Alaska Park Science

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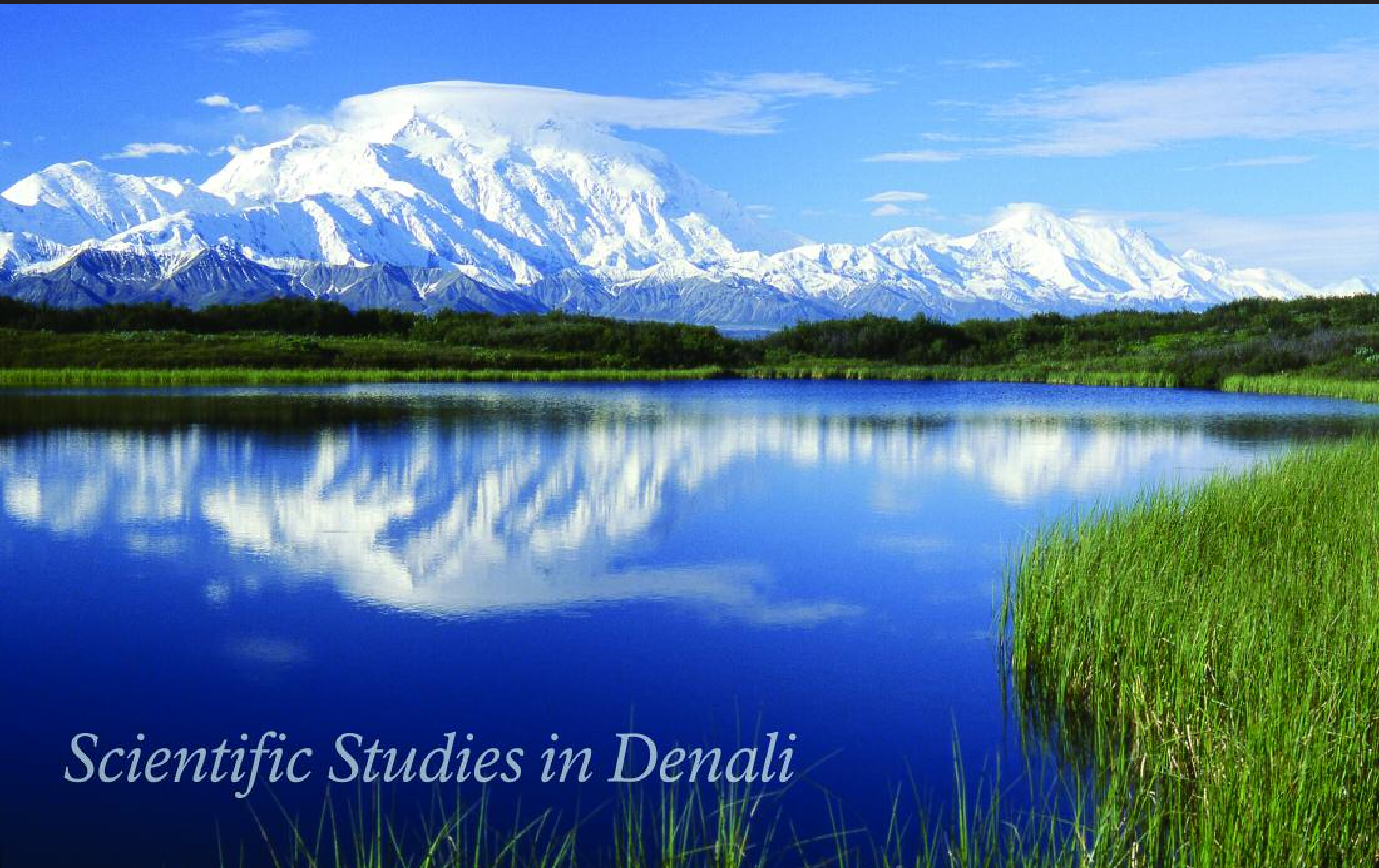

Scientific Studies in Denali

Volume 5, Issue 1

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Bridging Science and Education for the Future

Created in 1917 and enlarged in 1980, Denali National Park and Preserve offers excellent opportunities to study large natural systems in settings that are primarily undisturbed by humans. As one of the largest and longest protected subarctic ecosystems in the world, Denali is recognized internationally as a biosphere reserve. The park protects world-class wildlife and geological resources. Visitors are able to witness a naturally functioning predator/prey ecosystem, while enjoying incredible vistas of North America's highest peak. The accessibility, environmental complexity, rapid tourism growth, and intense public interest in park management and development have led to a strong park science program.

To support this program, we created the Denali Center for Resources, Science and Learning. The center is a science-based organization comprised of professional and technical staff with specialties in the biological and physical sciences, history, ethnography, archeology, interpretation and education. Acquiring new knowledge through scientific research is integral to the center's programs. Equally important is effectively communicating that knowledge to park management, other scientists, academics, and the public. The Center provides a strategic and interdisciplinary approach to address complex and sensitive management issues, challenges that include: aircraft, off-road vehicle, and snowmachine use; wilderness; wildlife; sport and subsistence harvesting; air quality; fire; mining reclamation; and archeological and historical preservation.

Denali is also home to the Murie Science and Learning Center (MSLC), whose mission creates a bridge between science and education. The MSLC is a public, nonprofit partnership between the National Park Service, the Alaska Natural History Institutes, the Denali Foundation, the U.S. Geological Survey, several universities, and the Denali Borough School District. The MSLC promotes and facilitates research on northern Alaska park ecosystems and shares scientific findings with park managers, visitors, researchers, students, and the general public. It provides a forum for examining issues relevant to northern Alaska parklands and serves as a center for promoting park protection through education.


National Park Service photograph

The park provides excellent opportunities to explore, study, and learn about natural systems and processes, as well as area history and culture. We hope this issue of *Alaska Park Science* will help you better understand and appreciate Denali. Through broad public understanding and appreciation of the importance and significance of this park, we strive to preserve our heritage for ourselves, our children, and generations yet to come. We welcome you to join us!

Paul R Anderson

Paul R. Anderson, Superintendent
Denali National Park and Preserve

National Park Service photograph by Pamela Sousanes

Ecological Overview of Denali National Park and Preserve

By Philip Hooge, Guy Adema, Thomas Meier, Carl Roland, Phil Brease, Pam Sousanes, Lucy Tyrrell

Left: Interior subalpine ecosystem.

"During the past two million years, Denali's history has been characterized by repeated advances and retreats of a massive ice sheet .... Landforms such as sculpted valleys, terraces, moraines, and kettle ponds are common in the northern river valleys."

The landscapes of Denali National Park and Preserve (Denali) are a legacy of the region's geological history and the advance and retreat of glaciers. One of the major influences on Denali's ecosystems is the Alaska Range, the massive wall of rock, glacial ice, and snow running from southwest to northeast across the park's six million acres (2.4 million hectares). It towers above and separates the Kuskokwim and Tanana river basins to the north and from the Susitna River lowlands to the south *(Figure 1)*. This mountain barrier creates two major climate zones in the park and dramatic elevation differences. As a result, the ecosystems range from lowlands with taiga forests, braided glacial stream floodplains, and meandering sloughs; to subalpine woodlands, meadows, and scrub tundra; to alpine low-shrub tundra slopes and steep peaks, including Mt. McKinley at 20,320 feet (6,194 m).

Geologic History

The oldest rocks in the park, collectively called the Yukon-Tanana terrane, were ocean sediments deposited in shallow seas during the Paleozoic era some 300 to 500 million years ago. Later in the Paleozoic and into the Early Mesozoic (100 to 300 million years ago), other terranes, fragments of the larger continental plates, migrated north on the Pacific Plate and attached to the Yukon-Tanana terrane, creating the current jigsaw puzzle of rocks from many depositional environments.

During the last 100 million years, the assembled terranes buckled from continuous tectonic collision, uplifting to create the present-day topography of the Alaska Range. About six million years ago, a regional uplift that began in the Alaska Range spread north to push up the Outer Range (Mts. Healy, Margaret, and Wright) *(Fitzgerald et al. 1993)*.

Around 70 million years ago, alternating warm, near-tropical conditions and cooler, drier periods enhanced erosion and deposition in sedimentary basins such as the

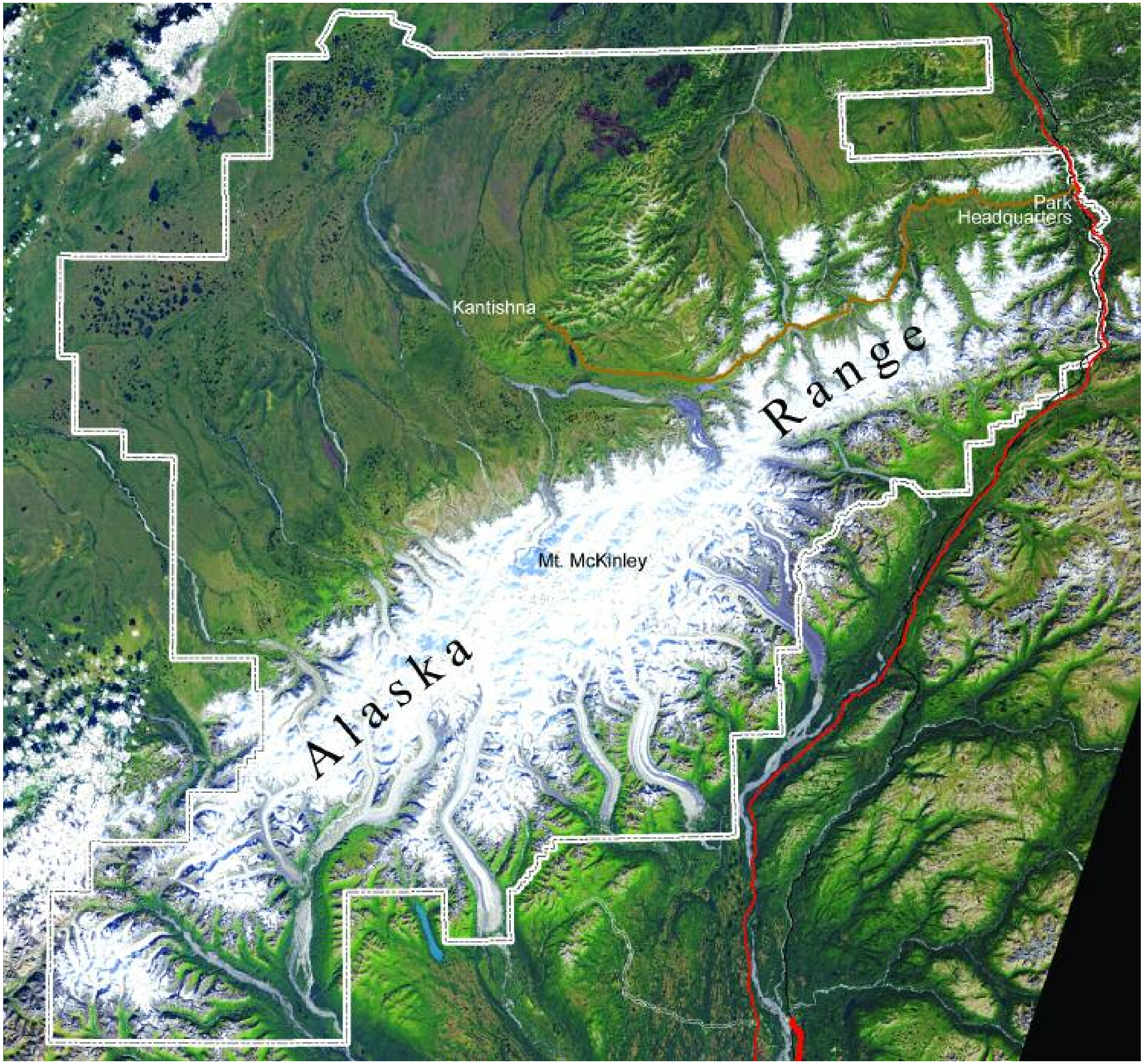


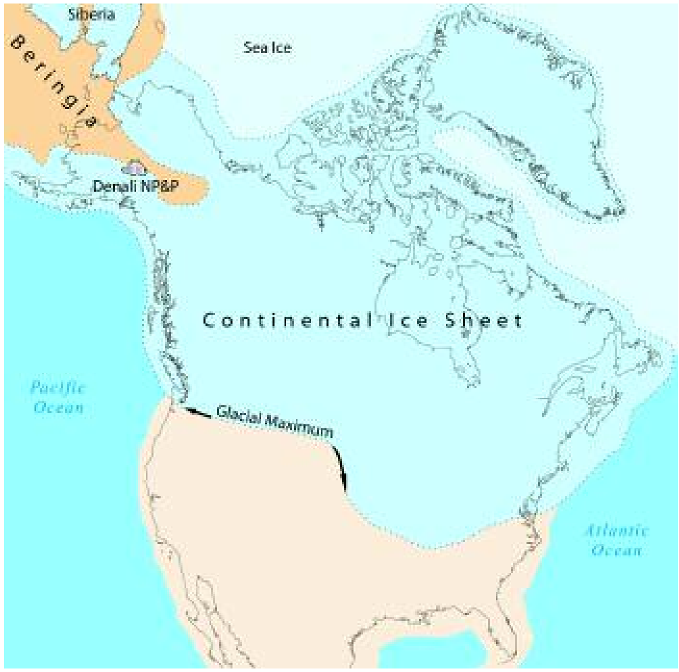
Figure 1. Satellite photo of Denali National Park and Preserve with political boundaries.

Cantwell, where dinosaurs walked among ancestral lakes, braided streams, and alluvial fans. Volcanic eruptions dominated the scene 40 to 50 million years ago, creating the colorful rocks at Polychrome Pass. Subsurface magma cooled to become the granitic bulk of Mt. McKinley and Mt. Foraker *(Cole 1999)*.

Because the Pacific Plate continues to collide with and slide beneath Alaska, the buckling and uplift continues, creating a seismically active area around Mt. McKinley. Generally following the Alaska Range, the Denali fault system extends for about 750 miles (1200 km). In November of 2002, the magnitude 7.9 earthquake centered on the Denali fault east of the park ruptured the surface with up to 30 feet (9 m) of strike-slip offset. Seismic events of similar magnitude may occur in the park in the future.

Glacial History

During the past two million years, Denali's history has been characterized by repeated advances and retreats of a massive ice sheet. Over half of the park (Alaska Range and south) was intermittently covered by an extension of the ice sheet in Canada *(Figure 2)*. During glacial maxima, valley glaciers dominated the northern foothills of the Alaska Range, and ice lobes extended into the lowlands. As many as seven major glacial advances and several minor advance-retreat sequences have been identified on the north side of the range *(Thorson 1986)*. Landforms such as sculpted valleys, terraces, moraines, and kettle ponds are common in the northern river valleys.



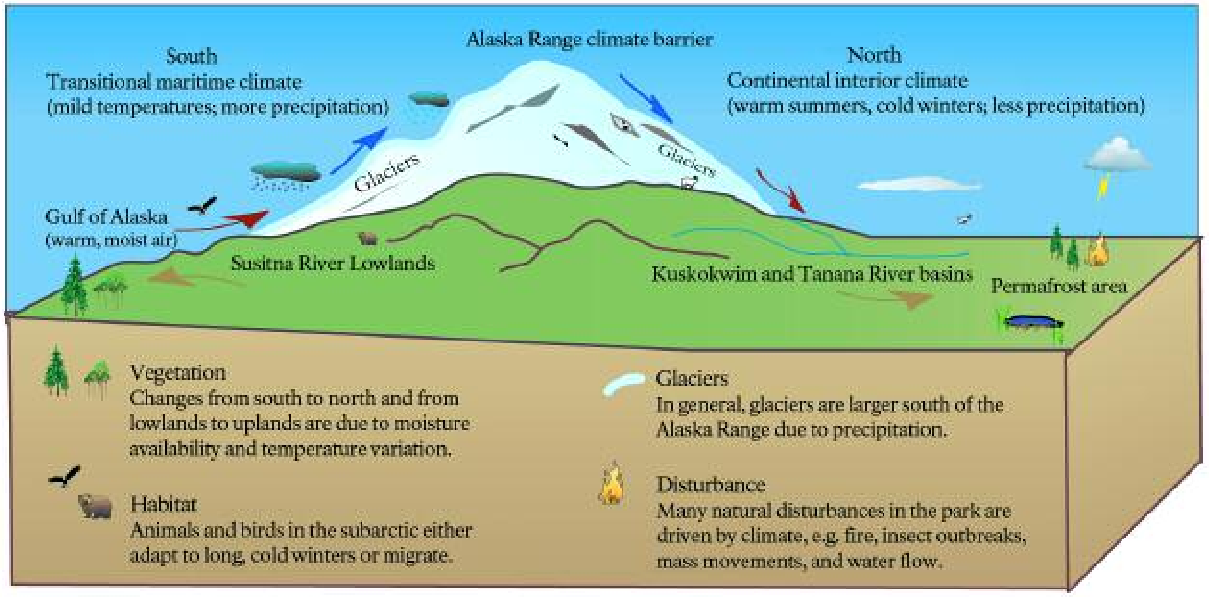


Figure 2. (Left) Map of North America showing extent of glaciation in relation to Alaska and Denali.

Figure 3. (Above) The two major climate zones in Denali National Park and Preserve.

During these Pleistocene glaciations, the northern area of the park was part of Beringia—a vast ice-free refuge for plants and animals, connected to northeastern Asia by the Bering Land Bridge, and isolated from the rest of North America by the ice sheet. These areas in Denali were probably colder and much drier than the present climate. Trees were essentially absent, and the vegetation was more tundra-like than today. Because of this history of repeated land connections to northern Eurasia with isolation from the rest of North America, there is a high degree of similarity of animals and plants between interior Alaska and north Asia.

Glacial ice has retreated significantly since the Pleistocene. Today, only about 16% of the park is covered by ice or perennial snow fields. However, glaciers continue to have a cooling effect near their termini and downstream. Glacial meltwaters affect local weather conditions and reconfigure floodplains downstream. Glacial action has been a major factor in breaking down rocks to produce the soils on which Denali's ecosystems depend *(Clark and Duffy 2004)*.

Climate

There are two distinct climates in the park, separated by the Alaska Range. They differ not only in physical measurements, but also in the types of vegetation and landscape features they produce *(Figure 3)*. South of the range, maritime air masses moderate air temperatures and bring considerable rain and snow. On the north side, an area of Arctic high pressure generates continental climate conditions with high variations in temperature and low precipitation.

At park headquarters (north of the Alaska Range), daily weather observations have been recorded since 1925. Temperature extremes range from 91°F (33°C) to -54°F (-48°C). Summers are short and warm, and winters are long and cold. The average daily high temperature in July is 66°F (19°C), and the average daily low temperature in January is -8°F (-22°C). Total precipitation is relatively low at 15 inches (382 mm). The sub-zero temperatures in winter coupled with relatively low snowfall contribute to the presence of widespread permafrost.

The climate south of the range is transitional between the mild and moist conditions near the Gulf of Alaska and the cold and dry of Interior Alaska. The mean annual precipitation at Talkeetna, southeast of the park border, is 28 inches (711 mm), nearly double that at headquarters. The average daily high temperature in July is 68°F (20°C), and the average daily low temperature in January is 1.4°F (-17°C). Along the southern flanks of the Alaska Range, snowfall is high, and snowcover is often present through late spring. Permafrost is generally absent.

Natural Disturbance

The local ecosystems are shaped by the physical environment (geology, glaciers, climate). Interactions among these factors and the habitat preferences of plants create

National Park Service photograph by Larissa Yocum

Figure 4. A thermokarst is ground subsidence resulting from melting permafrost.

the mosaic of vegetation on the landscape. For example, stunted scattered spruce in northern areas of the park grow over permafrost, while more lush vegetation is supported on permafrost-free areas. In addition, natural disturbances such as earth movements, fire, and water flow alter the local landscape patterns.

The major processes on the landscape vary across ecological zones. Geomorphic disturbances such as landslides, avalanches, and other mass movements predominate in the alpine region. Freeze-thaw conditions, especially in the active layer above permafrost, often create landform features such as slumps, gelifluction (creeping soil lobes), frost heaves, hummocks, and ice-wedge polygons. Thermokarst features (ground subsidence from melting permafrost) are found in isolated plateaus in the northeast portion of the park *(Figure 4)*.

Fire plays a dominant role in modifying the lowlands *(Figure 5)*, particularly in the basins north of the Alaska Range that are characterized by low precipitation and hot summers. The action of flowing water is another important natural disturbance process in boreal lowlands. Large braided glacial rivers such as the McKinley, Toklat, Yentna, and Chulitna are constantly reshaping the land by shifting channels, creating new floodplain deposits, and eroding old terraces with established forests. Beavers also have a considerable influence on the distribution of wetlands by impounding streams, especially in forested lowlands of the Yentna, Susitna, Kantishna, and Kuskokwim river basins.

Cultural Influences

Humans have been present in the Denali area for at least 11,000 years, but the park represents a rare place where human influence has never fundamentally altered the natural ecosystems. From the end of the last ice age until roughly 100 years ago, the upland areas were occupied seasonally by bands of hunters and gatherers who lived the rest of the year in forested areas near the larger rivers.

Because none of the large navigable rivers flowed near the high Alaska Range, the area that was to become the park was among the last parts of Alaska to be explored by non-natives. Explorers, prospectors, and trappers trickled into the area in the 1890s, and a series of gold strikes between 1903 and 1906 briefly brought large numbers of miners into the Kantishna area.

Concern about market hunting in the game-rich Alaska Range foothills was one of the driving forces that led to the creation of Mount McKinley National Park in 1917 *(Brown 1993)*. The Alaska Railroad was completed through Broad Pass and the Nenana Valley in 1923, providing tourist access to the park, and the park road to Kantishna was completed by 1938. Since 1972, visitors have had easy access to the park by way of the George Parks Highway between Anchorage and Fairbanks. Today, roughly 450,000 people visit the park yearly.

Ecology of Plants and Wildlife

Denali is located in the northern boreal forest biome *(Figure 6)*. The landscape is predominantly forested at elevations less than 2,500 feet (760 m), with scrub vegetation and spruce woodland in the subalpine zone (2,500 to 3,500 feet, 760 to 1070 m) and low tundra in the alpine zone (above 3,500 feet, 1070 m). Limits of local treeline and the subalpine and alpine zones depend on topography, site history, and local variations in climate.

Currently, there are 39 species of mammals and 165 species of birds documented in Denali, along with one amphibian (the wood frog), and 15 species of fish. More than 750 species of vascular plants grace the landscape, along with approximately an equal number of nonvascular plant species (mosses, lichens and liverworts) *(MacCluskie and Oakley 2004, Roland 2004)*.

