	9	9	17
	1990	24	82	10	0	2	1	9	4	13	5
	2003[A]	15	50	6	0	0	1	0	2	4	1
	2003[B]	8	34	3	0	0	1	2	5	4	7
	2004	10	38	8	0	1	0	0	7	5	5

A - Based on the fixed wing survey completed between 6/13/03-6/20/03

B - Based on the fixed wing survey completed between 8/02/03-8/04/03

Appendix YY (continued). Dall's sheep population, sex, and age composition within survey units 1 and 2 of LACL (NPS 2004).

Unit	Year	Unclass Rams	Total Ram	Total Sheep	Lamb:100 Ewes	Ram:100 Ewes	Percent Sheep in Unit
1	1978	0	11	48	42.3	42.3	33%
	1984	0	36	183	53.0	43.4	*
	1985	0	24	68	20.0	80.0	46%
	1987	0	35	124	87.8	85.4	41%
	1990	0	9	43	70.0	45.0	22%
	2003[A]	0	64	216	34.5	58.2	73%
	2003[B]	18	68	196	23.5	69.4	74%
	2004	4	53	199	20.9	48.2	73%
2	1978	0	19	96	60.4	39.6	67%
	1985	0	26	79	41.9	83.9	54%
	1987	0	51	178	79.7	86.4	59%
	1990	0	32	150	29.3	39.0	78%
	2003[A]	0	8	79	30.0	16.0	27%
	2003[B]	4	23	68	23.5	67.6	26%
	2004	0	17	74	26.3	44.7	27%

A - Based on the fixed wing survey completed between 6/13/03-6/20/03

B - Based on the fixed wing survey completed between 8/02/03-8/04/03

Appendix ZZ. Dall's sheep population, sex, and age composition combined between units 1 and 2 of LACL (NPS 2004).

Unit	Year	Lamb	Ewe	Yearling	Ewe-like	Unclassified	Rams<1/4	Rams 1/4	Rams 1/2	Rams 3/4	Rams 4/4
1,2	1978	40	0	0	74	0	0	0	7	18	5
	1985	19	61	17	0	0	0	12	10	14	14
	1987	83	100	25	0	8	15	11	15	16	29
	1990	38	102	10	0	2	1	13	4	17	6
	2003 [A]	53	156	10	4	0	1	6	20	24	21
	2003 [B]	31	87	10	45	0	1	8	14	22	24
	2004	33	105	21	43	1	0	5	19	13	15

A - Based on the fixed wing survey completed between 6/13/03-6/20/03

B - Based on the fixed wing survey completed between 8/02/03-8/04/03

Appendix ZZ (continued). Dall's sheep population, sex, and age composition combined between units 1 and 2 of LACL (NPS 2004).

Unit	Year	Unclassified Rams	Total Ram	Total Sheep	Lamb:100 Ewe	Ram:100 Ewe
1,2	1978	0	30	144	54.1	40.5
	1985	0	50	147	31.1	82.0
	1987	0	86	302	83.1	86.0
	1990	0	41	193	37.3	40.2
	2003 [A]	0	72	295	33.1	45.0
	2003 [B]	22	91	264	23.5	68.9
	2004	18	70	273	22.3	47.3

A - Based on the fixed wing survey completed between 6/13/03-6/20/03

B - Based on the fixed wing survey completed between 8/02/03-8/04/03

Appendix AAA. Dall's sheep observations at mineral licks over three known sites for various years between 1993 and 2003 (NPS 2013).

Unit	Subunit	GMU	Mineral Lick/Site	Date	Lambs	Yearlings	Ewe	Unknown	Total	Ram uncl.
4	14	17B	Camp/Emerson Creeks	6-Jul-96	31	13	41	7	92	12
4	14	17B	Emerson Creek	25-Jun-93	14	6	15	0	35	0
4		17B	Fall Mt./Twin Lakes	2-Jun-94	5	4	8	0	17	0
1	41	9B	Holy Mountain	23-Jun-97	1	4	11	0	16	0
4	14	17B	Sheep Canyon	30-Jul-93	7	3	23	0	33	0
4	14	17B	Sheep Canyon	1-Jul-94	12	3	22	0	37	0
4	14	17B	Sheep Canyon	19-Jun-97	14	8	38	0	60	0
4	14	17B	Sheep Canyon	20-Jul-99	3	5	12	0	20	0
4	14	17B	Sheep Canyon	10-Jul-03	45	15	76	0	136	0

Appendix AAA. Dall's sheep observations at mineral licks over three known sites for various years between 1993 and 2003 (NPS 2013).