Many birds that breed in Denali migrate long distances to reach the park, some from as far away as South America, Asia, and Africa. Great numbers of sandhill cranes and trumpeter swans create a stirring sight as they migrate in skeins above Denali.

Each year, king, silver, and chum salmon migrate more than 1,000 miles (1,600 km)

National Park Service photograph by Eric Olson

Figure 5. Fires are ignited by the frequent lightning strikes during summer storms.

from the Bering Sea to spawn and die in Denali's rivers, providing an important food source for many mammals and birds.

Boreal Lowlands

Denali's lowland zone includes black spruce forests and woodlands in areas underlain by permafrost and white spruce and paper birch forests in well-drained upland areas and river corridors *(Figure 7)*. Forests have become established in the last 6,500 years, after the last glacial retreat, but probably also existed during earlier interglacial periods. Recently disturbed and warmer south-facing slopes support stands of trembling aspen and balsam poplar. River bars support early successional herbs scattered among groves of balsam poplar, aspen, and spruce.

Shrubs that grow slowly in the cold soils of black spruce forests include alder, dwarf birch, Labrador tea, shrub cinquefoil, several species of willow, and blueberry. Black spruce stands burn periodically, so trees seldom reach ages beyond 120 years. Common shrubs in the more nutrient-rich spruce-birch forests are dwarf birch, rose, willows, and high-bush cranberry.

Interspersed in the forested areas are dry, open sites, wetlands and kettle-hole ponds. Dry sites often include a tangle of kinnikinnik, rose, and soapberry. The warmest, driest sites on the north side of the Alaska Range are dry meadows of grasses, sagebrush, juniper shrubs, and herbaceous perennials. Equivalent slopes on the south side can be lush meadows of grasses, lupine, geranium, and cow parsnip because even the dry slopes have more moisture. The wetland and riparian areas support sedges, rushes, grasses, forbs, and mosses.

An assortment of resident and migratory birds lives in the lowland forests including northern goshawk, great-horned owl, boreal owl, woodpeckers, black-capped and boreal chickadees, ruby-crowned kinglet, yellow-rumped warbler, and white-winged crossbill. Wetlands are nesting grounds for sandhill cranes, trumpeter swans, common loons, many species of waterfowl, arctic tern, northern waterthrush, and rusty blackbirds.

The most noticeable mammal in spruce forests is often the red squirrel, due to that species' high numbers, bold behavior, and daytime activity. But many other species with more secretive lifestyles, including voles, lemmings, shrews, snowshoe hares, and flying squirrels, are also common in the taiga forest. These small mammals provide the food base for a variety of medium-sized predators, including lynx, marten, and red foxes. Several species of large mammals live at low densities throughout the lowland areas but are more common in higher elevation areas. These include moose, wolves, caribou, and grizzly bears. The black bear is the only large mammal species that is more common in the lowland areas of the park than in the higher elevations.

Subalpine

In the subalpine zone, there is a mosaic of scrub vegetation (dwarf birch, alder, and willow), open spruce woodland, and meadow (see photo page 6). Near treeline, the land cover shifts from open woodland to tundra shrubs (willow, blueberry, dwarf birch, rhododendron), dwarf shrubs (bearberry, mountain avens, crowberry, and netted willow), grasses, and annual plants.

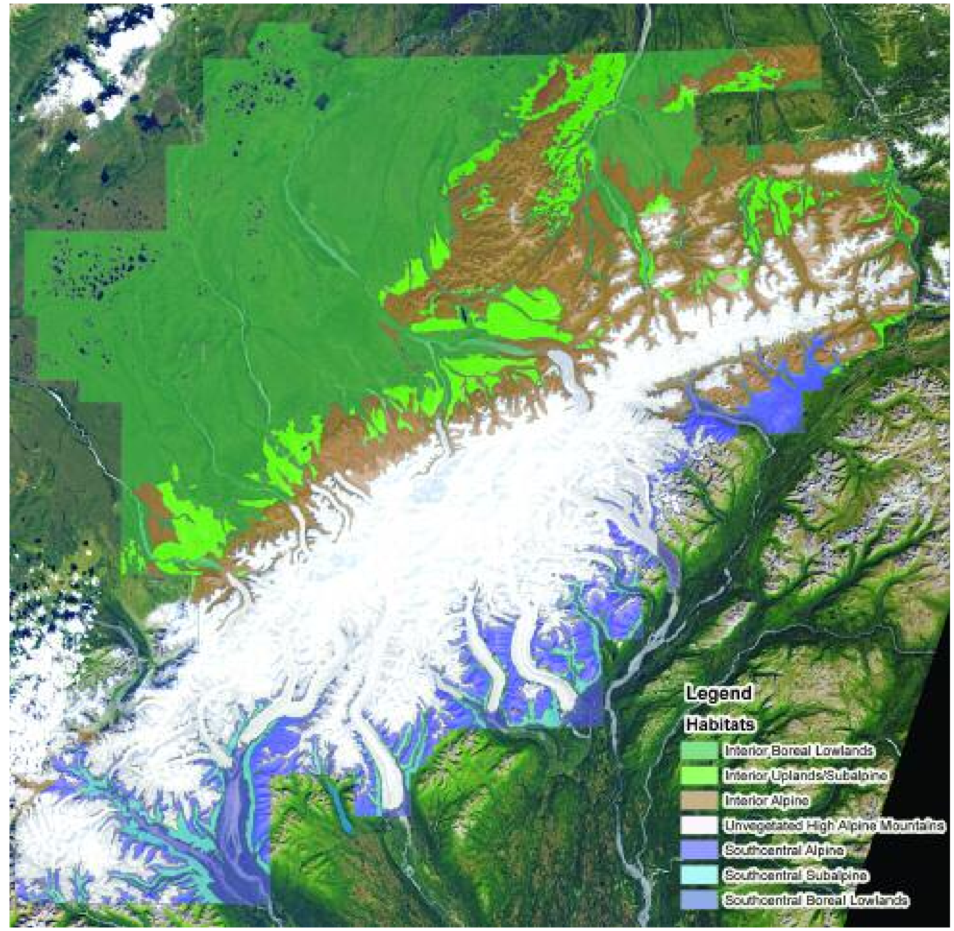


Figure 6. Satellite photo of Denali with overlay of major habitats.

Bird denizens of this zone include willow ptarmigan, northern harrier, merlin, upland sandpiper, northern hawk-owl, arctic warbler, olive-sided flycatcher, gray-cheeked and Swainson's thrushes, fox sparrow, golden-crowned sparrow, blackpoll warbler, and orange-crowned warbler.

The subalpine zone is the area most visited by humans today, and provides the scenery and wildlife viewing that we commonly associate with the park. It is here that the park road provides not only vistas of the Alaska Range, but unparalleled opportunities for visitors to see grizzly bears, caribou, Dall sheep, moose, and wolves. Other commonly seen mammals in the subalpine zone are arctic ground squirrels, snowshoe hares, porcupines, and red foxes.

National Park Service photograph by Thomas Meier

Figure 7. Interior boreal lowlands, Bearpaw River.

Alpine

The species growing in Denali's alpine tundra vary according to site characteristics and geographic location. In areas of frequent landslides and avalanches, the high slopes are barren or support only a few scattered herbaceous plants. Typically, the alpine tundra includes mountain avens, dwarf willows, dwarf shrubs (such as bearberry, cassiope, and crowberry), grasses, and forbs *(Figure 8)*.

Where snowmelt is late, as on north-facing slopes, the alpine zone also includes spring beauty, mountain heather, mountain sorrel, and buttercups. In sunny but moist areas, the vegetation is a mixture of dwarf shrubs and sedges. On windswept ridges, lichens add to the relatively sparse cover of mountain avens and grasses. Dry sites can be variable (from scattered grasses to complete plant cover) depending on the growing conditions, but harbor some of the rarer plants, including many species with evolutionary roots in the Beringian tundra and ultimately in Asia.

A diverse community of open-landscape birds lives in the alpine region including golden eagle, gyrfalcon, white-tailed ptarmigan, American golden-plover, surfbird, long-tailed jaeger, horned lark, northern wheatear, and gray-crowned rosy finch.

Dall sheep are among the most obvious and spectacular residents of the alpine habitats. Other large mammals, including wolves, caribou, and grizzly bears, spend much of their time in the alpine zone. Pikas and hoary marmots are two of the park's mammal species that live only in alpine areas.

Unvegetated High Alpine

Nearly one-third of the park is made up of high, glaciated mountains and bare rock outcrops *(Figure 9)*. The upper limit of plant growth is about 7,500 feet (2290 m). Above 8,000 feet (2440 m), alpine areas are generally covered by glacial ice. Only scattered traces of vegetation occur there, mostly lichens on isolated patches of bare rock.

No birds or mammals make their homes in these barren reaches, but wolverines, wolves, and caribou occasionally negotiate high mountain passes, ravens and redpolls are seen at very high elevations, and many species of birds migrate over the mountains. More than 1,000 humans annually attempt to climb Mt. McKinley during the spring and early summer climbing season, but for most of the year and for most of the area, the mountains and icefields are nearly devoid of life.

The Future

Despite being a wilderness park, Denali faces threats from human activity on many scales, including increased tourism and development, introduction of exotic species, increased hunting pressures, and accumulation of trace amounts of global airborne

More than 1,000 humans annually attempt to climb Mt. McKinley during the spring and early summer climbing season, but for most of the year and for most of the area, the mountains and icefields are nearly devoid of life.

National Park Service photograph by Carl Roland

Typically, the alpine tundra includes mountain avens, dwarf willows, dwarf shrubs (such as bearberry, cassiope, and crowberry), grasses, and forbs.

Figure 8. (Left) Interior alpine.

Figure 9. (Right) Unvegetated high alpine.

National Park Service photograph by Thomas Meier

contaminants. The retreat of glaciers and changes in vegetation due to climate change are easily seen in photographs taken only decades apart. These influences and their effects are difficult to measure, but they may dramatically alter the distribution and visibility of wildlife. Park management faces an increasing challenge to protect resources in the face of climate change and other human effects.

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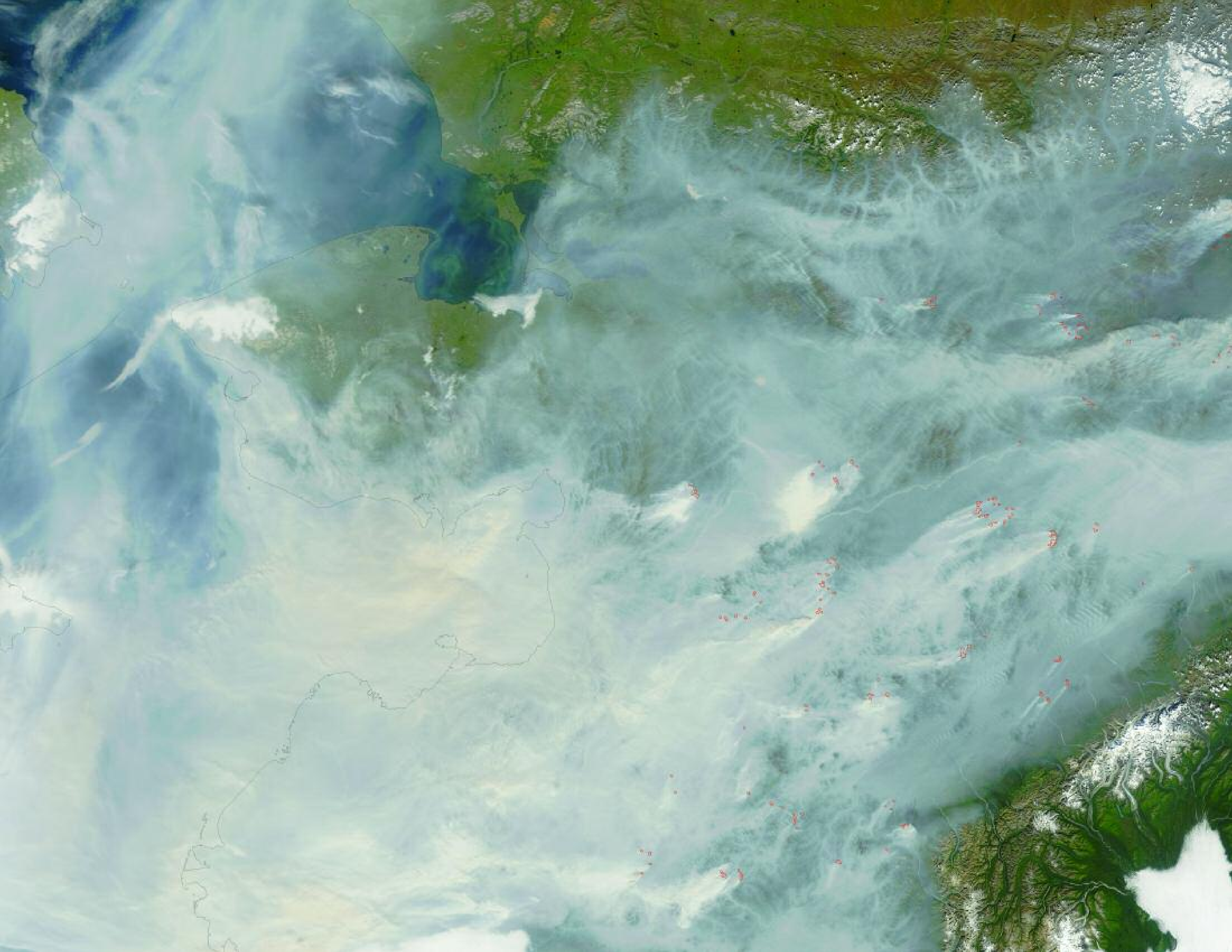


MODIS Rapid Response Team, NASA Goddard Space Flight Center

Air Quality Monitoring: An Intercontinental Connection

By Andrea Blakesley

On a clear day, Mount McKinley dominates the landscape from the vantage point of Wonder Lake, impressively tall and snowy, seemingly close enough to touch. These are the days when people in Anchorage look out their windows 130 miles away to gaze at the mountain on the horizon, and the air quality monitoring instruments near park headquarters measure some of the cleanest air in the nationwide monitoring network. This is the Alaska that people expect to see when the weather cooperates—clean, crisp views of distant snowy peaks, and deep blue skies above.

But some days, the view is obscured by more than clouds. During the summer, wildfires burn throughout Alaska, agents of change and renewal in the state's relatively undisturbed arctic and subarctic ecosystems. Some years, wildfire smoke blankets wide swaths of the state, a naturally occurring nuisance that can be seen from outer space. At ground level, the smoke can sometimes make the mountains disappear, causing eyes to sting and lungs to burn. But like the troublesome mosquitoes, which are an integral part of Denali's food web, the lightning-sparked wildfires and their accompanying smoke play an important ecological role. As long as the fires are burning in areas where they do not threaten human life or valuable cultural resources, the smoke must be tolerated or avoided, not suppressed.

With the availability of satellite imagery today, it is fairly straightforward to determine which fires send smoke swirling into the park. In addition to smoke from fires in Denali and around the state, traces of smoke from fires as far away as Canada, Russia, and Indonesia have been documented in Denali. In 2004, the largest fire year on record in Alaska, wildfire smoke from Alaska fires extended as far south as the Mississippi River Delta. Since wildfire

(Left) Wildfire smoke covers much of Alaska in this MODIS satellite image taken during the 2005 fire season.

Mt. McKinley from Wonder Lake on a clear day.

smoke is observed to travel such long distances, is it reasonable to expect that human-caused pollution does not follow some of the same pathways across and between continents? The answer seems obvious now, but before satellite imagery was widely available, conventional wisdom held that pollution was primarily a local and regional phenomenon. Places like Denali, a six million acre wilderness tucked away in a vast, sparsely populated, sparsely industrialized state, seemed safe from pollution.

Therefore, when nationwide air quality monitoring networks were established to address airborne contaminant issues such as acid rain, reduced visibility, and smog, they included Denali as a “background” site, a monitoring station which was expected to measure air quality conditions close to pre-industrial values. The experts turned out to be not far off the mark. Through 25 years of continuous air quality monitoring, Denali nearly always records the cleanest values in the country. However, when the data are analyzed for trends, some curious patterns emerge, leading to questions such as: a) why do small amounts of sulfur compounds show up each winter, grow in concentration until they peak in early spring, and diminish again in the summer? and b) why does dust show up on the monitoring filters in springtime when there is still snow on the ground in Interior Alaska?

The simple answer to both questions is that Denali is linked to the rest of the world through atmospheric pathways that carry industrial and agricultural contaminants, as well as smoke and dust, across the oceans from one continent to another. Two pathways in particular carry airborne contaminants to Denali, each with a characteristic seasonal pattern of transport.

The first pathway brings industrial pollution over the North Pole into arctic and subarctic regions around the world, primarily from metal smelters and power plants in Europe and Asia. The resulting pollution is called arctic haze, named for the visible haze layers first documented in arctic Canada and Alaska, far from any known sources of pollution. Arctic haze occurs during winter and early spring, when the arctic air mass covering the top of the globe expands into industrial areas and traps airborne contaminants within its circumpolar boundary. The arctic air mass is cold, stable, and relatively dry, so there is limited opportunity for pollution to be washed out of the air through rain or snowfall. Sulfates and sulfur dioxide, two important components of arctic haze, demonstrate this strong seasonal pattern in Denali, though in relatively low concentrations.

The second pathway brings airborne contaminants directly across the Pacific Ocean into western North America. At times, these air currents sweep across deserts in Asia before crossing the ocean, picking up soil particles along the way. Like wildfire smoke, dust storms can be seen in satellite photos, serving as tracers for the invisible pollutants carried along by the same winds. This is why dust is often found on Denali air quality monitoring filters in springtime while the ground in Alaska is still frozen and covered with snow.

Although the amount of pollution reaching Denali from international sources is currently low, knowledge that the park’s air quality is affected by sources thousands of miles away is a concern as well as a reminder of the numerous connections that exist between continents. Airborne contaminant pathways are like superhighways in the sky, carrying the equivalent of either sparse or heavy traffic. If emission levels increase in the source areas over time, pollution will increase in Denali. As the global human population continues to grow, industrial and agricultural contaminants are bound to increase as well.

The good news is that emission control technology is continually improving, significantly decreasing emissions where control measures are in place. If we tackle international pollution problems as a species, rather than as members of particular nations, regions, or continents, then remote wilderness areas like Denali will continue to inspire future generations with their crisp air and spectacular vistas.

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National Park Service photograph

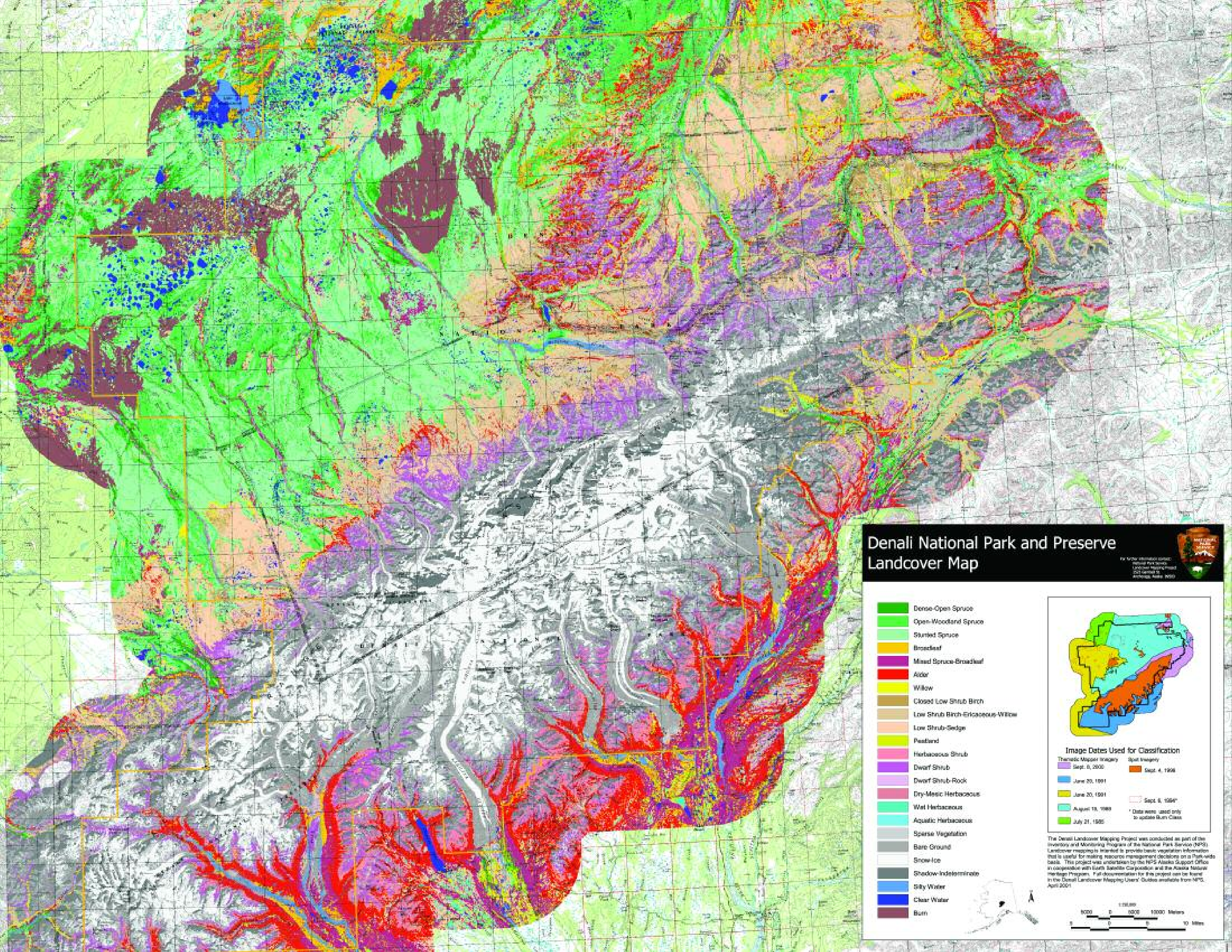
Air quality monitoring shelter near park headquarters.

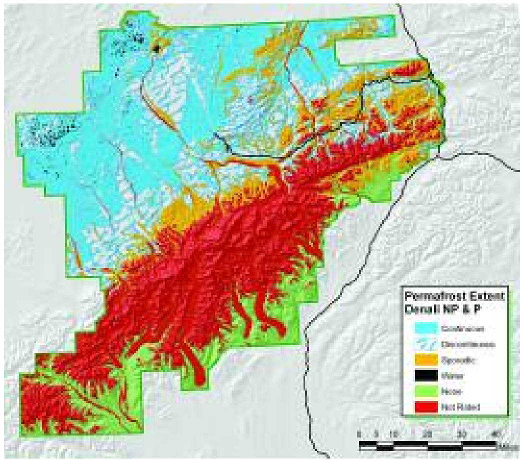
National Park Service photograph

The Denali web camera, which runs on solar power, documents visibility conditions during the summer months. www2.nature.nps.gov/air/webcams/parks/denacam/denacam.cfm

National Park Service photograph

Wildfire smoke obscures the view from 17,200 feet on Mt. McKinley.


Denali National Park and Preserve
Landcover Map
Dense-Open Spruce
Open-Woodland Spruce
Stunted Spruce
Broadleaf
Mixed Spruce-Broadleaf
Alder
Willow
Closed Low Shrub Birch
Low Shrub Birch-Ericaceous-Willow
Low Shrub-Sedge
Peatland
Herbaceous Shrub
Dwarf Shrub
Dwarf Shrub-Rock
Dry-Mesic Herbaceous
Wet Herbaceous
Aquatic Herbaceous
Sparse Vegetation
Bare Ground
Snow-Ice
Shadow-Indeterminate
Silty Water
Clear Water
Burn
Image Dates Used for Classification
Thematic Mapper Imagery
Spot Imagery
Sept. 4, 1998
June 20, 1991
August 18, 1988
July 21, 1985
* Data were used only to update Burn Class
The Denali Landcover Mapping Project was conducted as part of the Inventory and Monitoring Program of the National Park Service (NPS). Landcover mapping is intended to provide basic vegetation information that is useful for making resource management decisions on a Park-wide basis. This project was undertaken by the NPS Alaska Support Office in cooperation with Earth Satellite Corporation and the Alaska Natural Heritage Program. Full documentation for this project can be found in the Denali Landcover Mapping Users' Guides available from NPS. April 2001
Meters
Miles



The Denali Soils Inventory allows users to generate interpretive maps that display data at any desirable scale. This example illustrates the permafrost distribution across Denali.

National Park Service photograph

NRCS Soil Scientist Mark Clark, the primary field scientist for the soil inventory, shown here making observations in the Toklat Basin.

(Left) The Denali Landcover Map delineates 23 cover classes that allow visitors and researchers to quickly comprehend the scale and distribution of the primary vegetation classes.

Ecological Goldmine: The Denali Landcover Map and Denali Soil Inventory with Ecological Site Classification

By Guy Adema, Jess Grunblatt, Mark Clark

The Inventory and Monitoring Program has recently produced two new tools for natural resource monitoring and management of Denali National Park and Preserve: a comprehensive soil inventory and ecological classification, and a landcover map based on satellite imagery. The products provide researchers, educators, and managers data that will allow for more informed research design, detection of natural resource change at a park-wide scale, more accurate and comprehensive education material, and baseline information for park management.

The landcover mapping program was completed by the NPS Alaska Support Office in collaboration with the Alaska Natural Heritage Program (University of Alaska Anchorage) and Earth Satellite Corporation (Rockville, MD). The development of the landcover map involved collection and analysis of field-verified datasets, and the analysis and interpretation of remotely sensed imagery (satellite and aerial photography). Landcover was mapped at intermediate scales (1:63,360 to 1:100,000) with 25 classes, following a modified version of the Alaska Vegetation Classification system. The classification system was based primarily on vegetation structure (plant height) and form (tree, shrub or herbaceous), and to a lesser extent genera and species information. Landsat Thematic Mapper multi-spectral imagery was the primary data source, and SPOT XS data was the secondary source. Digital image processing was refined through iterative modeling using environmental and spectral data layers such as slope, elevation, the Normalized Difference Vegetation Index (NDVI), and available field data.

The landcover map allows users to understand the distribution of vegetation across the landscape and determine relative distribution of plant associations across the park. The most dominant of the 25 landcover classes are: snow-ice (16%), stunted spruce (14%), bare ground (10%), low shrub birch-ericaceous-willow (10%), open-woodland spruce (9%), shadow (7%), and dwarf shrub (6%). Plant associations were described using the ground data and a literature review. Plant associations provide a hierarchical link between the coarse scale landcover classes and finer scale species information.

While the landcover map provides an overall view of the plant cover types and their distribution, the recently completed soil inventory provides detailed mapping and site information, including comprehensive ecological site classifications for over 2,200 sites in Denali. The survey was a cooperative effort of the Natural Resources Conservation Service, the National Park Service, and the University of Alaska Fairbanks. The final product, a result of fieldwork completed from 1997 to 2002, includes a 1:63,360 scale soils map with an attribute database and metadata, a database containing detailed soil and ecological data, digital site photographs, landtype and map unit distribution maps, figures, illustrations, soil temperature graphs, and a complete orthophoto mosaic of Denali. The data provide a comprehensive delineation of park ecosystems, including new discoveries of range extensions and previously undocumented natural processes in the park. The spatial database allows user-defined interpretations, including permafrost extent, extent of potential natural vegetation, landscape processes, and countless other queries.

Soundscapes of Denali National Park and Preserve

By Chad Hults and Shan Burson

Soundscapes, the combined sounds from natural and non-natural sources, are recognized as an important resource in national parks. The natural soundscape is generally comprised of two main sound categories — those from biological or those from physical sources. Organisms such as

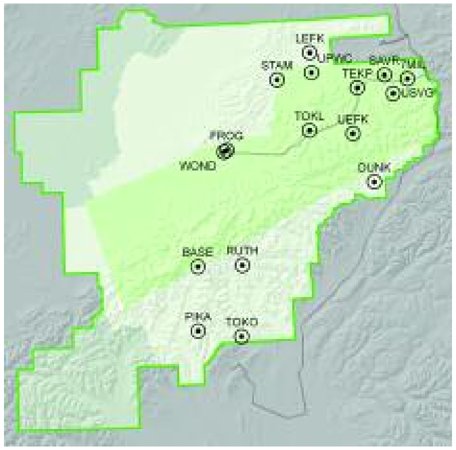


Figure 1. Sound monitoring locations in Denali National Park and Preserve, 2000-2005.

(Left) Sound station microphones at the Upper East Fork Toklat River location near Sable Pass, July 2004.

birds, frogs, and plants, create biological sounds, while forces such as wind, rock fall, and rivers, create physical sounds. These two types of sounds can be used to characterize different habitats. The specific soundscape characteristics are an important attribute of Denali National Park and Preserve's (Denali) natural systems, for non-natural sounds can obscure or disturb ecological functions, as well as adversely influence visitor experiences *(NPS 1995)*.

Natural soundscapes are components of "the scenery and the natural and historic objects and the wildlife" as protected by the Organic Act *(Public Law 64-235)*. They were specifically recognized and protected by the National Parks Overflights Act of 1987 *(Public Law 100-91)*. Due to ongoing concern about aircraft overflight noise, the National Parks Air Tour Management Act was established, which requires the Federal Aviation Administration and the National Park Service to cooperatively develop air tour management plans for any park where commercial air tour operations exist or are proposed *(Public Law 106-181)*. Although Alaska parks were excluded from the act, they were not excluded from aircraft noise and other influences on the natural soundscape and visitor experience.

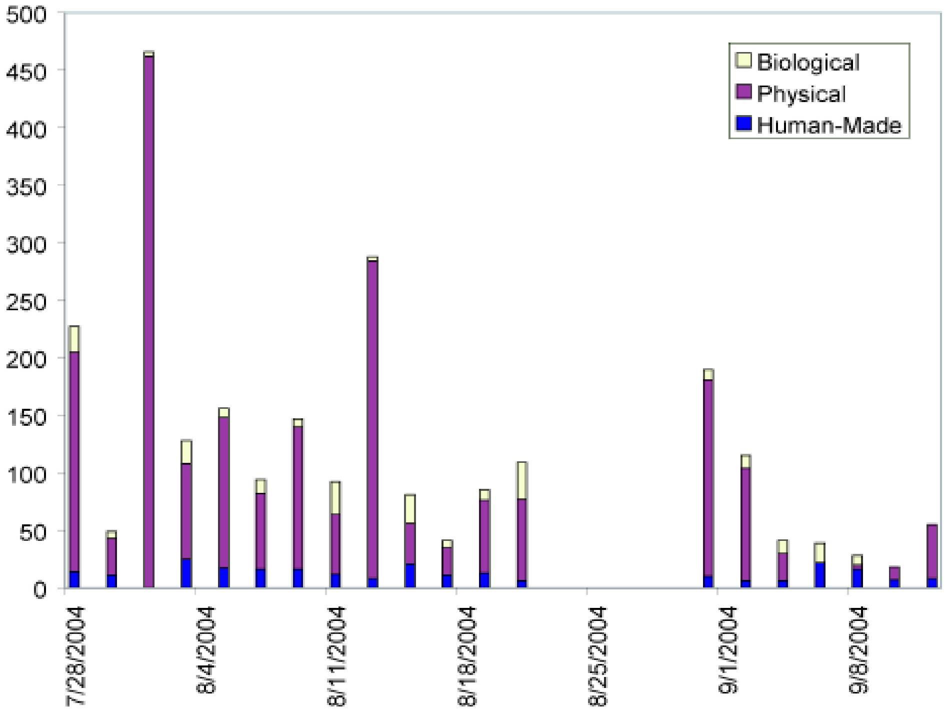


Figure 2. Quantity and types of sounds audible at the Upper East Fork Toklat River (UEFK in Figure 1) location, July-September 2004. Each bar represents the number of recording samples for each type of identified sound. Days without sounds were not analyzed.

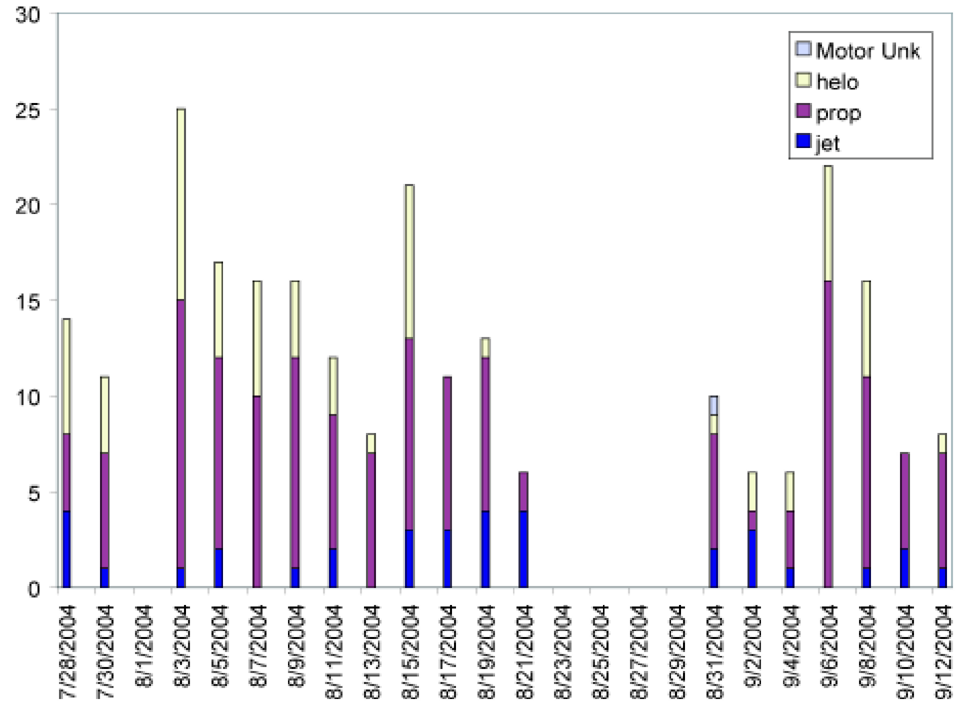


Figure 3. Quantity and type of non-natural sounds audible at the Upper East Fork Toklat River location, July-September 2004. Each bar represents the number of recording samples for each type of identified sound.

By 2000, park managers recognized that the natural soundscape of Denali was increasingly affected by non-natural sounds. Because preserving the natural soundscape also helps preserve the associated wilderness values and visitor experiences, a soundscape program was initiated. The hope was to better understand, manage, and preserve the natural soundscape of Denali. In addition, soundscape measurements provide objective scientific data for future management decisions.

Systematic measurements of the current acoustic conditions of all major habitats, air traffic corridors, and management zones in Denali have begun and a preliminary baseline study will be completed by 2008. Four automated sound stations collect data every summer, with fewer locations sampled during the winter. Soundscape data has been collected at 16 locations *(Figure 1)*. Representative areas were chosen for sampling in the three major acoustical zones (alpine, alpine tundra, and boreal forest/scrub), and to compare areas of low and high motorized use. Each sound station records sound levels every second and collects five-second digital recordings every five minutes (288 samples per day). With this information we can identify the sound sources present at each sampling location, the sound levels of each sound source, and calculate the number of times per day each sound is audible. These data are used to compare the natural ambient sound levels to the sound levels of non-natural sounds. From the data analyzed to date, wind is the most widespread natural sound in all areas, and aircraft overflights are the most common human-generated sound.

Soundscape data can be displayed in many ways. For example, Figure 2 illustrates the number and types of sounds audible at the Upper East Fork Toklat River location. The biological sounds at this site consist of bird song and insect sounds. The physical sounds consist primarily of wind, with some rain. The type and number of non-natural sounds recorded are shown in *Figure 3*. The Upper East Fork Toklat River sound station was placed

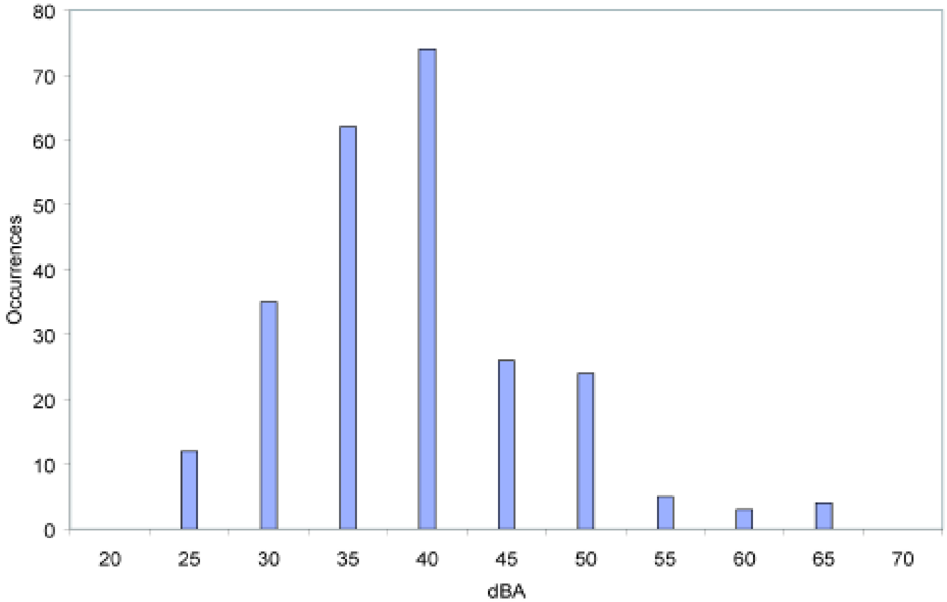


Figure 4. The sound levels of aircraft overflights audible at the Upper East Fork Toklat River location, July-September 2004. The sound level of most overflights were between 30 and 45 dBA, with a maximum of 65 dBA.

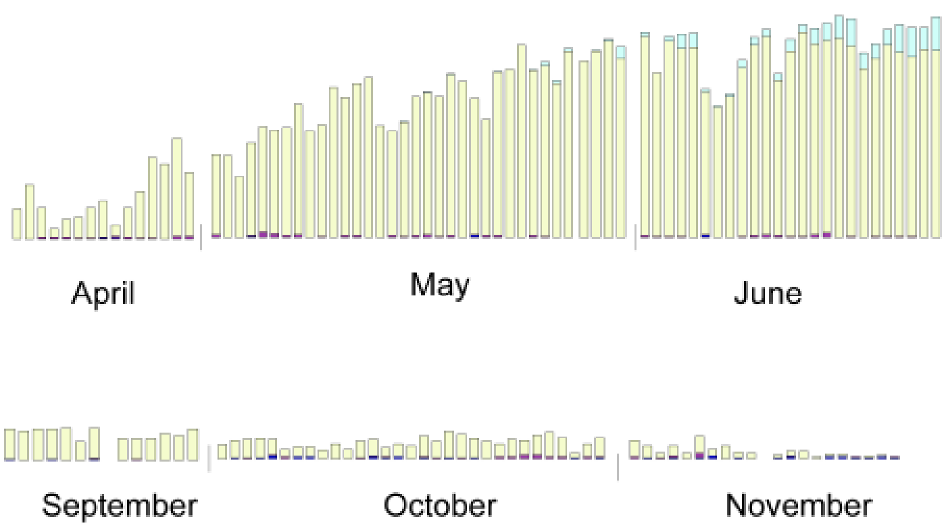


Figure 5. Daily number and type of animal sounds audible at the Stampede Airstrip (STAM in Figure 1) location. Red = squirrel, yellow = bird, blue = mosquito.

along a popular flightseeing corridor in 2004. Most days analyzed had at least five aircraft with a maximum of twenty-five aircraft recorded on August 3 *(Figure 4)*. Weather also influences the number of motorized sounds heard. Strong wind can mask other sources of motorized sound, and aircraft often do not fly on days with inclement weather. For example, August 1 was windy and raining, and there were no aircraft audible. The highest number of audible aircraft was two days later on August 3, and the number of aircraft overflights remained high for the next two weeks.

The natural ambient sound level at the Upper East Fork Toklat River location is 30 dBA ±5 (dBA is the sound level, in decibels, weighted for human hearing), calculated using the median sound level after removing motorized sound levels. The natural ambient level at this site is higher than many other sites (typically around 25 dBA) because of a small steep creek nearby. Many sites have sound levels lower than the 18 dBA detection minimum of the microphone, therefore we are not able to calculate the absolute minimum natural ambient levels presently.

Additional benefits of making audio recordings over long time periods include the capturing of animal sounds and estimating species presence/absence, distribution, and number of times audible per day *(Figure 5)*. As expected, animal sounds gradually increase during the spring and are much less frequent during the fall. These soundscape recordings are supplementing ongoing bird surveys.

Soundscape studies are relatively new for the National Park Service. The Denali Soundscape Program is developing new techniques and important information about soundscapes in Alaska parks. As identified in a new draft management plan, soundscape measurements are an important indicator of the level of human influence on park resources (NPS 2005). Information provided through this program will help managers protect natural soundscapes and preserve high quality visitor experiences in Denali.

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Photograph courtesy of Steve Estes, Alaska Earthquake Information Center

Maintenance at the seismic site KTH (Kantishna Hills) in the autumn.

Earthquake and Seismic Monitoring in Denali National Park

By Roger A. Hansen

Denali lies in the heart of earthquake country, and visitors may be treated to a ground shaking experience. Scientists, on the other hand, view the park as a natural laboratory for studying earthquakes and tectonics. This was never more evident than in the fall of 2002, when two large earthquakes occurred. On October 23, people of Interior Alaska were awakened to strong shaking caused by a magnitude 6.7 earthquake. The epicenter was located west of Nenana Mountain on the Denali fault, 2.6 miles (4.2 km) beneath the ground surface. Though damage from this quake was limited to a small area around the epicenter, it was only the beginning of a larger sequence of events. Ten days later on November 3, a magnitude 7.9 earthquake began to the east of the Nenana Mountain earthquake and ruptured for nearly 217 miles (350 km) to the east. The fact that the Denali fault continues from the eastern boundary of the park westward into the park is one of the many reasons that the Alaska Earthquake Information Center (AEIC) maintains an active monitoring and research program in Denali.

The tectonics of Alaska is dominated by the processes associated with plate tectonics. Earthquakes are caused by the movements of tectonic plates that form the earth's crust and occur at the boundaries where the plates meet. Along the southern coast of Alaska, the Pacific plate is colliding with Alaska (the North American plate), with a convergence rate of 2-3 inches (5-7.5 cm) per year. This gives rise to the subduction zone (the sinking of the Pacific plate underneath Alaska) and the cause of the many deep earthquakes that occur throughout Alaska and the Aleutian Islands. The subducting Pacific plate makes a fairly sharp bend directly under Mt. McKinley and is particularly seismically active at that location. This seismicity is often referred to as the McKinley Cluster.

In addition to convergence by subduction, deformation of the continental plate due to this collision extends far into the Interior creating a system of long crustal faults. The Mt. McKinley massif is bounded to the north by such a fault, the Denali fault, where inferred right-lateral motions are ~0.5 in/yr (~1 cm/yr). This fault extends

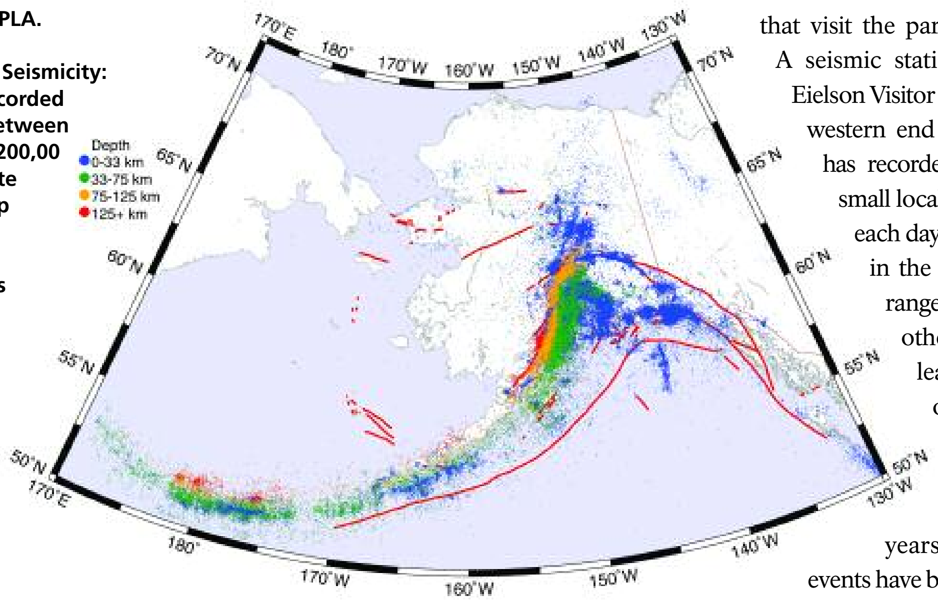
Photograph courtesy of Steve Estes, Alaska Earthquake Information Center

Scouting trip for station PPLA, in the southwest corner of the park.