Unit	Subunit	GMU	Mineral Lick/Site	Date	1/4	1/2	3/4	7/8	Full	Total Rams	All Sheep Total
4	14	17B	Camp/Emerson Creeks	6-Jul-96	0	0	0	0	0	12	104
4	14	17B	Emerson Creek	25-Jun-93	0	0	0	0	0	0	35
4		17B	Fall Mt./Twin Lakes	2-Jun-94	0	0	0	0	0	0	17
1	41	9B	Holy Mountain	23-Jun-97	0	0	0	0	0	0	16
4	14	17B	Sheep Canyon	30-Jul-93	0	4	2	0	1	7	40
4	14	17B	Sheep Canyon	1-Jul-94	1	0	1	0	0	2	39

Appendix AAA (continued). Dall's sheep observations at mineral licks over three known sites for various years between 1993 and 2003 (NPS 2013).

Unit	Subunit	GMU	Mineral Lick/Site	Date	1/4	1/2	3/4	7/8	Full	Total Rams	All Sheep Total
4	14	17B	Sheep Canyon	19-Jun-97	0	5	0	5	1	11	71
4	14	17B	Sheep Canyon	20-Jul-99	0	0	0	0	0	0	20
4	14	17B	Sheep Canyon	10-Jul-03	6	1	6	0	3	16	152

Appendix BBB. Arsenic results for each lake and fish species. First row of results represents the muscle plug analysis; the second row of results represents the whole body analysis. All results presented as mg/kg wet weight (Retrieved from Shearer and Young 2012).

Waterbody	Species	Sample Size	Size Range (mm)	Mean (+ 1 SD)	Minimum	Maximum
Lake Clark	Lake trout	11	520 – 631	0.086 (0.022)	0.059	0.14
				0.148 (0.021)	0.12	0.18
	Northern pike	10	443 – 774	0.098 (0.036)	0.049	0.17
				0.134 (0.021)	0.11	0.18
	Humpback whitefish	20	313 – 509	0.069 (0.020)	0.038	0.099
				0.133 (0.033)	0.088	0.19
Lake Kontrashibuna	Lake trout	10	354 – 455	0.047 (--)	0.047	0.047
				0.068 (0.015)	0.051	0.094
Pickerel Lake	Northern pike	10	603 – 806	--	--	--
				0.043 (--)	--	--
	Humpback whitefish	4	371 – 644	0.078 (--)	0.078	0.078
				0.083 (0.033)	0.055	0.12

-- results below detection level

Appendix BBB. Cadmium results for each lake and fish species. First row of results represents the muscle plug analysis; the second row of results represents the whole body analysis. All results presented as mg/kg wet weight (Retrieved from Shearer and Young 2012).

Waterbody	Species	Sample Size	Size Range (mm)	Mean (+ 1 SD)	Minimum	Maximum
Lake Clark	Lake trout	11	520 – 631	--	--	--
				0.011 (0.002)	0.008	0.014
	Northern pike	10	443 – 774	--	--	--
				0.012 (0.004)	0.009	0.010
	Humpback whitefish	20	313 – 509	0.011 (--)	0.011	0.011
				0.026 (0.014)	0.011	0.049
Lake Kontrashibuna	Lake trout	10	354 – 455	--	--	--
				0.026 (0.007)	0.012	0.035
Pickerel Lake	Northern pike	10	603 – 806	--	--	--
				--	--	--
	Humpback whitefish	4	371 – 644	--	--	--
				0.009 (--)	0.009	0.009

-- results below detection level

Appendix BBB. Copper results for each lake and fish species. First row of results represents the muscle plug analysis; the second row of results represents the whole body analysis. All results presented as mg/kg wet weight (Retrieved from Shearer and Young 2012).