Photograph courtesy of Steve Estes, Alaska Earthquake Information Center

(Left) Installing station PPLA.

(Right) Historic Regional Seismicity: The distribution of all recorded earthquakes in Alaska between 1898 and 2004 (roughly 200,00 events). Of particular note is the orientation of deep earthquakes along the Alaska Subduction Zone from the Aleutian Islands to Denali National Park, and the concentration of shallow earthquakes in Southcentral and Interior Alaska.



from Southeast Alaska, through the Alaska Range and Denali National Park, and west towards the Bering Sea. The lateral horizontal motion of this fault is a result of the Pacific plate pushing the Yakatat block against North America in Southcentral Alaska. The crustal material south of the fault is essentially rotating past the crust to the north with a pole of rotation near the Kenai Peninsula. The question remains when, not if, an earthquake will occur on sections of this fault not ruptured in 2002.

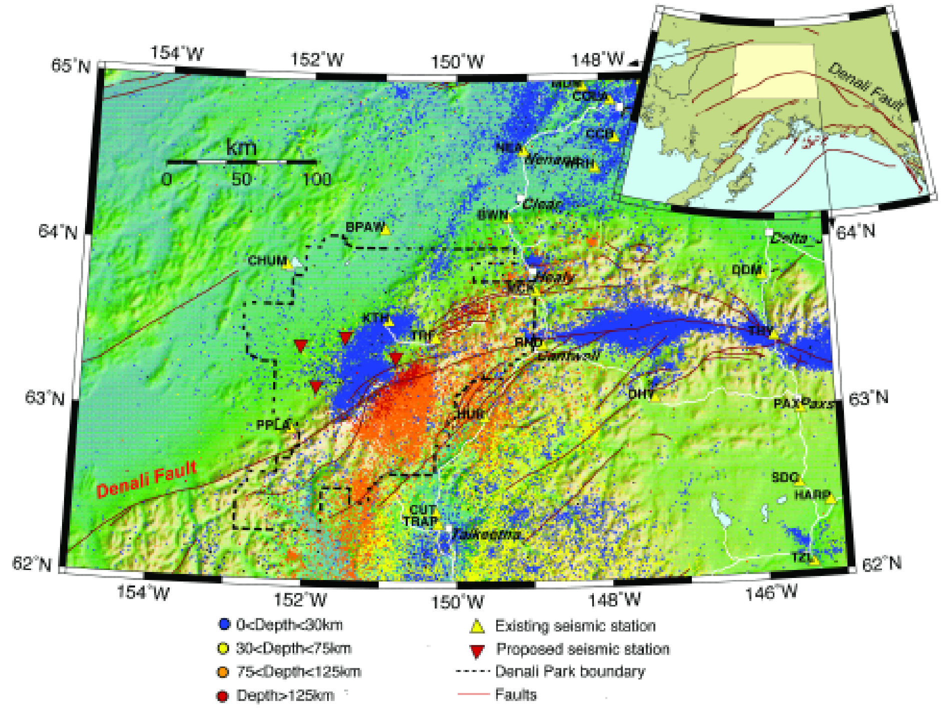
Just north of Mt. McKinley, on the other side of the Denali fault, is a second cluster of seismic activity. Over the last several decades, the crustal seismicity in the Interior of Alaska has been dominated by the Kantishna cluster, located at the western end of Denali. Events in the Kantishna cluster are commonly felt by the people of Kantishna, the employees of the park, and the half-million or so tourists that visit the park each year. A seismic station near the Eielson Visitor Center, at the western end of the park, has recorded dozens of small local earthquakes each day, earthquakes in the magnitude 2 range nearly every other day, and at least one event over magnitude 4 each year. Over the last ten years over 2,700 events have been recorded (about 270/year) with 163 each year greater than or equal to magnitude 2. The largest earthquake to occur in the cluster was magnitude 5.2.

While the Kantishna cluster is not on the visible trace of the Denali fault, it may be related to the Denali fault system. The Kantishna cluster also lies along the southwest extension of the Minto Flats Seismic Zone, a northeast-southwest striking zone of earthquakes between the Tintina fault to the north and the Denali fault to the south.

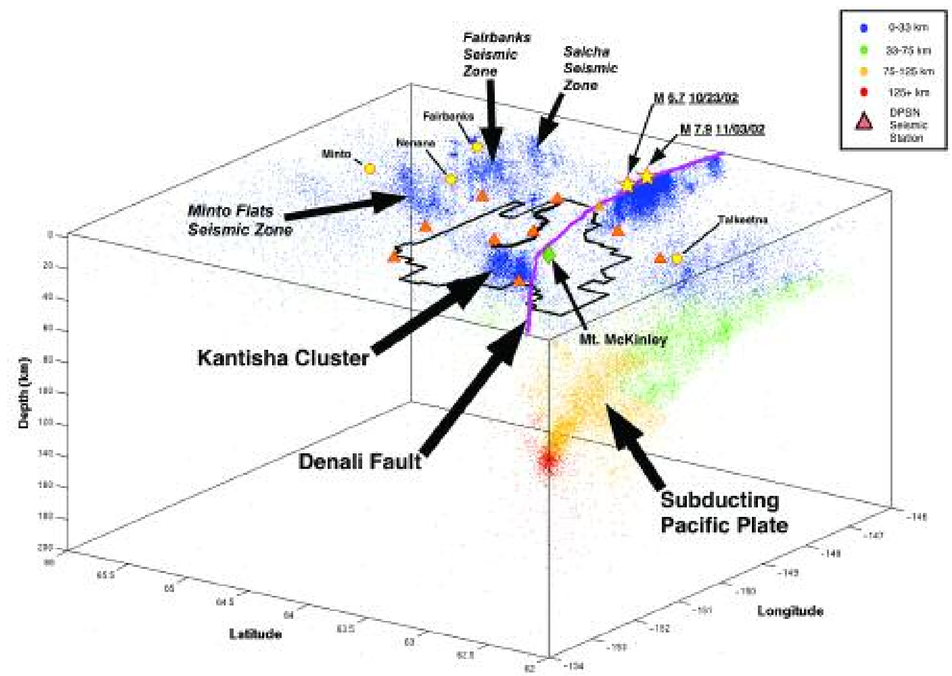
It is clear that many earthquakes occur on structures (faults) that radiate from or are parallel to the Denali fault. The more interesting question is to understand why the Kantishna cluster is more active than the other major features in the area, including the Denali fault. Is it possible that motion associated with the Denali fault system is being redirected to other active features? How is this motion related to the uplift associated with Mt. McKinley? The recent magnitude 7.9 Denali fault earthquake provides additional motivation to understand the seismicity in the region. Will the rupture of the central segment of the Denali fault have a noticeable effect on the western section of the fault running through the park? Will the western section of the Denali fault rupture in the near future producing another large earthquake? Broader questions include: What factors contribute to the continued growth of Mt. McKinley? Is there a relationship between the Kantishna cluster, the Minto Flats Seismic Zone, and the McKinley cluster?

Answers to these questions will come from careful analysis of the seismic observations of the earthquakes and associated deformations. To accomplish this, AEIC has been upgrading and expanding the seismic network in Denali and the surrounding area. Currently, there are three seismic stations installed in the park, with another seven surrounding the park. In order to observe the seismic wavefield from an earthquake for advanced analysis we need stations every 6 to 12.5 miles (10-20 km). Future plans are to move in this direction, particularly around the Kantishna area and Denali fault. The first step is a new station to be installed to the west of Kantishna in summer 2006.

Through the partnership between the park and AEIC, much of the Denali Seismic Network will be available for use in the Murie Science and Learning Center. This will create the opportunity for public education on how seismic waves are recorded, analyzed, and used in research to study tectonics and earthquakes. Park staff have already been instrumental in the deployment, maintenance, and telemetry of the seismic stations and data, and continued interaction will expand public displays and presentations related to this ongoing research.



(Right-top) Locations of the existing and proposed seismic monitoring stations in the vicinity of Denali National Park. Also included are the known faults and earthquake locations as color coded dots.



(Right-bottom) Denali Region 3-D Seismicity, 1898-2004: A 3-d projection of all earthquakes in the region of Denali National Park between 1898 and 2004, showing both shallow crustal events and deep events associated with the Alaska subduction zone.

Photograph courtesy of Victor Van Ballenberghe

Rutting Behavior of Moose at Denali National Park

By Victor Van Ballenberghe

In 1980, I began a long-term study of moose ecology at Denali National Park and Preserve (Denali). One study component was behavioral ecology—the interrelationships between behavior and ecological factors that moose experience. We were particularly interested in the behavioral ecology of the rutting (mating) season when moose display behaviors not seen at any other time of year. From late August to mid-October, summer feeding gives way to increased social behavior as moose are preoccupied with reproducing.

At Denali we were able accomplish more than other biologists had previously because moose were abundant and observable in most habitats. In addition, we could approach moose closely without disturbing them or placing ourselves in danger.

Aerial observations indicate that large bulls controlled groups of cows during the rut, and smaller bulls wandered in search of cows away from groups or hung around the edges of groups hoping to mate when the large bulls were distracted.

The studies of rutting behavior began with descriptions of the behaviors that moose displayed. After five years and about 1,000 hours of observation, we compiled a good catalog of rutting behavior—recording the frequency of each behavior, and its duration. Separate categories for cows and bulls were established as their behaviors were vastly different, and bulls were grouped by size in order to test whether the mature, largest males did most of the mating, as we suspected.

My colleagues and I were interested in more than just describing moose behavior. That was merely the first step. Much more interesting was the next phase, to develop and test hypotheses that explained the function of these behaviors. Moose evolved certain behaviors for definite reasons, and they invested a lot of energy and time performing them. As we observed moose during the rutting season, numerous questions arose. Why did large bulls cease feeding

Photograph courtesy of Victor Van Ballenberghe

During the rutting season in September and October, cows and bulls display distinct behaviors related to courtship. Here, a cow carefully approaches a dominant bull in order to signal her interest in mating.

for two weeks prior to mating? Which bulls were most successful in mating, and what factors determined their success? Why did young males spend so much time sparring? Why did mature bulls risk death by fighting? After we catalogued rutting behavior, we set about conducting studies to answer these and other questions.

One topic we were anxious to study was mating success of individual bulls in relation to age, size, and dominance rank. Before studying moose at Denali, I had observed many of them during the autumn rutting season from airplanes. The aerial observations indicated that large bulls controlled groups of cows during the rut, and smaller bulls wandered in search of cows away from groups or hung around the edges of groups hoping to mate when the large bulls were distracted. Although I never saw fights or mating from the air, some of the bulls showed signs that they had fought, including broken antler tines, and mating was obviously occurring. The brief amounts of time that we spent circling moose, often only a few minutes each day, did not allow much opportunity to see important behaviors.

At Denali we were able to spend large amounts of time observing moose on the ground, for the moose had not been hunted for several decades, and there were large numbers of big bulls present. We tried to determine which bulls were most successful at mating and which ones were not, and perhaps explain the difference. We also had radio-collared bulls that we could follow throughout their life, documenting changes in their mating success as they aged.

Despite ideal opportunities to observe rutting moose, it took a long time to acquire enough observations to provide meaningful results. Over a 12-year period we observed mating 86 times. Mating began as early as September 24 and continued as late as October 8. As in other areas of North America, the peak mating for moose was centered on October 1. The rut occurred at the same time each year, evidently independent of differences in temperature or snowfall, suggesting that it was controlled by changes in day length, which remained constant from year to year.

Ninety-eight percent of observed mating involved females mating with only one male. Very rarely did females mate with two males, and none mated with more than two. Large males performed 88% of all mating, and yearling males accounted for less than two percent. Clearly, the largest, highest-ranking bulls were doing most of the mating. Field observations indicated that they accomplished this by defending cows from smaller bulls, aggressively chasing other bulls away, and by defeating challengers in fights. The lowest ranking animals, including yearlings, had very little success. Even some older males that were small for their age, or were poor fighters, could not compete with the top ranking bulls.

We observed bulls mating up to three times per day, and estimated that some might mate up to 25 times per year if they possessed large groups of cows. This was very rare, however, as bulls seldom were able to control groups throughout the entire rut. Some groups had five or more dominant males by the time the rut was over, each in control for only a few days.

Our results generated several questions about the importance of preserving large bulls in moose populations. In some areas hunting removes many bulls, and the ratio of cows to bulls may be ten to one. At what ratio do some cows fail to mate during the main rutting period? If many cows conceive after the main rut, is the survival of calves affected? If small bulls do most of the mating, are there long-term effects? If most of the small males are successful at mating as opposed to only a few of the large males, how are the genetics of the population affected? These questions are unanswered at present.

We also studied sparring and fighting. Each is a distinctly different behavior. Sparring is practice fighting that bulls use to gain experience. It superficially resembles fighting as two or more bulls engage their antlers and push each other back and forth. Fighting is far more serious and violent. At worst, sparring results in minor breakage of antlers or perhaps minor wounds inflicted by accident. Fights often result in serious injuries, and at worst, result in death.

If sparring involves learning about fighting and about rivals, inexperienced bulls should participate more than older bulls. Field observations at Denali indicated just that: younger bulls sparred to excess at times, and older bulls rarely sparred. If sparring is merely practice fighting, it should lack preliminary threats and displays. Again, we observed this to be the case: bulls sparred after feeding side-by-side or engaging in some other harmless behavior. Practice sparring should result in no winners or losers, and there should be no serious efforts to wound opponents. Again, bulls observed in the field did not chase each other after sparring, nor did they engage in all-out efforts to crush opponents. Sparring often consisted of little more than gentle antler contact and mild pushing. It did not escalate to fighting and did not determine dominance or rank.

Fights are another matter entirely. Bull moose are well-equipped to fight. At up to 1,600 pounds they are enormously powerful. Their shoulders are huge, and during the rut, their neck muscles expand to twice their normal size. The skin on their foreheads is thick providing armor against punctures by opponents. In addition, they possess weapons and shields in the form of antlers—large, strong organs specifically designed for fighting. Antlers have sharp points attached to broad palms that can severely wound opponents, puncturing the body, injuring eyes, or bruising muscles.

Photograph courtesy of Victor Van Ballenberghe

Bull moose are well-equipped to fight. At up to 1,600 pounds they are enormously powerful. Their shoulders are huge, and during the rut, their neck muscles expand to twice their normal size. The skin on their foreheads is thick providing armor against punctures by opponents. In addition, they possess weapons and shields in the form of antlers—large, strong organs specifically designed for fighting.

The fights we observed always involved only two opponents, never three or more as sometimes seen in sparring. On occasion, young bulls fought, but most fights were between two mature bulls of approximately equal size. Prior to clashing antlers, fighting bulls engaged in intense displays including pawing the ground, thrashing their antlers against shrubs, and displaying their bodies and antlers. Clashes were extraordinarily violent in an attempt to twist an opponent's head, shove him backwards, cause him to fall, and gore him. Bulls in fights each sought tactical advantages including gaining the uphill position to maximize battering effects. Losers knew the dangers of remaining nearby and either left or were escorted out of the area by their rivals. Dominant bulls were willing to risk fighting since it is the only way they could control female groups, mate, and pass on their genes—their evolutionary task, which they take very seriously.

Twenty-five years after the study began we are still gathering data on these and other behavioral ecology questions. Data are slow to accumulate at times as the moose population has declined, and field observations are now much more difficult to conduct. We have learned much but each research question generates several others. In the coming years we will continue to uncover some of the biological mysteries of this fascinating species that plays a major role in the ecology of Denali.

National Park Service photograph by Thomas Meier

Tracking the Movements of Denali's Wolves

By Thomas Meier, John Burch, and Layne Adams.

The wolves of Denali National Park (formerly Mount McKinley National Park) were the subject of some of the earliest research on wolf ecology. From 1939 to 1941, Adolph Murie performed ground-breaking studies of wolves, observing wolves and their prey and collecting wolf scats and prey remains. His work resulted in one of the first major scientific publications about wolves, *The Wolves of Mount McKinley (Murie 1944)*. Continuing the research started by Murie, the National Park Service (NPS) began using aircraft to locate and count wolves in the 1960s *(Prasil 1967, Singer 1986)*. Beginning in 1969, Gordon Haber used aircraft to make prolonged observations of wolf packs, studying their behavior and relations with prey species *(Haber 1977)*.

Figure 1. John Burch collaring McKinley Slough alpha female wolf 107, March 2005.

When the park was expanded into the present Denali National Park and Preserve in 1980, it incorporated the territories of many more wolf packs. A complete survey of the park's wolf population was undertaken in 1985 *(Dalle-Molle and Van Horn 1985)*, and in the course of that aerial survey, the remains of eight wolves that had been poached from aircraft were found in the park. Concern over the extent of wolf poaching led the NPS to begin extensive wolf research in 1986, using radio collars to keep track of the packs *(Mech et al. 1998)*. With more than a dozen wolf packs roaming over many thousands of square miles, radio collars have provided the means to study wolves throughout the park, and throughout the year.

Techniques for Radio-Tracking Wolves

Wolves are a difficult species to monitor. They are inconspicuous and live at low density in a structured population of territorial packs *(Mech and Boitani 2003)*. In Alaska, wolves live at particularly low densities, and in many areas, human access is limited to air travel. If wolf pack territories

Darted wolves become immobilized in a few minutes, and remain down for an hour or two, while we weigh, measure, take a blood sample, and attach a radio collar.

were regular and predictable, wolf surveys would be much easier, but it is seldom possible to predict the arrangement of pack territories from studying the terrain. Wolf pack territories overlap one another and change over time. Effective monitoring needs to address not only wolf numbers but the spatial structure of the population. Radio tracking of wolves in Denali has revealed that the park's wolf population is made up of a shifting mosaic of pack territories. As packs die out and are replaced by new packs, territory boundaries and patterns of habitat use change.

The first step in radio-collaring wolves involves locating packs by tracking them in the snow. This is usually done in November or March, when days are long. The best conditions are a few days after a fresh snowfall, when wolf packs have left a trail. Once a pack is located, researchers dart one or two wolves from a helicopter. Over the years, we have learned the advantage of capturing the leading members of the pack. Wolf packs are typically made up of a breeding pair and their offspring. While most of those offspring eventually leave the pack, the breeding pair can be relied upon to stay. As the wolf pack travels, the breeding pair usually lead the way, and it is those two which we attempt to tranquilize. Darted wolves become immobilized in a few minutes, and remain down for an hour or two, while we weigh, measure, take a blood sample, and attach a radio collar *(Figure 1)*.

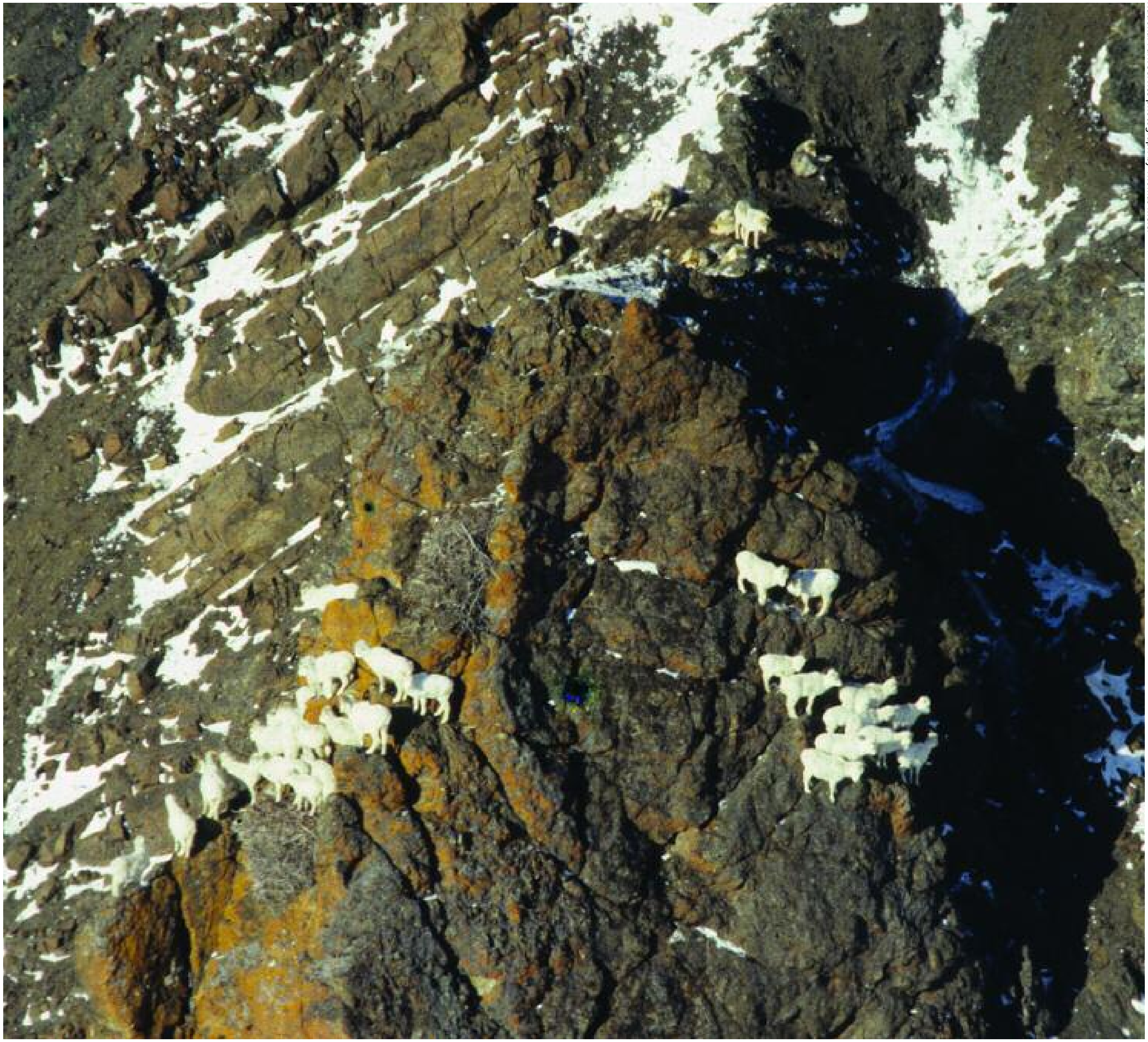
Collared wolves are tracked from a small airplane equipped with wing-mounted radio antennae *(Figure 2)*. From such a plane, researchers are able to locate the collared wolf, circle its location, and usually see the wolf pack. This allows the counting of wolves in a pack and observation of their behavior *(Figures 3, 4)*. Collaring also allows researchers to collect other valuable data, including den site use, pup production, predation patterns, dispersal, and wolf mortality. The basic unit of information is the wolf's location, usually described as coordinates of latitude and longitude. It is these fragments of data, providing a point on a map or a few characters in a database, that make up the building blocks of wolf research *(Figure 5)*. By obtaining enough locations for a wolf pack, its territory is outlined. By outlining the territories of a cluster of packs and counting the number of wolves in each pack, we can describe the population.

Wolf Pack Territories

Wolf pack territories are typically drawn by connecting the outermost locations of the pack's known movements on a map *(Figure 6)*. As more locations are added, the territory gets bigger, until the collection of locations includes all of the places where the pack is likely to go. Various studies have estimated that 30 to 150 locations are needed to adequately describe a wolf pack

Figure 2. A Supercub with telemetry antennae.

Figure 3. The East Fork Pack (19 wolves) crossing the Muldrow Glacier.



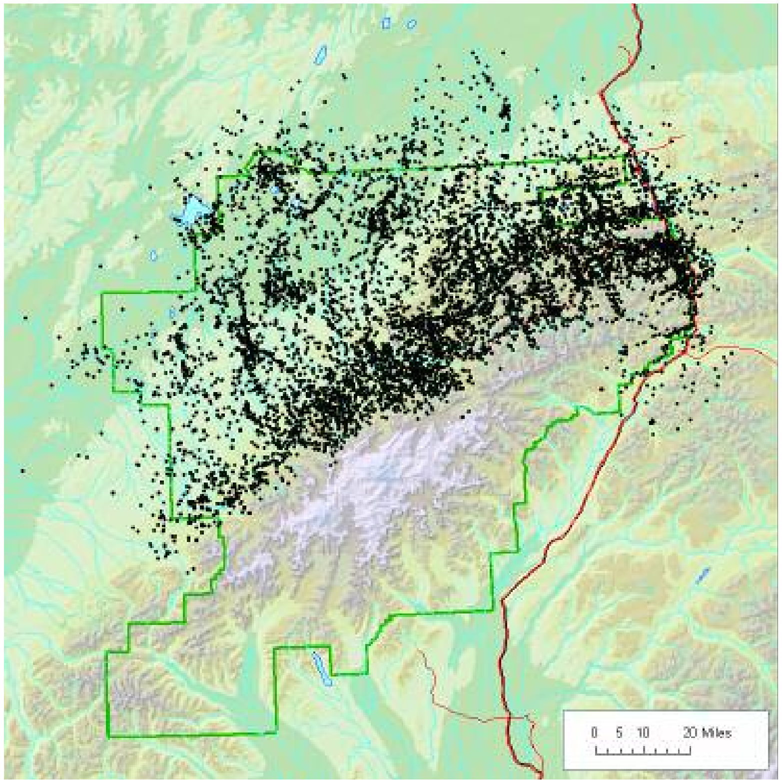
National Park Service photograph by Thomas Meier

Figure 4: Wolves and sheep, Sanctuary River.

territory. Burch et al. *(2005)* found that there was no "magic number" of radio locations guaranteed to adequately describe a wolf pack territory, but that monitoring a number of adjacent packs in a block allows territories to be defined with fewer locations. The crucial question is whether pack territories are sufficiently defined to ensure that undetected wolf packs do not exist between the monitored packs. More sophisticated treatment of location data is possible, including kernel analyses that show the relative intensity with which different parts of the territory are used *(Figure 6)*.

Wolf Dispersal

In addition to describing pack territories, radio telemetry allows the study of wolves that leave their home territories. On average, 28% of wolves in Denali leave their packs each year. Most leave alone, but some pairs disperse, and in one case 11 wolves left together. Male and female wolves disperse in approximately equal numbers and for similar distances. At least 14 wolves have dispersed long distances away from Denali *(Figure 7)*, and dozens more wolves dispersed shorter distances, within the study area or just outside of it. The longest documented dispersal was by a female wolf that left the Headquarters Pack and was shot by an Inupiat hunter near the Canning River, 40 miles from the Arctic Ocean and (in a straight line) 435 miles from Denali. Dispersing wolves seldom remain alone for long. In nearly 20 years of wolf research, only one territorial, solitary-living wolf has been found in the park. All other "lone" wolves that survived for more than a few



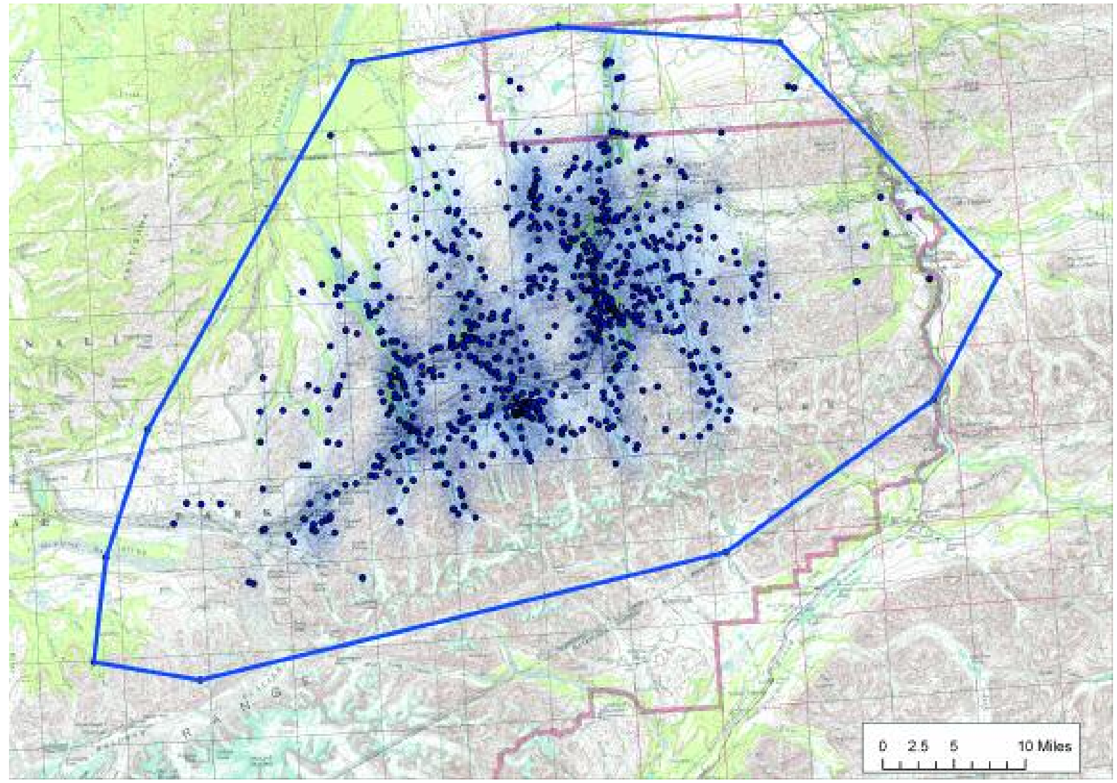


Figure 5. (Left) Map showing 20 years of wolf locations in and around Denali.
Figure 6: (Right) East Fork Pack territory, showing individual locations, minimum polygon, and kernel analysis of pack territory. Shading shows the likelihood of finding the wolves in any particular part of the territory. This map is based on nearly 20 years of tracking wolves in the East Fork territory.

months either started new packs, joined existing packs, or dispersed far away and were lost from monitoring. A surprising result of wolf studies in Denali has been the frequent observations of existing packs adopting unrelated wolves *(Meier et al. 1995)*.

Wolf Pack Formation

Typically, a new wolf pack is formed when two or more dispersing wolves come together in an area that is not currently occupied by wolves and take up residence there. We have observed many cases of new pair and pack formation in Denali. Many of them have been unsuccessful, when a pair of wolves sought to carve out a territory between existing wolf packs, or attempted to live in an area without a year-round food supply. Most of these unsuccessful pairs were killed by neighboring packs. Several new packs that did succeed were formed when a large wolf pack killed off a neighboring pack and colonized the vacant area with its own members. Another way for new packs to be formed is for an existing pack to split in two. There have been four cases where large wolf packs split roughly in half, subdividing the territory into two new territories. The largest wolf packs in Denali have been just under 30 wolves, and packs of more than 15 or 20 wolves do not seem to last for long. Either the pack splits, or members die or disperse away. A similar pattern has been seen as wolves become established in Yellowstone *(Smith et al. 2005)*.

Relationships Between Pack Territories

The pack territories, as they existed in spring 2005, form a sort of sloppy jigsaw puzzle, with overlap between packs in some areas and spaces between packs in others *(Figure 8)*. These territories are based on a limited number of wolf locations, and so they do not show the full extent of a pack's movements. If they did, overlap between packs would be even more extensive. Some overlap is actually displacement over time,

Figure 7. Map of Alaska showing long-range dispersals of 14 wolves from Denali.

as one pack takes over an area formerly occupied by another. But much of the overlap between packs is real, and several packs have made forays that took them completely across neighboring pack territories. This "trespassing" of one pack into another's territory is not without risk. At least 60% of wolf deaths in Denali come from wolves being killed by other wolf packs. A further risk occurs when the wolves travel to places where it is legal to trap or shoot wolves. Nearly every winter, news stories document the killing of one or two park wolves outside of the park boundaries.

Using GPS Collars to Learn More About Wolf Movements

There are presently seven wolves in the park wearing collars that allow researchers to determine location information with a Global Positioning System (GPS) receiver. The data is collected once per day and then uploaded through a satellite. While this method provides no information on wolf behavior, pack sizes, or pup production, it does provide enough location points to accurately depict a pack's territory *(Figure 9)*. By comparing conventional telemetry (locations from aircraft) with daily GPS locations, we see that the larger numbers of locations obtained from GPS collars result in significantly larger estimates of territory size *(Figure 10)*. Combined with periodic flights for visual observations of packs, GPS collars have the potential to provide much more complete data on wolf movements.

Conclusions

By tracking the movements of Denali's wolves for 20 years, large contributions have been made to the study of wolves, specifically those within the park boundaries. The park's wolf population is more fluid and dynamic than had been expected, and wolf numbers vary two- or three-fold, depending on food supply. The packs are not static, but have finite lifespans and are replaced by other packs. Most of this flux results from strife between the various packs. Most importantly, the more closely one observes a wolf pack or a wolf population, the more new phenomena and unique events are witnessed. Wolves and wolf packs are dynamic. They demonstrate their intelligence and impressive physical abilities by occasionally doing something that you least expect.

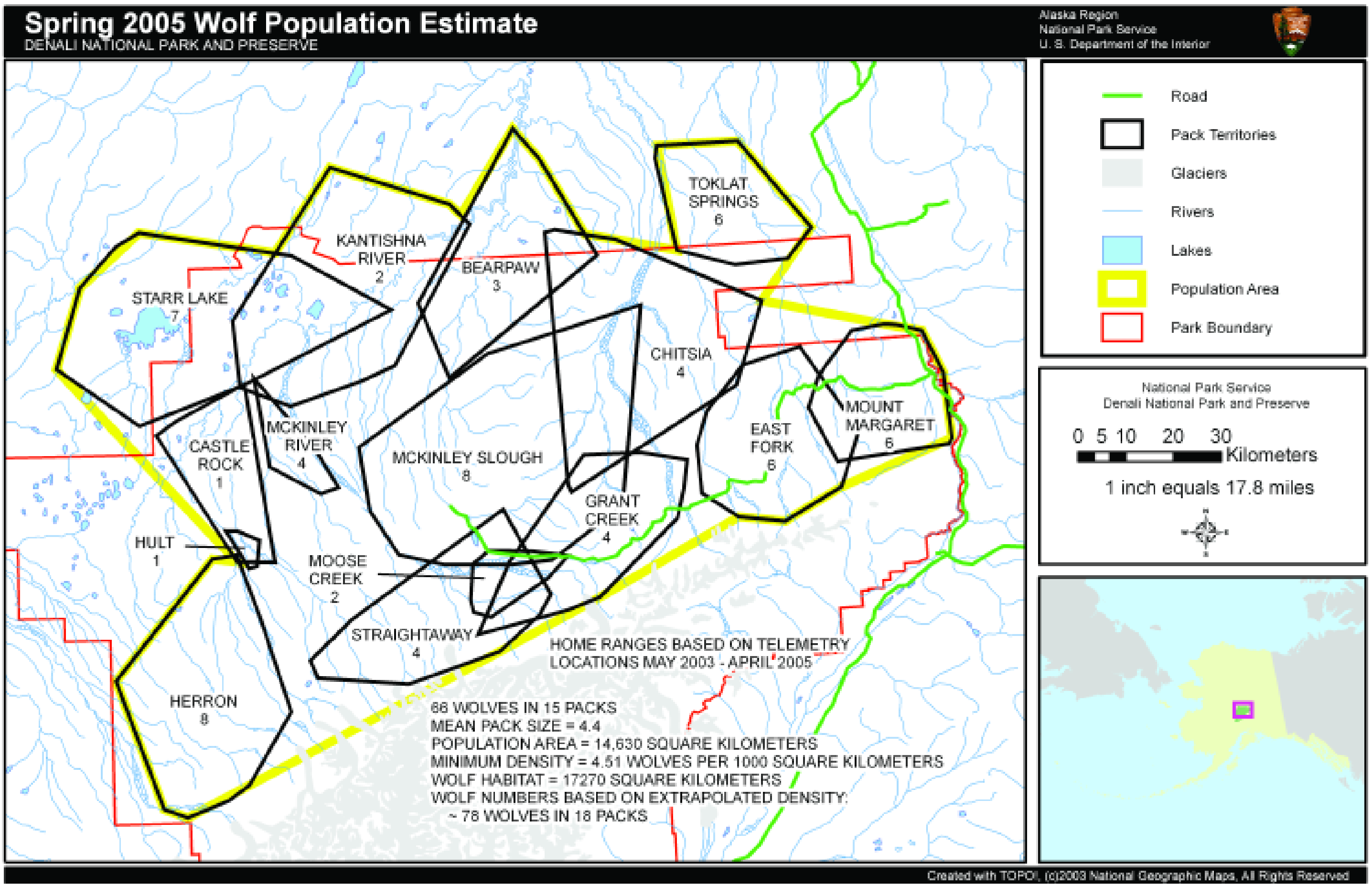
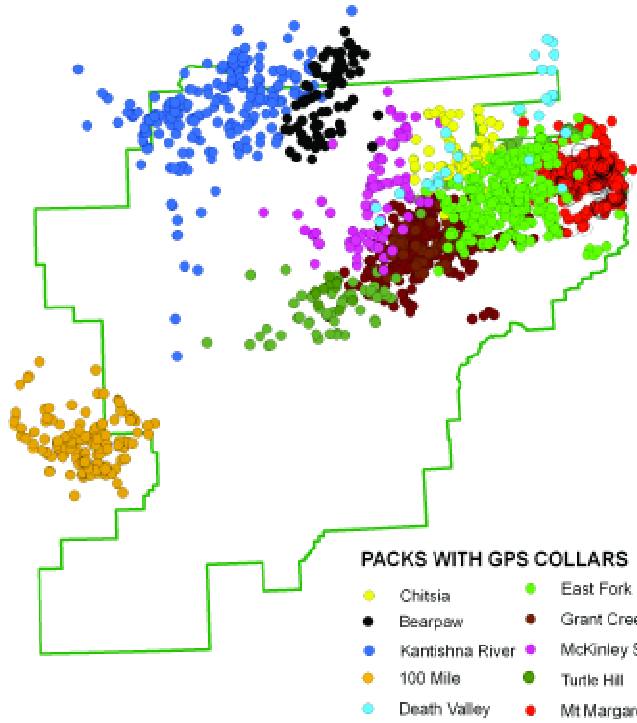


Figure 8: Denali wolf pack territory map, spring 2005.



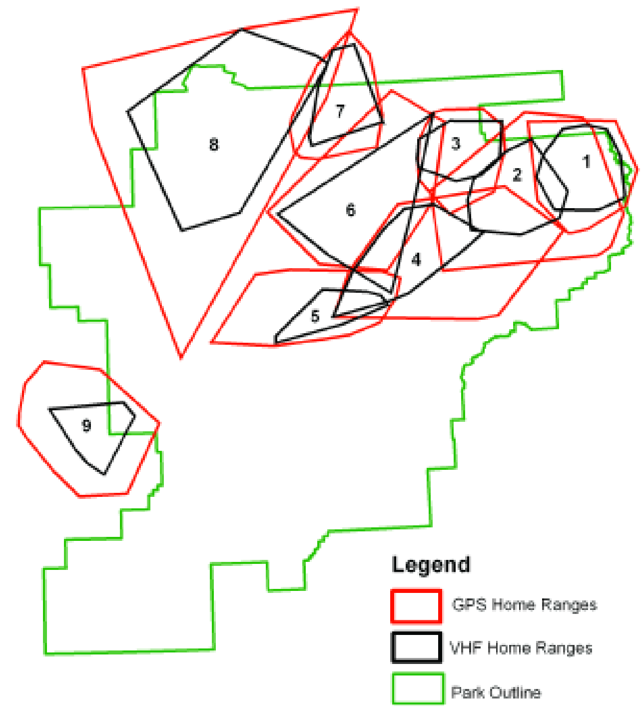


Figure 9: (Near right) GPS collar locations of 10 wolf packs over a two-year period, 2003-2005.

Figure 10: (Far right) Comparison of home ranges determined by conventional (boundaries in black) and GPS telemetry (boundaries in red).
1 - Headquarters Pack;
2 - East Fork Pack;
3 - Chitsia Pack;
4 - Grant Creek Pack;
5 - Turtle Hill Pack;
6 - McKinley Slough Pack;
7 - Bearpaw Pack;
8 - Kantishna River Pack;
9 - 100 Mile Pack.

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National Park Service photograph by Bruce Dale

A wolf carries off a caribou calf it has killed.

Interrelationships of Denali's Large Mammal Community

By Layne Adams, Thomas Meier, Patricia Owen, and Gretchen Roffler

Along with its sweeping mountain landscapes, Denali National Park and Preserve (Denali) is probably best known for opportunities to observe the large mammals common to Interior Alaska. Locally known as the "Big Five," gray wolves *(Canis lupus)*, grizzly bears *(Ursus arctos)*, moose *(Alces alces)*, caribou *(Rangifer tarandus)* and Dall sheep *(Ovis dalli)* have coexisted in the region for millennia. While many other animals occur in Denali, none are as readily associated with the park environment as these species.

In addition to the opportunities for viewing or photographing Interior Alaska's large mammals, Denali is a great natural laboratory to study the species and their interrelationships. Unlike the rest of Interior Alaska, the Denali carnivore/ungulate community has been little affected by human harvests for several decades, and interactions of these species are driven largely by natural phenomena.

It is a common perception that large mammals are "abundant" within the protected confines of the park boundaries, but that is not the case. Throughout much of Interior Alaska, large mammals occur at low densities naturally, and Denali is no exception. Although Denali encompasses over 6,600 square miles (17,100 km^2) of suitable habitat, currently about 100 wolves, 350 grizzly bears, 2,000 caribou, 1,900 moose, and 1,800 Dall sheep occur there. In comparison, areas of the Tanana Flats and northern Alaska Range adjacent to Denali on the east have long been managed for human harvests, and moose occur there at about six times the density of Denali.

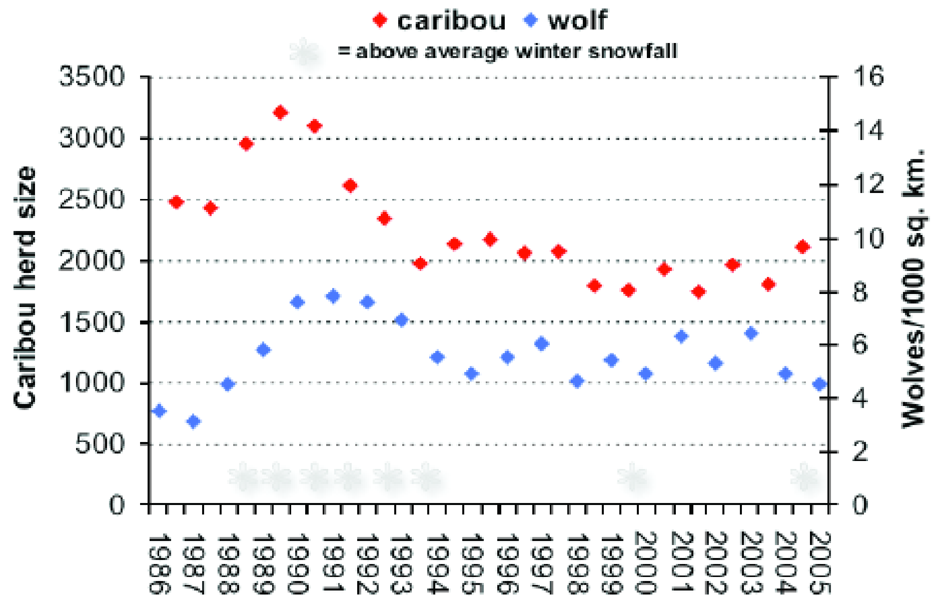
Denali's large mammals interact in an age-old drama in their roles as predators and prey. While each species has a substantially different role, each individual has the same goals of survival and reproduction. Predators must find and kill sufficient prey, while ungulates employ strategies to minimize their risks of becoming a meal. For both predators and prey to persist, the capabilities of predators must be roughly counteracted by the vigor and predation-avoidance behaviors of the ungulates. However, the stage for this drama is constantly changing, providing challenges or advantages to the participants, and affecting the numbers that survive at any given time.

Winter snowfall is probably the most obvious factor that influences predator/prey relationships and population trends *(Mech et al. 1998)*. Since 1924, total winter snowfall measured at park headquarters has averaged 80 inches (203 cm), but has varied from 31 to 174 inches (79-442 cm), indicating an extreme range of winter conditions experienced by wildlife in Denali.

Denali's large mammals interact in an age-old drama in their roles as predators and prey. While each species has a substantially different role, each individual has the same goals of survival and reproduction.

We know most about the effects of winter snowfall on wolf and caribou populations in Denali because of intensive studies of each species begun in 1986 *(Adams 1996, Mech et al. 1998)*. Those studies began near the end of more than a decade of winters with snowfalls that were well below average and continued through six consecutive winters of deep snows of 90 to 155 inches (229-394 cm), providing a powerful opportunity to gain insights into effects of winter conditions on these two species.