Waterbody	Species	Sample Size	Size Range (mm)	Mean (+ 1 SD)	Minimum	Maximum
Lake Clark	Lake trout	11	520 – 631	0.369 (0.065)	0.26	0.49
				0.916 (0.362)	0.61	1.90
	Northern pike	10	443 – 774	0.295 (0.064)	0.19	0.42
				0.568 (0.108)	0.38	0.69
	Humpback whitefish	20	313 – 509	0.387 (0.149)	0.18	0.68
				1.145 (0.512)	0.31	2.10
Lake Kontrashibuna	Lake trout	10	354 – 455	0.296 (0.036)	0.25	0.37
				0.665 (0.185)	0.37	1.00
Pickerel Lake	Northern pike	10	603 – 806	0.380 (0.224)	0.22	0.99
				0.407 (0.094)	0.33	0.58
	Humpback whitefish	4	371 – 644	0.345 (0.173)	0.23	0.60
				1.413 (0.975)	0.53	2.40

Appendix BBB. Selenium results for each lake and fish species. First row of results represents the muscle plug analysis; the second row of results represents the whole body analysis. All results presented as mg/kg wet weight (Retrieved from Shearer and Young 2012).

Waterbody	Species	Sample Size	Size Range (mm)	Mean (+ 1 SD)	Minimum	Maximum
Lake Clark	Lake trout	11	520 – 631	0.283 (0.031)	0.24	0.34
				0.438 (0.077)	0.31	0.54
	Northern pike	10	443 – 774	0.421 (0.043)	0.17	0.29
				0.319 (0.042)	0.24	0.37
	Humpback whitefish	20	313 – 509	0.287 (0.071)	0.17	0.46
				0.407 (0.091)	0.25	0.54
Lake Kontrashibuna	Lake trout	10	354 – 455	0.438 (0.070)	0.32	0.55
				0.568 (0.073)	0.48	0.69
Pickerel Lake	Northern pike	10	603 – 806	0.223 (0.037)	0.14	0.27
				0.319 (0.042)	0.23	0.38
	Humpback whitefish	4	371 – 644	0.310 (0.067)	0.22	0.37
				0.393 (0.029)	0.37	0.43

Appendix BBB. Total mercury results for each lake and fish species. First row of results represents the muscle plug analysis; the second row of results represents the whole body analysis. All results presented as mg/kg wet weight (Retrieved from Shearer and Young 2012).

Waterbody	Species	Sample Size	Size Range (mm)	Mean (+ 1 SD)	Minimum	Maximum
Lake Clark	Lake trout	11	520 – 631	0.296 (0.118)	0.13	0.52
				0.216 (0.102)	0.1	0.39
	Northern pike	10	443 – 774	0.169 (0.078)	0.06	0.28
				0.099 (0.043)	0.053	0.17
	Humpback whitefish	20	313 – 509	0.056 (0.028)	0.021	0.13
				0.061 (0.078)	0.012	0.38
Lake Kontrashibuna	Lake trout	10	354 – 455	0.285 (0.151)	0.064	0.47
				0.219 (0.115)	0.059	0.36
Pickerel Lake	Northern pike	10	603 – 806	0.317 (0.174)	0.14	0.68
				0.176 (0.089)	0.054	0.34
	Humpback whitefish	4	371 – 644	0.106 (0.064)	0.051	0.18
				0.067 (0.037)	0.042	0.12

Appendix BBB. Methylmercury results for each lake and fish species. All results presented as mg/kg wet weight (Retrieved from Shearer and Young 2012).

Waterbody	Species	Sample Size	Size Range (mm)	Mean (+ 1 SD)	Minimum	Maximum
Lake Clark	Lake trout	7	535 – 631	0.230 (0.092)	0.141	0.416
	Northern pike	5	520 – 773	0.140 (0.085)	0.044	0.241
Lake Kontrashibuna	Lake trout	7	354 – 455	0.093 (0.043)	0.03	0.142

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