In 1986, the Denali Caribou Herd numbered about 2,600 animals and was increasing 7% per year. At the time, the wolf population in Denali included about 60 animals, a number lower than expected based on the abundance of ungulates. Wolf pup production was poor, and dispersal of young wolves was high. With severe winters from 1988 to 1994, wolf numbers rapidly increased, reaching 130 wolves by late winter 1990 and staying high through the 1992-93 winter. The caribou herd reached 3,200 individuals by autumn 1989 but declined to about 2,000 by autumn 1993. Recruitment of calves was poor, averaging only 12 calves per 100 cows in fall 1990-93, compared to 35 per 100 during 1984-89. Further, winter mortality rates of adult cows tripled from about 5% to 15% annually. Winter snowfalls have returned to more average levels since 1994. Wolf numbers declined to an average



Population trends of caribou and wolves in Denali National Park and Preserve relative to severe winters.

Photograph courtesy of Rick McIntyre

A wolf consumes a mature Dall sheep ram killed on the Toklat River.

Photograph courtesy of Rick McIntyre

A wolf and a grizzly bear check each other out.

of 92 wolves during 1994-2005, and the caribou population leveled off at about 2,000 animals, with improvement in adult survival but continued poor recruitment of calves.

These trends in population size for wolves and caribou resulted from several cascading effects linked to changes in winter conditions. With low snowfall, caribou have large expanses of wind-blown, snow-free terrain to seek forage, and they can maintain adequate nutritional condition to make it through the winter in good shape. Additionally, with little snow most can easily evade wolves by running from them. At the same time, wolves can find it difficult to acquire adequate prey when few ungulates are vulnerable, and they must focus on killing individuals that are injured, old, otherwise debilitated, or unlucky *(Mech et al. 1995)*. With few vulnerable prey, wolf packs tend to be small in number because of lower pup production or survival and increased dispersal of young wolves.

As winter snowfalls increase, the balance tips in favor of wolves. Caribou have more difficulty finding enough to eat because they must either forage on wind-blown alpine ridges where little forage occurs or expend energy digging through deep or crusted snow. Deep snow can also impede their ability to evade wolves. Although caribou prefer to feed on wind-blown areas like mountain ridges, such places are commonly surrounded by deep snow, and it is relatively easy for wolves to chase caribou into the deep snow where they are highly vulnerable, regardless of their physical condition. In particularly severe winters, multiple kills of caribou are not uncommon in these situations, and selection for debilitated individuals is less obvious *(Mech et al. 1995)*. With food easier to acquire, wolves can flourish. New packs form, and existing packs get bigger because more pups survive and fewer young wolves disperse from their natal packs *(Meier et al. 1995)*. Together these changes can result in big increases in wolf numbers over a short time period; Denali wolves increased by 30% a year during 1988-1990 as a result of severe winter conditions *(Mech et al. 1998)*.

National Park Service photograph by Thomas Meier

Two wolves consume a Dall sheep ram on Stony Creek.

In addition to the direct effects described above, we have also found indirect effects of winter severity on caribou calf production and survival resulting from the nutritional restriction they experience in harsh winters. If winters are severe enough, poor nutritional condition can carry through the summer to the fall breeding season, affecting pregnancy rates *(Adams and Dale 1998a)* and the timing of calving the next year *(Adams and Dale 1998b)*. Female calves that experience severe winters are unlikely to breed until they are 2 or 3 years old, whereas about half of those that have it easy their first winter breed as yearlings *(Adams and Dale 1998a)*. Calves that are born following a severe winter are lighter at birth *(Adams 2005)*, grow more slowly *(Adams 2003)*, and experience higher mortality in the weeks following birth *(Adams et al. 1995a, 1995b)*.

Moose and Dall sheep are also affected by the magnitude of winter snows, but each is influenced differently depending on its body size, food habits, and habitat selection. It takes more snow to affect the nutritional status of moose because of their taller stature and because their winter forage of twigs and branches largely occurs above the snowpack. However, moose calves begin to feel the effects of severe winters at lower snowdepths than do adults. Dall sheep winter on wind-blown mountain slopes

Unlike wolves, grizzly bears have low reproductive rates, low survival of young, little dispersal, and can live for over 30 years. With these life history traits and their limited reliance on ungulates in their diet, population trends of grizzly bears are very loosely tied, if at all, to the status of ungulate populations.

that provide forage and escape cover among the rocky crags. These areas tend to be snow-free in all but the most severe winters, but wet snow or rain in midwinter can encase the forage on which sheep rely in a covering of ice. With their relatively short legs and reliance on rocky terrain for security from predation, Dall sheep have limited ability to move through deep snow to areas with better foraging conditions when icing occurs, and such movements make them highly vulnerable to wolf predation.

Because moose, caribou, and Dall sheep are affected differently by winter conditions, their relative vulnerability to predation by wolves changes from year to year. Also, each ungulate population is made up of a variety of ages, and each sex/age class has its own vulnerabilities. In general, the year's young, older individuals, and mature males, worn out from the fall breeding season, are more vulnerable to predation than prime-aged adult females. Further, these ungulates are not equally distributed across the landscape, so each wolf pack has a different assemblage of prey to pursue. Moose are more numerous in the foothills along the Alaska Range in winter and relatively rare in the forested flatlands of the park. Sheep are found in some of the mountainous areas of the park; they do not occur in the Kantishna Hills and are rare in the foothills immediately north of Mt. McKinley. Caribou aggregate in only a few areas in winter, and important wintering areas can change as winter progresses as well as from year to year. Therefore, caribou and sheep may be abundant in some wolf pack territories and absent from others. All of these factors complicate the relationships between wolf predation and the population dynamics of both wolves and their ungulate prey.

Grizzly bears add another degree of complexity. While ungulates and wolves can be neatly categorized as primary consumers (herbivores) and secondary consumers (carnivores) in Denali's food web, grizzlies fit in both categories. As omnivores, they rely on plant material for part of their diet and therefore are affected by growing season conditions, similar to the ungulates. In particular, berry production in late summer can greatly affect nutritional status of bears as they enter dens for the winter. Bears also are significant predators of young ungulates, particularly caribou and moose, in the weeks following birth. Unlike wolves, grizzly bears have low reproductive rates, low survival of young, little dispersal, and can live for over 30 years. With these life history traits and their limited reliance on ungulates in their diet, population

USGS photograph by Layne Adams

Biologist Gretchen Roffler transports an immobilized wolf via helicopter to a location where it will be radio-collared.

trends of grizzly bears are very loosely tied, if at all, to the status of ungulate populations. As a result, their influences on ungulate population dynamics may be diminished when those populations are high and increase as populations decline.

Although we have focused on how population trends and interactions of Denali's large mammals are affected by winter severity, other climatic factors are undoubtedly important in the dynamics of this system, but their effects can be more difficult to discern. In general, variability in weather may be the greatest driver for fluctuations in the large mammal predator/prey community. Our understanding of this particular system has largely accumulated as warming trends in global climate have become more recognizable in northern latitudes. It is too early to tell how climate change will influence the large mammal species in Denali. Given the complexities involved in the day-to-day interactions of these species, we expect that many of the effects will be difficult to predict, or downright surprising.

Photograph courtesy of Layne Adams

Researcher Layne Adams radio collars a wolf for studies in Denali National Park and Preserve.

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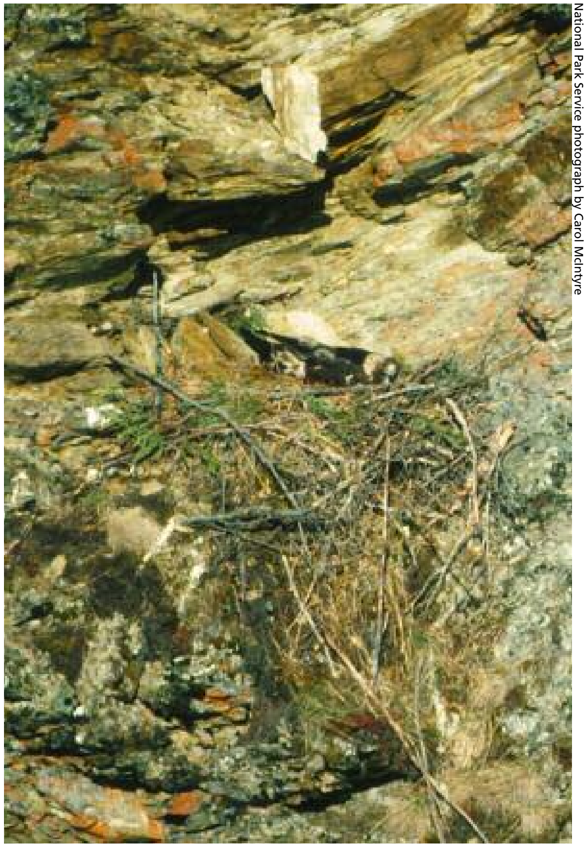

National Park Service photograph by Carol McIntyre

Photograph courtesy of Michael Collopy

Long-Term Golden Eagle Studies in Denali National Park and Preserve

**by Carol McIntyre,
Karen Steenhof, Michael N. Kochert,
and Michael W. Collopy**

Viewing predators is one of the highlights of a trip to Denali. Just a few years ago, visitors generally fixed their gaze on terra firma hoping to see a wolf or a grizzly bear. Now, thanks to results of our long-term monitoring program for golden eagles *(Aquila chrysaetos)*, visitors frequently turn their eyes skyward in hopes of seeing one of North America's largest aerial predators. With an abundance of cliffs and rock outcroppings for nest sites, as well as a diversity of prey, the northern foothills of the towering Alaska Range are well suited for this large aerial predator.

In the early twentieth century, Joseph Dixon and Adolph Murie recognized that golden eagles were integral components of this region's fauna *(Dixon 1938, Murie 1944)*. In 1987, Denali biologists conducted the first formal inventory of golden eagle nesting sites and found more than 50 occupied nesting territories in the northeastern region of Denali. This exciting discovery spurred the National Park Service to develop a long-term study of the nesting ecology and reproductive success of golden eagles in

Figure 1. (Top Left) All known nests in the study area are on cliffs and rock outcrops. Nests range in size from 3.3 feet (1 m) to 9.8 feet (3 m) wide and 3.3 feet (1 m) to 9.8 feet (3 m) high.

Figure 2. (Top Right) Broods of two nestlings are common in Denali in years when prey is abundant.

Denali. To make comparisons with other study areas, Denali's biologists modeled their new program after the long-term monitoring program in the Snake River Birds of Prey National Conservation Area in southwest Idaho *(Steenhof et al. 1997, McIntyre and Adams 1999)*. This NPS study has provided internationally significant information on golden eagles *(Watson 1997, Kochert and Steenhof 2002, Kochert et al. 2002)* and some of our results are highlighted in this article.

Monitoring Reproductive Success

Denali's golden eagles are migratory, and the territorial population occupies the foothills of the Alaska Range from March until October. A few hardy individuals may spend the winter, especially when snowshoe hare are abundant, but most return to their territories in March and begin repairing their nests. Nests range in size, but all nests in our study area are built on cliffs or rock outcroppings *(Figure 1)*. The female completes her clutch of one to three eggs by mid-April. Incubation requires about 42 days, most hatching occurs by early June, and most nestlings fledge by early August. The eaglets grow rapidly during the 70-day nestling period, and successful pairs raise from one to three nestlings *(Figure 2)*.

We monitor the reproductive success of the eagles using two standardized aerial

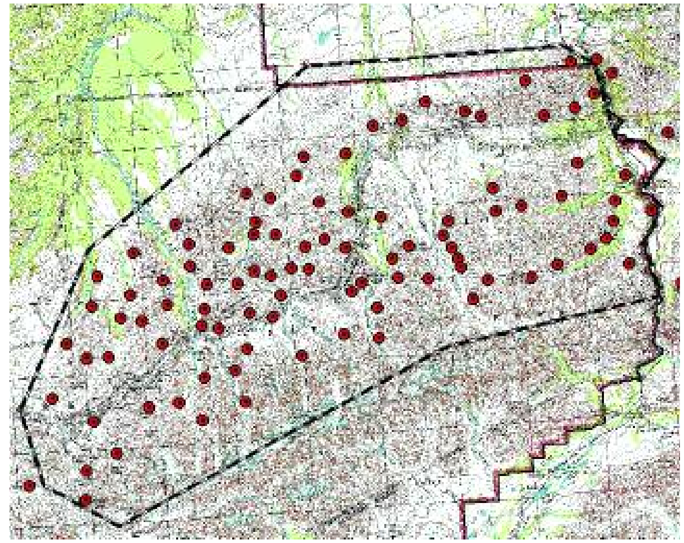

Figure 3. Our study area (within the dashed lines) contains more than 365 nest sites in 85 golden eagle nesting territories (indicated by the red circles).

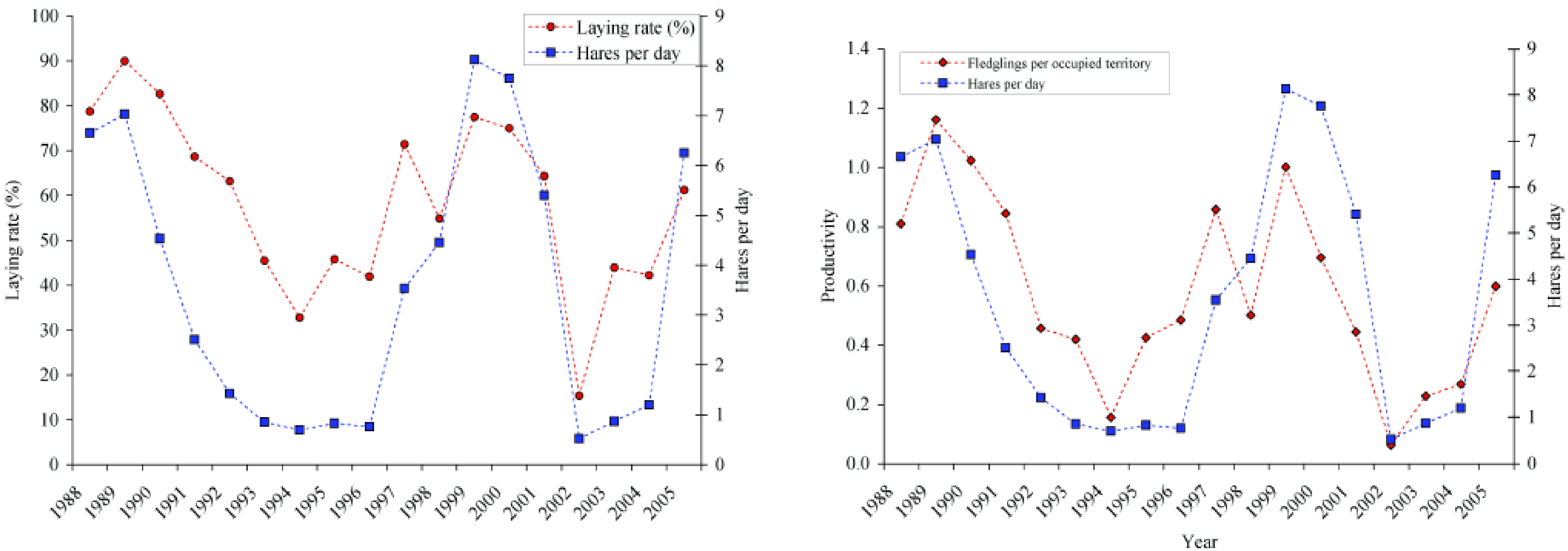

Figure 4. The laying rate (left) and productivity (right) of golden eagles in relation to the abundance of snowshoe hare (an index based on the number of hares detected per field day).

Figure 5. Results of the National Park Service banding and satellite telemetry programs indicate than many of Denali's golden eagles winter across southwestern Canada, the Rocky Mountains and Great Plains regions in the United States, and northern Mexico.

surveys annually from a small helicopter. In late April, after most clutches of eggs are completed, we observe all nesting territories to determine their occupancy and breeding status. We know that a territory is occupied if we observe a newly repaired nest or a pair of eagles engaged in territorial or reproductive activities. Observation of an incubating eagle or eggs in a nest tells us that a laying pair is present. In late July, we count the number of nestlings and successful pairs (pairs that raise at least one fledgling) *(Steenhof 1987)*. Data from these two surveys allows us to monitor nesting territory occupancy and reproductive success of golden eagles in Denali.

Providing New Information on Golden Eagles

Several of our studies have yielded exciting information about golden eagle nesting ecology. The results highlight the importance of the park to nesting golden eagles, and the importance of the eagles to visitors' experiences.

Nesting densities are higher for golden eagles in Denali than anywhere else in North America *(Figure 3) (Kochert et al. 2002)*. Occupancy rates are stable, and the territorial population consists mostly of adults. This suggests either that survival of territorial eagles is high or that sufficient numbers of non-territorial eagles (or floaters) are available to fill voids left by birds that die. Like many other northern predators, breeding golden eagles in Denali respond to the snowshoe hare cycle — more eagles lay eggs and raise more fledglings in years when snowshoe hares are abundant *(Figure 4) (McIntyre and Adams 1999)*. Still, some pairs of eagles produce substantially more fledglings than others *(McIntyre 2002)*, and productivity is significantly lower in areas with more closed-canopy vegetation *(McIntyre 2004)*.

Our studies are particularly useful for comparing life history characteristics between migratory populations in northern latitudes and resident populations in southern latitudes in North America *(McIntyre and Adams 1999, Kochert et al. 2002)*. For instance, mean brood size and overall productivity in Denali is lower than in most temperate study areas *(McIntyre and Adams 1999)*. Additionally, the post-fledging dependence period is shorter and survival of juveniles is lower for Denali's golden eagles than for resident populations at lower latitudes *(McIntyre and Collopy 2006, McIntyre et al. 2006)*.

The Future of Denali's Golden Eagles

Although Denali's landscapes are relatively free from habitat alteration directly attributed to humans, landscapes are dynamic and major perturbations will continue to shape their future. The cascading effects of global climate change may have profound effects on Denali's landscape and its entire fauna. For example, climate change could cause regional changes in vegetation patterns *(Rupp et al. 2000, Sturm et al. 2001)*, potentially affecting the habitat of many species of golden eagle prey *(McIntyre 2004)*.

We live in a rapidly changing world. Humans have substantially altered much of the habitat in migration corridors and winter ranges of Denali's golden eagles *(Figure 5)*. Further, habitat alteration in areas bordering the park is also increasing. Long-lived, wide-ranging, slow reproducing animals such as golden eagles generally do not thrive in landscapes altered by human activities *(Watson 1997, Kochert and Steenhof 2002)*. Long-term monitoring programs in the Snake River and in Denali provide valuable data to investigate responses of golden eagles to different environmental issues across diverse geographical areas *(Kochert and Steenhof 2002)*. Will golden eagles thrive in Denali in the next century? Results of our long-term monitoring program in Denali, now a component of the Central Alaska Network Vital Signs Monitoring Program *(MacCluskie and Oakley 2005)*, should provide answers to this and other questions.

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National Park Service photograph by Carl Roland

A long-tailed Jaeger sits atop a wind-pruned white spruce tree in the open permafrost landscape of the Toklat Basin in Denali National Park.

Integrated Monitoring of Physical Environment, Plant, and Bird Communities in Denali

By Carl Roland and Carol McIntyre

The physical environment strongly affects vegetation patterns in Alaska, and songbird communities are tied to vegetation patterns. In designing a long-term monitoring program for Denali, we saw an opportunity to collect integrated data to better understand how the ecosystem functions as a whole and to delineate the specific relationships among these elements of the biota.

We developed a sampling design where repeated observations of the physical environment, vegetation and birds are made at randomly selected points *(Roland et al. 2003)*. This design will allow detection of changes in the ecosystem at a landscape scale, for long periods of time. The sampling design is comprised of five rows of five plots, all 547 yards (500 m) apart, arranged in a grid pattern at each study area. These "mini-grids" are themselves arranged on a macro-grid with 6.2 miles (10 km) spacing. By utilizing a randomized site selection procedure, the program provided unbiased data about the status and trend of park resources over large spatial scales.

One focus of data collection was the Toklat Basin in the northeastern region of Denali *(Figure 1)*. We collected data on the physical environment, vegetation, and passerine birds on nearly 200 plots in eight mini-grids in this region from 2001 to 2003. This data set has allowed us to establish a baseline of ecological conditions for this area and to quantify some of the primary ecological dynamics in

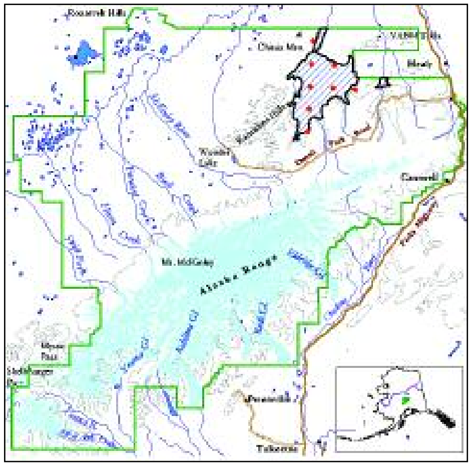

Figure 1. Map showing the location of the Toklat Basin study area (cross-hatched area) and sampling locations (red dots) for the data cited in this article.

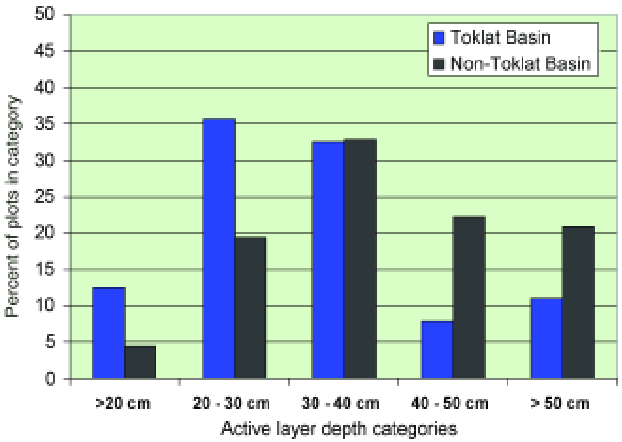

Figure 2. A comparison of the active layer depth of plots from two study regions, those in the Toklat Basin region and all others in Denali. All plots included in this analysis were located below 3,600 feet (1,100 m) in elevation. Note the higher percentage of plots in the shallow active layer categories for Toklat Basin in contrast to plots outside this region, where the higher percentage is in the deep depth categories.

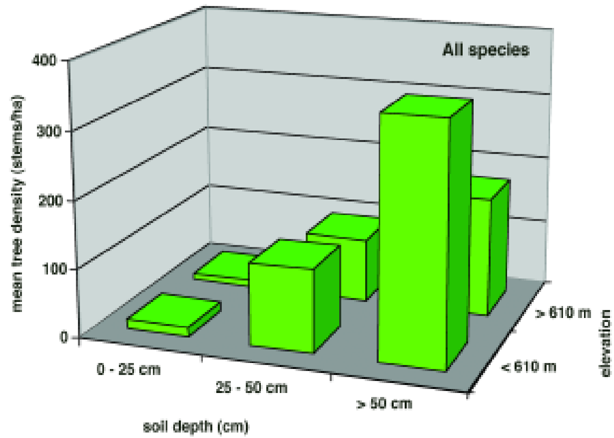

Figure 3. Variation in mean tree density for different active layer depths and elevations observed in the Toklat Basin study area. Tree density is nearly 30 times higher in the low elevation, deep active layer category as compared to the high elevation, shallow active layer category.

Figure 4. The percent of live plant cover (above 6.6 feet or 2 m in height) for different active layer depths and elevations in the Toklat Basin study area. Plant biomass is nearly 30 times greater in deeply thawed sites in the lowlands as compared to shallow active layer sites at high elevation.

this ecosystem. In this article, we highlight our research by presenting one example of the benefits of integrated data collection of physical attributes, vegetation, and birds for understanding ecological dynamics.

An Example of Integrating Monitoring at a Landscape Scale

A main attribute of the Toklat Basin region is permanently frozen ground (or permafrost), which affects many aspects of the ecosystem. The basin slopes to the north and lies in the shadow of the Alaska Range. Thus, solar energy inputs in this area are low compared to areas with southerly aspects, or those not in the shadow of the Alaska Range. In addition, strong winter winds often blow away the insulating blanket of snow, allowing the subarctic winter cold to penetrate and freeze soils deeply.

During fieldwork, it was noted that active layer depth and elevation were strong predictors of the vegetation patterns in the Toklat Basin. Many predictions concerning the nature of landscape change focus on vegetation changes along elevation gradients and on interrelationships between warming, permafrost degradation, and resulting vegetation change. The integrated monitoring program allows us to quantify and monitor these dynamics through time, providing insight into the relationships among permafrost, vegetation structure, and bird distribution.

Physical Environment

One measure of the intensity of permafrost in an area is the summer active layer depth, the depth to which the soil thaws in the summer. The deeper the thawed or active layer, the greater the amount of substrate available for plant roots to colonize, to draw nutrients from, and to support life functions. Sites with deeper active layers often have warmer soils that are more favorable to plant growth and the microbial activity that frees nutrients for plants to use.

To illustrate the importance of permafrost in the Toklat Basin relative to other areas of Denali, we compared the data from plots in this region to all of the low elevation plots (<1100 m in elevation) that we measured in Denali. We observed some differences in soil temperature and active layer depth values between these two data sets. Mean soil temperature for the Toklat Basin plots was 38.1°F ±1.6°F (3.4°C ±0.9°C), whereas for all other low-elevation plots the mean soil temperature was 46.2°F ±3.8°F (7.9°C ±2.1°C). Mean active layer depth in the Toklat Basin plots was 13 inches ±2.2 (33 cm ±5.7), whereas in low elevation plots outside of this study area, mean active layer depth was 16.5 inches ±3.8 (42 cm ±9.7). The soil temperature and active layer depth values are lower in the Toklat Basin, as compared to other low elevation sample locations *(Figure 2)*.

Tree Density and Live Plant Cover

Many important vegetation attributes in the Toklat Basin varied in response to the active layer depth and elevation. These two physical factors influence the microclimate of a site, and thus the conditions for plant

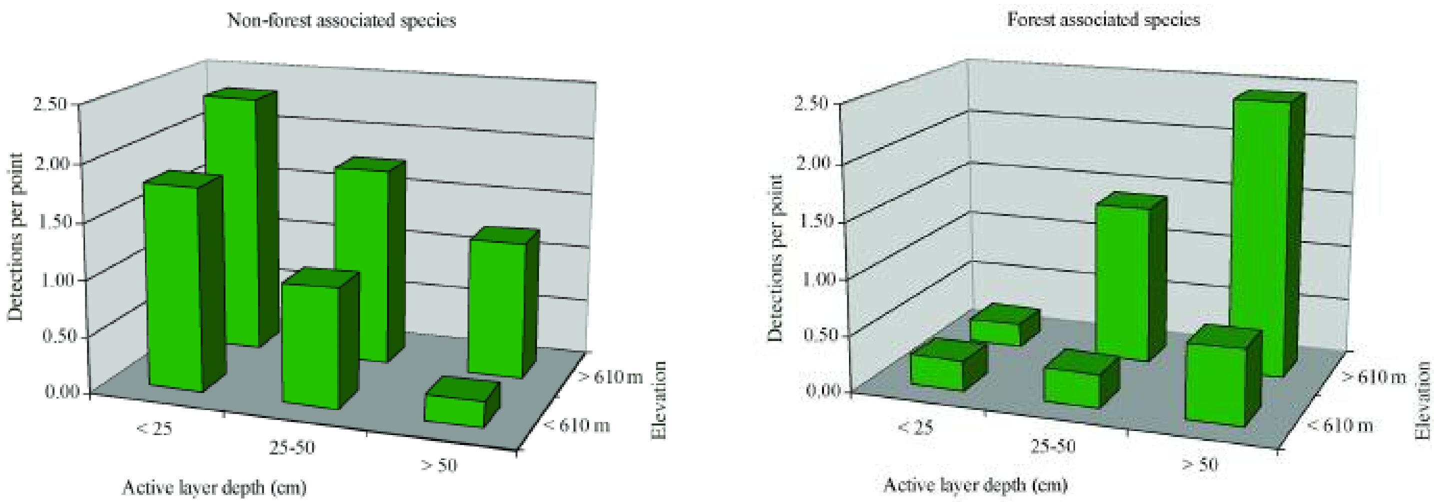

Figure 5. Mean number of detections of non-forest (left) and forest-associated (right) songbird species for different active layer depths and elevations in the Toklat Basin study area.

growth. Here we focus on the responses of two vegetation parameters that are relevant to bird habitat selection: the quantity of vegetative cover at specific heights off the ground (percent cover of live vegetation), and tree density.

The data showed that percent of plant cover higher than 6.6 feet (2 m) and density of trees varied in response to the active layer depth and elevation. Specifically, tree density was very low in plots that were most highly permafrosted in both elevation categories *(Figure 3)* and was highest in low elevation sites with deeply thawed soils. Intermediate positions along this gradient had intermediate values for tree density, as did sites at high elevation. Plant cover greater than 6.6 feet (2 m) showed essentially the same response to this set of gradients, with highest biomass in deeply thawed soils at low elevation and lowest biomass in sites with thin active layers *(Figure 4)*.

Overall, at this large spatial scale, the data reflected predicted variation in response to important environmental variables. At sites with shallow active layers, the vegetation was generally low with little plant cover over 6.6 feet (2 m) in height and very few, scattered trees. With increasing active layer depth, plant cover increased in higher height strata, and generally, the vegetation was more productive with a greater density of trees.

Songbirds

For species associated with open, non-forested landscapes (e.g., horned lark, American tree sparrow, white-crowned sparrow) more individuals were detected in plots where there was permafrost closer to the surface and consequently less vegetative cover. The mean number of detections of these species was substantially higher at plots where the active layer was less than 9.8 inches (<25 cm) *(Figure 5)*. Correspondingly, for species strongly associated with forests (boreal chickadee, ruby-crowned kinglet, American robin, and yellow-rumped warbler), more individuals were detected where the active layer was deep, and there was more vegetative biomass. The mean number of detections of these species was substantially higher at plots where the active layer was greater than 9.8 inches (25 cm) *(Figure 5)*.

Discussion

Two goals of the integrated monitoring program are to quantify the relationships between environment, vegetation, and songbird distributions across Denali's landscape and to detect changes in these distributions in response to ecological changes over time. Many complex factors influence the distribution of both vegetation and songbirds; however, our analysis suggests that we can partially explain the distribution of boreal vegetation and songbird populations using active layer depth and elevation. Current scientific literature suggests that vegetation change along these two environmental gradients may be very pronounced in Alaska in the coming decades *(Camill 2005, Calef et al. 2005)*. Our data show that any changes in the active layer depth resulting from thawing permafrost could lead to major changes in vegetation patterns, which in turn could profoundly alter bird habitats over large regions of the park.

This program was specifically designed to monitor the interrelationships between physical attributes of the ecosystem, vegetation patterns, and bird distribution at large spatial scales. We co-located our sampling activities to maximize the information gained about a diverse cross-section of the park biota and to help understand the complex interactions among species and their environments. By collecting baseline data using a rigorous sampling design, we are establishing a foundation for effective long-term monitoring of resources that will allow us to better understand and manage park resources in a changing world.

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Hardy as Chickadees: Denali's Winter Citizen Scientists

By Carol McIntyre, Nan Eagleson, and David Tomeo

The Christmas Bird Count (CBC) is the longest-running and most widespread bird survey in the Western Hemisphere *(Dunn et al. 2005)*. With nearly 50,000 volunteers participating in 2,000 CBCs across North America annually, the CBC is a shining example of how the public can contribute to scientific research. The Denali CBC is conducted by volunteers that are as hardy as the birds they seek. With temperatures rarely rising above −20° F (−29° C) and the sun barely peeking over the Alaska Range, these volunteers travel via dog sled, skis, and snowshoes searching for birds. While enjoying this celebration of birds, these volunteers are providing park scientists with a valuable data set.

Twenty-six species were recorded in the Denali CBC between 1992 and 2004 *(Table 1)*. Spruce grouse, gray jay, black-billed magpie, common raven, black-capped and boreal chickadees, pine grosbeak, and redpoll were detected in most years. The count in Denali tends to be a boom-or-bust experience; the number of individual birds counted annually ranged from 71 to 935. The boom comes in years when seed-eating redpolls and white-winged crossbills take advantage of massive crops of viable white spruce seeds. These finches accounted for 64% to 76% of birds detected in the years with the highest counts.

Scientists are using the CBC data on multiple scales to monitor bird populations. On a hemispheric scale, CBC data are valuable for monitoring broad-scale trends of bird species abundance and distribution. Statewide, CBC data are valuable for monitoring numbers of birds wintering in Alaska. Locally, CBC data are valuable for monitoring the presence and relative abundance of winter birds in this area and for monitoring changes in the ecosystem. You can learn more about the Christmas Bird Count at http://www.audubon.org/bird/cbc/index.html

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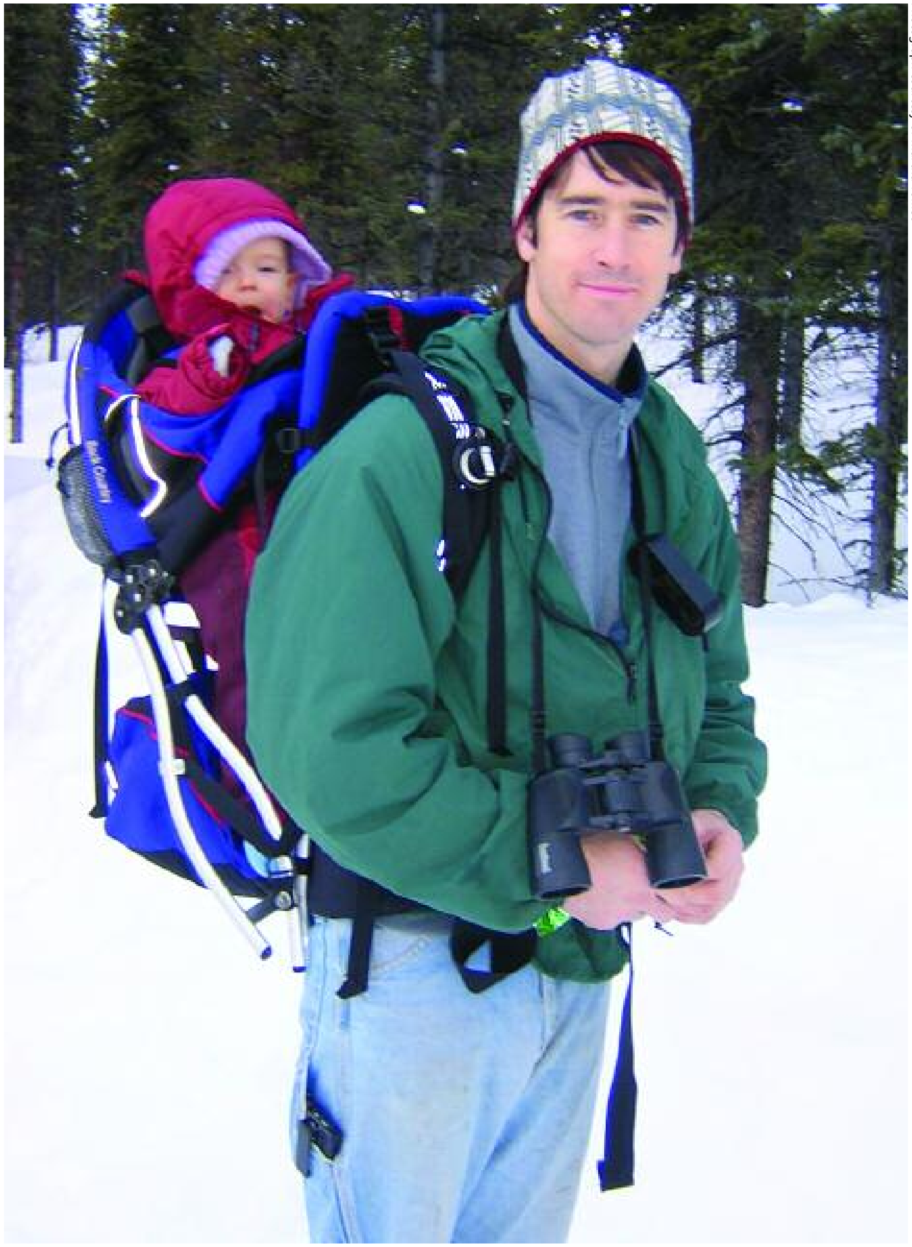
Table 1. Species observed on the Denali Christmas Bird Count, 1992 to 2004

Bald eagle	Northern hawk owl	Boreal chickadee
Northern goshawk	Downy woodpecker	Red-breasted nuthatch
Golden eagle	Hairy woodpecker	American dipper
Ruffed grouse	Three-toed woodpecker	Dark-eyed junco
Spruce grouse	Northern shrike	Pine grosbeak
Willow ptarmigan	Gray jay	White-winged crossbill
Rock ptarmigan	Black-billed magpie	Common redpoll
White-tailed ptarmigan	Common raven	Hoary redpoll
Great horned owl	Black-capped chickadee	



Photograph courtesy of Martha Tomeo

David Tomeo and daughter Emma participating in the 2004 Denali Christmas Bird Count.

Photograph courtesy of Ashley Feerer

Photograph courtesy of Clay Roscoe

Dr. Caitlin Gustafson and climber in the heated first aid tent at 14,200 feet.

"Your tent partner complains of nausea, vomiting, and headache. He also cannot figure out which boot is right or left. Which of the following may cause these symptoms?" Dr. Julianna Montooth, of the Alaska Family Practice Residency, was interested in climbers' knowledge of Acute Mountain Sickness (AMS) and frostbite, and asked this question and others to 82 climbers at Kahiltna Base Camp (photo at left) in 2002 *(King 2002).* Montooth found that climbers are well informed about AMS and frostbite.

Medical Research Climbs Denali

By Lucy Tyrrell

Late spring sunlight glows through a tent at the 14,200-foot (4328 m) camp. Dr. Caitlin Gustafson is taking 0.3 cc of blood from a climber who wears a wool hat, her turtleneck pushed up to the elbow, and a grin.

Dr. Clay Roscoe stands by, ready to insert a cuvette into a portable cooximeter that measures the amount of carboxyhemoglobin (COHb): carbon monoxide (CO) bound with hemoglobin in the blood. The level of COHb indicates exposure to CO from heaters or cooking stoves in poorly ventilated tents.

It is another day of research on the mountain.

Among those who ascend the slopes of Denali (Mt. McKinley) are physicians and health care professionals who conduct research on the common maladies of mountaineers—carbon monoxide exposure, frostbite, diarrhea, dehydration, and high altitude illness, which can plague even the fittest climber. These research projects are part survey (questioning climbers about activities or symptoms) and part assay (assessing chemical or physiological status from blood samples). Below and in the caption at left are brief synopses of four of these studies.

Do climbers exposed to carbon monoxide have higher risk of Acute Mountain Sickness?

The woman volunteering a blood sample in the first aid tent was one of 146 climbers that Roscoe and Gustafson, both of the Family Medicine Residency of Idaho, enlisted in 2004 to assess CO exposure risk in climbers *(Roscoe et al.)*. To test the relationship between elevated COHb and Acute Mountain Sickness (AMS), Roscoe and Gustafson took blood samples in addition to asking climbers about exposure to CO, past history of AMS, and symptoms of AMS (headache, nausea, fatigue, dizziness, and sleeping difficulty).

The majority (97%) of climbers reported ventilating their cooking space, yet 18 climbers (13%) tested positive for CO exposure. While 20 climbers (13.7%) met the criteria for AMS, contrary to hypothesized results, there was no significant relationship between elevated COHb and AMS. However, Roscoe still thinks there may be an important link. Climbers with symptoms of AMS did report operating stoves longer than those without AMS, a finding that Roscoe thinks supports the hypothesis that some individuals who believe they have AMS may also be affected by CO exposure.

A result Roscoe was not expecting was that descending climbers had higher CO exposure compared to ascending climbers. These results raise questions about how long COHb persists in climbers at high elevations and if CO toxicity is cumulative while climbers are on Denali.

A result Roscoe was not expecting was that descending climbers had higher CO exposure compared to ascending climbers. These results raise questions about how long COHb persists in climbers at high elevations and if CO toxicity is cumulative while climbers are on Denali.

Another important result was that more than 75% of the climbing rangers who were tested had elevated COHb levels. The elevated COHb levels may be correlated with insufficient ventilation of tents or possibly with cumulative impacts from long intervals in tents. Although the study does not confirm causes, it does suggest hypotheses and future research needs.

Photograph courtesy of Clay Roscoe

Medical research at 14,200 feet is of special interest because some high altitude physiological factors related to lower barometric pressure and resulting hypoxia are compounded because of Denali's location at high latitude (63° N).

What are the major risk factors for getting diarrhea while climbing Denali?

Following reports of a possible outbreak of diarrheal illness among climbers on Denali in May 2002, epidemiologists from the Alaska Division of Public Heath flew to the Kahiltna Base Camp at 7,200 feet (2195 m) to conduct a survey of climbers. Their mission was to determine the extent of diarrhea and what factors put climbers at risk *(McLaughlin et al. 2005)*.

Health workers learned that 27% of the 132 surveyed climbers experienced diarrhea after arriving on the mountain. At high camps with no latrine, 69% of climbers saw feces near their camp. More than 10% of climbers had defecated directly on snow, rather than using a waste disposal bag or latrine. Most climbers (78%) collected snow for consumption within 30 feet (9 m) of camp, and most (67%) rarely or never boiled their snow-water. In addition, about 30% of climbers rarely or never washed their hands with a disinfectant after defecating.

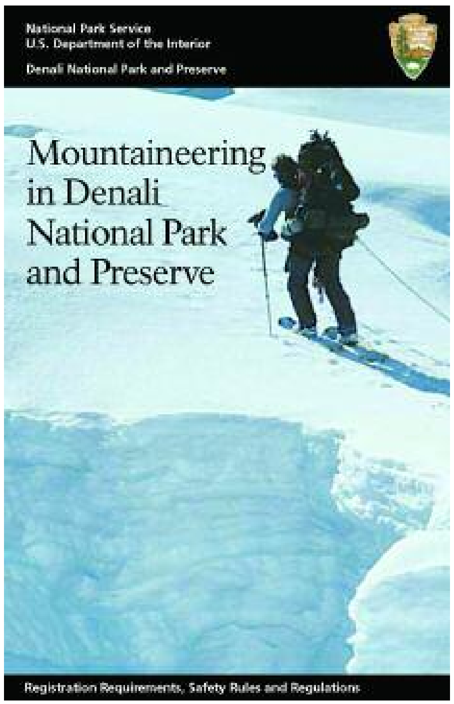
Based on the collected data, the factors that appeared to place climbers most at risk were spending eight or more days at the 17,200-foot (5243 m) camp, being a member of a climbing party in which at least one other person had diarrhea, and not receiving education about disease risk-reduction from a guide. The two most likely causes of infectious diarrhea among climbers were consumption of fecally-contaminated snow and lack of personal hygiene.

Are levels of a blood serum compound known as VEGF correlated with AMS?

At high elevations, capillaries become leaky. As the leaking plasma fluids pool in the brain, the resulting headache is a key symptom of AMS. Above 10,000 feet (3048 m), severe pooling in the lungs causes High Altitude Pulmonary Edema, and persistent brain-swelling produces life-threatening High Altitude Cerebral Edema.

To explore how capillaries become leaky at high altitudes, Dr. Eric Nilles, then at Yale University School of Medicine, studied whether levels of a blood chemical believed to cause leakiness in vascular tissue (vascular endothelial growth factor or VEGF) was higher in climbers with AMS *(Nilles 2005)*. In 2002, Nilles enlisted ascending climbers who had been acclimating at 14,200 feet (4328 m). Climbers self-assessed whether they were experiencing AMS, and their blood samples were tested for levels of plasma VEGF.

Of the 51 climbers recruited in the study, 14 experienced AMS. Climbers with AMS had higher levels of VEGF than non-AMS climbers (79 versus 58 m pg/mL), but the difference was not significant statistically. Nilles wonders if his study failed to show a significant relationship because the VEGF responsible for brain capillary permeability is an intra-cerebral VEGF and not the VEGF he sampled in venous blood.



Research findings are put to practical use. Beginning in 1982, Dr. Peter Hackett directed research on high altitude topics for more than a decade. Now, medical issues of high altitude arctic climbs are covered in this new booklet for Denali mountaineers *(Denali Mountaineering Staff and Medical Advisors 2005).*

Application of mountain research

Each of the approximately 1,200 mountaineers who attempt a summit of Denali each year is a potential subject for research on medical aspects of high altitude climbs. Research results are more than interesting to science. They lead to improvements in the health and safety of climbers and climbing rangers on the high peaks of Denali.

National Park Service photograph

Research projects are not only interesting to science, but also valuable to the health and safety of both climbers and climbing rangers on the high peaks in Denali.

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Photograph from Stephen Foster Collection, 69-92-334, Alaska and Polar Regions Department, Archives and Manuscripts Unit, University of Alaska Fairbanks Archives.

(Left) "April 12, 1919. Indians at Lake Minchuminai."

Historic and Contemporary Ethnographic Landscapes of Denali National Park

By Terry Haynes and William Simeone

Management directives for Denali National Park and Preserve (Denali) stipulate that traditional lifeways and historic and contemporary activities of Alaska Native peoples be considered in the decision-making process. This article illustrates the types of information documented in recent research that can assist park officials in fulfilling this important mandate.

The area in and around Denali comprises part of the aboriginal homeland of five Northern Athabascan Indian groups—Dena'ina, Koyukon, Lower Tanana, Upper Kuskokwim, and Western Ahtna. The affiliation of five Native groups with one national park is unique and illustrates the rich and diverse cultural heritage of the Denali area.

The long-term use and occupancy of the area by these five groups is confirmed by examining the areas to which they assigned place names. The linguist James Kari (1999) assembled more than 1,650 names that these groups gave to geographic features within a 100-200 mile (161-322 km) radius of the summit of Mt. McKinley. Many of these names are associated with landmarks located on or near rivers and streams *(Figure 1)*.

Sociopolitical Organization

Like most hunter-gatherer peoples, Denali area Athabascans lived in small, autonomous groups comprised of close relatives. Political organization was decentralized and informal; most decisions affecting the group were reached by consensus. An exceptional man might exert his authority over the group, but people followed his decisions only if they considered doing so to be in their best interests.

Kinship ties extended beyond the immediate group and provided people with a network of relatives from which assistance could be obtained when resources were scarce. Descent was matrilineal so a child belonged to their mother's clan. Households typically consisted of two related families who shared a dwelling and functioned as a single economic unit. For much of the year, people lived in small aggregates referred to as the local band, which was a large extended family centered around a core group of siblings, their spouses, children, and other close relatives. Band size varied but usually numbered from 20-75 people. Two or more local bands in the same area often joined forces to harvest fish and wildlife. This larger group, or regional band, had as many as 200-300 members who were linked by kinship ties and language dialect.

Band Territories in the Denali Area

Regional bands were associated with a specific territory shaped by the drainage pattern of a major waterway. On the south side of the Alaska Range a Dena'ina band called the Susitnuht'ana or Susitna River people, used an area extending north from the mouth of the Susitna River to the Alaska Range and Talkeetna Mountains, while a mixed band of Dena'ina and Ahtna, called the "mountain people," exploited the Talkeetna River drainage. The home territory of the Western Ahtna included the Broad Pass area and upper Nenana River corridor. One Lower Tanana band had a territory that included most of the drainages of the Nenana and Toklat rivers. Several Upper Koyukon bands inhabited the Kantishna River drainage from the Tanana River south to Denali and from the Toklat River east to Lake Minchumina.

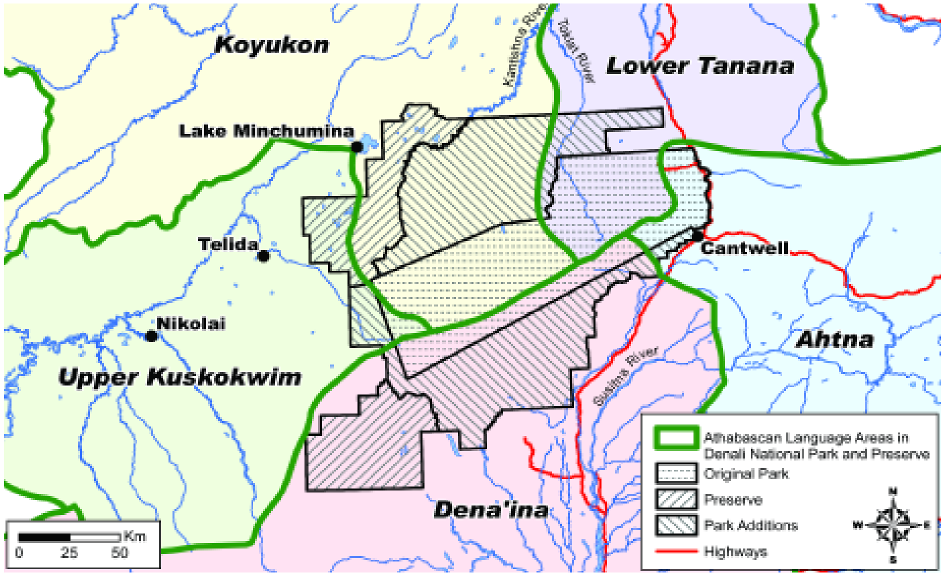

Figure 1. Athabascan language areas in Denali National Park and Preserve and adjoining areas.

Life Cycle

An Athabascan child was educated to become a skilled hunter or an industrious and accomplished housewife. Rigorous training began at puberty and included the strict observation of rules to ensure good health and a long life. Compliance, especially by young women during their first menses, also protected the community by assuring good luck and removing pollution that would drive away game animals.

Training for young men focused on physical conditioning and acquiring practical skills, spiritual power, and values necessary to become a good provider. Fathers initially trained their sons, but this responsibility eventually shifted to the maternal uncle because children belonged to the mother's clan.

Young women experienced equally demanding training, which began with a year of isolation from the family dwelling at the onset of menses. During this time female relatives provided food and instruction in sewing and proper behavior. Following a year of seclusion, young women were eligible for marriage and frequently married older men. A wealthy man might have more than one wife, the eldest of whom usually had seniority and supervised the younger wives.

People usually married outside of their local band but within the regional band. Among the Ahtna, a wealthy man reinforced his political standing by marrying women from different family groups; in doing so, he attracted followers—and especially brothers-in-law, who acted as his retainers. Marriage between cross-cousins (i.e., children of a brother and of a sister) was preferred because such alliances created bonds between widely dispersed groups.

Making a Living

Prior to European contact, Athabascan groups in Alaska moved seasonally within a defined territory to procure food resources and materials to make tools, clothing, and shelter. Because starvation was always a possibility, flexibility and specialization characterized the Athabascan bands that sought resources in the Denali area. If one resource was in short supply, efforts were redoubled to find alternatives.

The annual cycle of Upper Kuskokwim bands illustrates the importance of the Denali area for survival. People traveled by toboggan from winter camps to the Alaska Range foothills and Lake Minchumina areas in the early spring to harvest caribou, moose, bear, sheep, waterfowl, and fish. Two or more bands often collaborated to drive caribou into fences or surrounds, where they then dispatched the animals. Some of the harvest was cached and in the late fall transported by skin boats back to winter encampments. Winter activities included ice fishing, harvesting beaver, hare, game birds, and hunting hibernating bears.

Some band members remained at the winter camps throughout the year, where they harvested and processed wild foods. In the spring and summer, they caught several species of whitefish. Waterfowl eggs were gathered and birds captured in nets or killed by bow and arrow. Grizzly bears were taken with spears in the late fall near salmon spawning sites on the upper reaches of tributary streams.

Contemporary Subsistence

As resident zone communities, Nikolai, Telida, Lake Minchumina, and Cantwell are authorized to conduct subsistence activities in some areas of Denali by virtue of having significant concentrations of residents who have customarily and traditionally used these lands for subsistence purposes.

Nikolai become a permanent settlement after a school was established at its present location in the late 1940s. More families moved there after the school in nearby Telida closed in the mid-1990s. In 2002, the population of Nikolai was 96 people and predominately Alaska Native. Only a quarter of the adult population was employed year-round. Today, Nikolai families harvest primarily chinook salmon in June and July, and moose in the fall and winter. They also harvest chum and coho salmon, northern pike, whitefish and grayling, along with game birds and fur-bearing animals such as beaver. Trapping once provided cash income, but changes in habitat have reduced the abundance of fur-bearing animals, and low fur prices and the cost of gasoline have made trapping uneconomical. Caribou are scarce and seldom hunted, and changes in hunting regulations have made Dall sheep hunting difficult.

In 2002 the per capita harvest of wild resources in Nikolai was 401 pounds *(Figure 2),* half of what it was in 1984. Local people attribute this decline to environmental change, competition from non-local hunters, predation by wolves and bears, a change in values, and the high cost of gasoline. Increased competition from sport and commercial fisheries, regulatory prohibition against using a fish trap, and forced use of rod and reel are reasons given for the decrease in salmon harvests. Residents attribute declining chinook salmon stocks to falling water levels and warmer water temperatures. Some Nikolai elders believe that lower chinook harvests are also related to a loss of respect for animals and a decline in sharing and working together. While Nikolai elders believe that not upholding traditional values influences wildlife abundance, they also understand that the current scarcity of moose is a multifaceted problem tied to factors such as predation and competition from sport hunters and subsistence hunters downriver.

Historically, Lake Minchumina was a seasonal camp for staging caribou and sheep hunts in the Alaska Range foothills and for harvesting freshwater fish. In 2002, the population was 25 people, 12% of whom were Alaska Native. The per capita harvest of wild resources totaled 296 pounds, consisting primarily of northern pike, whitefish, moose, and black bear.

Residents say that moose are plentiful but changes in the lake may have long-term consequences for the community. Following the 1964 earthquake, the water level in Lake Minchumina dropped eight feet, and the wetlands surrounding Lake Minchumina drained. The water level fell another two feet in 2002, but it is uncertain whether this decline is related directly to the large 2002 earthquake, since little precipitation was recorded during the winter of 2002-2003 and the following summer. Coupled with the drop in water level, shifting channels in the Foraker River caused large amounts of silt to be deposited into the lake. In 2001, the river shifted back to its normal channel and the lake cleared, but silt deposits created thicker weed beds, which can benefit some species but can reduce oxygen levels in the water and kill fish or convert productive areas into dead habitat.

Cantwell is located at the junction of the George Parks and Denali highways, 211 miles north of Anchorage and 28 miles south of the entrance to Denali. In 2000, Cantwell had a population of 222 people and was 27% Alaska Native. Almost 69% of the adult population was employed sometime in 2000, but only 46% worked year-round. Cantwell residents harvested 135 pounds of subsistence resources per person. Moose are the largest component of the harvest, followed by caribou and sockeye salmon.

Cantwell residents harvest freshwater fish and black and brown bear in the early spring. Freshwater fishing continues in the summer, as does salmon fishing outside the local area. Berry-picking and hunting for Dall sheep and moose begin in mid-August. Caribou hunting begins in the fall and continues in winter and early spring. Other fall activities include hunting for grouse, ptarmigan, and ducks, and silver salmon fishing outside the region. During the winter, residents continue to hunt game birds, trap fur-bearing animals, and ice fish for trout and burbot.

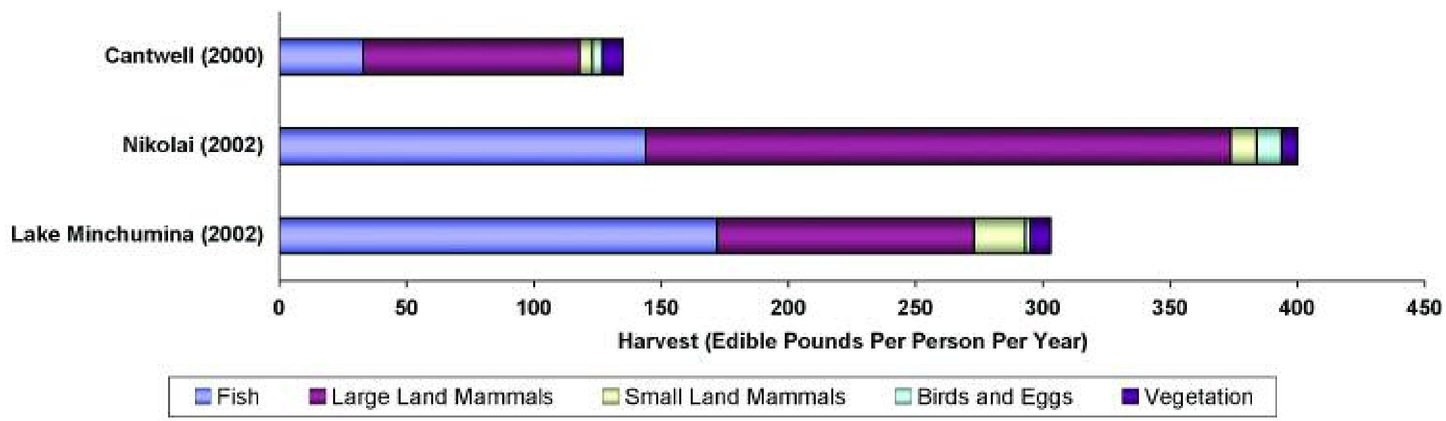

Figure 2. Per capita harvest levels in pounds of wild renewable resources by resident zone communities.

Photograph from Stephen Foster Collection, 69-92-354. Alaska and Polar Regions Department, University of Alaska Fairbanks

Figure 3. "Indians home and chief's house – Tolovana. July 30, 1919."

Feeling squeezed between urban Alaska and the National Park Service, Cantwell residents believe that pressure from urban hunters has caused game populations to decline, especially in areas that locals used traditionally. As a result, many residents now hunt almost exclusively in Denali. Cantwell people emphasize their dependence on hunting and fishing to provide for their families. They consider themselves stewards of the land with knowledge that should be utilized in wildlife management. There is also the view that Cantwell is not wilderness; therefore, Denali and adjacent lands should be managed for tourism rather than as wilderness. Some local people perceive the concept of ecosystem management as an excuse by the NPS to extend its influence beyond park boundaries and create more environmental regulation.

Summary

This article has summarized selected information presented in an ethnographic overview and assessment written for the National Park Service *(Haynes et al. 2001)* and in baseline studies describing contemporary subsistence practices in communities affiliated with Denali National Park and Preserve *(Simeone 2002, Holen et al. 2005, Williams et al. 2005)*. These reports should be consulted for more detailed information on the topics discussed here.

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Figure 1: Dr. Alfred Hulse Brooks.

Scientific Legacy of Denali

By Ann Kain

Denali National Park and Preserve has a long and interesting history of scientific research. Beginning with research by the U.S. Geological Survey (USGS), scientific studies have been carried out for over 100 years, helping officials manage the park and educating the public about park resources.

As early as 1902, USGS geologist Alfred Brooks began studies of the northern foothills of Mt. McKinley. With the discovery of gold in the Kantishna Hills, the USGS intensified its efforts in the region with geological surveys. Geologist Stephen R. Capps spent many seasons in Kantishna, studying and reporting on mining activity. He was instrumental in the movement to establish Mt. McKinley National Park when he wrote an article for the January 1917 issue of National Geographic Magazine. His article reported that large numbers of game animals were being taken by market hunters, supporting the conservation argument of Charles Sheldon and others. Geological studies and reports of the Kantishna Hills by the USGS continued until the 1970s.

Wildlife studies and observations by Charles Sheldon in 1907-08 began the long tradition of wildlife research and conservation in the park. Sheldon's work resulted in the identification of 23 different mammals and 32 species of birds. His diary, published as *The Wilderness of Denali,* was the earliest study of the natural habitat in Denali *(Dixon 1938)*.

Wildlife research in the park began in earnest when Dr. Olaus Murie of the U.S. Biological Survey arrived in the early 1920s to study caribou. In 1922, Adolph Murie joined his brother, researching and writing about the mammals and birds, as well as many other aspects of the ecology. Adolph's association and work in the park would continue until the early 1970s.

Other scientists arrived in 1926 to conduct animal population surveys and examine the dynamics between the various animals in the park. Research by George Wright and Joseph Dixon comprised the first “comprehensive, ecologically based survey of the park” *(Brown 1991)*. Wright and Dixon recorded 86 species of birds and 25 different mammals. Their research collections included 168 bird specimens, 83 mammal study skins, 350 photographs, and 280 pages of field notes *(Dixon 1938)*. Dixon returned to the park in 1932 to complete the 1926 study, resulting in his book, *Birds and Mammals of Mount McKinley National Park, Alaska* (1938).

During the first 20 years of the park’s existence, studies of large mammals concentrated on caribou, Dall sheep, and wolves. The early studies investigated the effects of interbreeding between caribou and local reindeer populations, as well as the size and movement of caribou herds. Adolph Murie continued the caribou studies in the late 1930s and early 1940s, when he recorded rutting and calving behavior and the sex and age composition of the herds. He tracked caribou numbers through 1965. In the late 1960s, aerial surveys were used to study seasonal movement and record population statistics. These survey practices increasingly were supplemented with radio collaring, which is the technique used today.

NPS photograph, Denali National Park and Preserve Archives #4.

Figure 2. Dr. Adolph Murie at old trapper cabin near the Toklat River, 1941.

(Adolf Murie’s) observation and study of the grizzly bear prompted him to comment that “...wild grizzlies in McKinley National Park, conducting their affairs undisturbed, are the essence of wilderness spirit...”

Results of these important studies of the caribou population led to studies of other mammals in the park. A significant decline in the Dall sheep population in the late 1920s and early 1930s led the NPS to institute a limited wolf control program. In 1939, Murie began to study the predator/prey relationship of wolves and Dall sheep, and he determined that the decline resulted from unusually harsh winters, rather than wolf predation. Murie’s conclusion led the NPS to end the wolf control program at Denali. However, by 1945 the sheep population was again very low. With the support of the scientific and wildlife conservation communities and in order to avoid legislation forcing rigid wolf control, the NPS instituted a limited wolf control program in 1945 and suspended the program by 1952 when the sheep population recovered. Murie’s study of the predator/prey relationship, published in 1944 as *The Wolves of Mount McKinley,* provides detailed information on wolves, and also includes Dall sheep, caribou, moose, grizzly bears, fox, and eagles.

In the late 1950s, Murie began a focused study of the grizzly bear population in the park that would last ten years. Murie gathered data regarding the life cycle, feeding habits, and range of the grizzly bear. His observation and study of the grizzly bear prompted him to comment that *“...wild grizzlies in McKinley National Park, conducting their affairs undisturbed, are the essence of wilderness spirit...” (Murie 1981)*. The observation of grizzlies in their natural habitat continues to be a main attraction in Denali. Although the most noted wildlife studies centered around wolves, sheep, caribou, and bears, scientists studied these large mammals in the context of the entire ecosystem. Observations and information gathered on moose, small mammals, birds, insects, and plants all add to our understanding of the natural dynamics. In 1980, Victor Van Ballenberghe began studying the moose population, a study that continues to the present (see article this issue). In the last 20 years, wildlife research has expanded to include studies of small mammals, such as voles and ground squirrels, and bird research also increased.

Wolf studies have continued, with Gordon Haber studying and observing two wolf packs from 1966 to 1974. Wildlife biologists L. David Mech, Layne Adams, John W. Burch, Thomas J. Meier, and Bruce W. Dale began a comprehensive wolf study in 1986 (see Meier et al. article, this issue). This team detailed their wolf-caribou findings in *The Wolves of Denali,* published in 1998. Observations and information gathered by many of the wildlife scientists included data on the flora of the park. In addition, several focused botanical studies have occurred. The first study of vegetation took place when Inez Mexia and Frances Payne of the University of California collected wildflowers and shrubs in 1927. The best known vegetation study occurred in the 1930s when Dr. Aven Nelson and Ruth Ashton Nelson of the University of Wyoming collected and classified plant

In more recent years, the Inventory and Monitoring Program has carried out systematic studies of the plant and animal populations in the park. Results of some of these research projects are presented in this issue, some are in progress, and some are just beginning.

growth for the Museum of London and the Smithsonian Institution. Their significant contribution regarding the study of vegetation resulted in the NPS identifying hundreds of plants within the park boundary.

Botanist Leslie A. Viereck studied plant succession and soil development on the outwash of the Muldrow Glacier in the early 1960s. The plots used by Viereck are currently being revisited and studied by NPS botanists as part of a comparative, long-range study. Viereck and others worked to develop the Alaska vegetation classification system and published *Alaska Trees and Shrubs* in 1972.

Vegetation studies continued in the 1970s and 1980s. Frederick C. Dean's botanical work was part of the studies conducted concerning the effects of development on the Denali wilderness. Dean provided the park with a mapping study of vegetation and an analysis of the effects of trampling on park vegetation *(Dean 1979, 1982)*.

Mt. McKinley itself was and is the site for numerous research projects. As early as 1932, scientific research on Mount McKinley began with the study of cosmic radiation at high altitudes. Following this work, the U.S. Army tested cold weather equipment on the mountain. Studies of glacier movement, geological specimens, and weather data are a few of the other research projects undertaken on the mountain. Even testing the effect of high altitude and extreme cold on photographic and motion picture equipment has taken place on the mountain. These research projects and current medical research provide a wealth of scientific information both about the mountain and the effects of high altitude and cold (see Tyrrell article, this issue).

Independent investigations early on provided a foundation for development of the ecosystem study framework that allows for more accurate interpretation of scientific data. In more recent years, the Inventory and Monitoring Program has carried out systematic studies of the plant and animal populations in the park. Results of some of these research projects are presented in this issue, some are in progress, and some are just beginning. Research conducted in Denali National Park and Preserve over many years has greatly expanded our knowledge and understanding of the physical, biological, and cultural history of the park region.

NPS photograph, Denali National Park and Preserve Archives #1966

Figure 3: Charles Sheldon

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National Park Service photographs

Sled Dog Kennels of Denali

By Karen Fortier

A unique relationship between sled dogs and scientific research has been occurring in Denali since before the lands were set aside as a national park in 1917. Charles Sheldon, known as the "Father of Denali National Park," employed Harry Karstens, who later became the park's first superintendent, and his team of sled dogs to assist in wildlife studies during the winters of 1907-1908. Since the early 1920s, Denali's sled dogs have been assisting park staff with a variety of research projects.

Park dog teams were used extensively during the mid-1980s by park biologists studying predator/prey relationships of wolves. In recent years the teams have hauled sound monitoring equipment to various backcountry locations (see Hults and Burson article, this issue) and have collected snow sampling data. They are also used to help in the historical restoration of some of the backcountry cabins. A U.S. National Weather Service Cooperative Weather station located at the kennels has collected weather and climatological data daily for over 80 years, making it one of the most prized climate data sets available in Alaska. In addition, the sled dogs have made it possible to conduct ground based censuses of golden eagles returning to nesting locations (see McIntyre et al. article, this issue).

Sled dogs provide a perfect tool for researchers accessing wilderness areas during winter months. This approach helps to minimize use of helicopters and is more aesthetically compatible with the philosophy of wilderness (as defined by the Wilderness Act) than motorized vehicles. Though dog team travel to remote locations will often mean a much slower means of access to research locations, and will likely incorporate a new set of challenges, the continued use of dog teams as a viable research tool is a priority for park management.

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