CHANGING STRATEGIES IN SEWARD PENINSULA REINDEER (*Rangifer tarandus tarandus*) MANAGEMENT

A

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Abstract

Reindeer (*Rangifer tarandus tarandus*) management techniques have changed since the founding of the reindeer industry on the Seward Peninsula in 1891. From 1891-1915, herds were small and management was intensive. Between 1915 and 1944, community herds and joint stock companies were formed. Herd management was extensive and herds were large and relatively free roaming. A period of re-privatization followed from 1944 to 1960, during which a limited number of moderately stocked ranges were established. The era after 1960 saw the introduction of several new forms of technology, some of which became catalysts for broad changes in reindeer management. Snow machines (c. 1960s), helicopters (c. 1970s), radio telemetry (c. 1980s), and Internet use became an integral part of how reindeer were managed. Most recently, satellite telemetry and online mapping have been developed as herd management tools. Combining telemetry, mapping programs, and the Internet allows herders to monitor range use, herd movement, and whether their animals need to be moved to refuge areas to prevent mixing with caribou. Equipped with this knowledge, herders can more effectively use ATV's and aircraft to manage their herds.

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List of Abbreviations and Acronyms

ADFG	Alaska Department of Fish and Game
ATV	All Terrain Vehicle
AU	Animal Unit
bash	Borne Shell Script
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
DEM	Digital Elevation Model (graphic format)
ftp	File Transfer Protocol
g	gram
GIS	Geographic Information Systems
GMT	Generic Mapping Tools
GPS	Global Positioning System
ha	hectare
HTML	Hypertext Markup Language
JPEG	Joint Photographic Experts Group (graphic format)
kg	kilogram
km	kilometer
LC	Location Class
m	meter
PHP	Personal Home Page Hypertext Preprocessor
PTT	Platform Terminal Transmitter

List of Abbreviations and Acronyms (continued)

RHA	Reindeer Herders Association
sed	Stream Editor
SQL	Structured Query Language
USFWS	United States Fish and Wildlife Service
USDA	United States Department of Agriculture
-NRCS	Natural Resources Conservation Service, previously known as the Soil Conservation Service
UAF	University of Alaska, Fairbanks
-RRP	Reindeer Research Program
USGS	United States Geological Survey
VHF	Very High Frequency
WACH	Western Arctic Caribou Herd
WGS84	World Geodetic System 1984
yr	year

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"Reindeer herd management requires a knowledge of reindeer behavior and needs, as well as knowledge of the location, distribution, and abundance, and seasonal uses of the various reindeer forage available on any particular range, …plus the ability, judgment, and experience to move animals safely to and from the proper ranges at any time of the day or season."

-Stern *et al.*, 1980.

Chapter 1: Introduction

Reindeer in Alaska

Reindeer (*Rangifer tarandus tarandus*) were introduced to the Seward Peninsula of Alaska in 1892 in response to a regional disappearance of caribou (*Rangifer tarandus granti*) and an abundance of high quality forage (Kerndt, 1990). Dr. Sheldon Jackson, Presbyterian missionary and General Agent for Education in Alaska, had observed the successful herding of reindeer in Siberia and believed reindeer might provide a solution to the lack of subsistence resources such as caribou and muskoxen (*Ovibos moschatus*). Reindeer herding offered a sustainable source of protein, which could supplement the Alaskan Native diet (Stern *et al.*, 1980; Dau, 1990, 2000).

Reindeer Management in Alaska: Establishment and Growth (1892-1915)

Cultural, economic, and political issues affected the establishment of a reindeer industry on the Seward Peninsula. Between 1892-1902, the United States government imported 1,280 reindeer from Siberia to ten Alaskan missions. Further importation was prevented when the Russian export of reindeer was prohibited in 1902 (Kerndt, 1990).

The federal government hired Siberian herdsmen to teach the aboriginal people of Alaska (Alaska Natives) herd management skills. However, traditional animosity between the Siberians and Alaskans inhibited the apprenticeship process (Stern *et al.*, 1980). In 1894, six Lapps, experienced in reindeer herding in northern Scandinavia, were employed as replacements and brought to the Seward Peninsula to teach reindeer herd management and husbandry. Despite Jackson's original intentions that reindeer be managed as a means of improved livelihood for the Alaska Natives, many reindeer were given to and retained by Lapps in return for their teaching services (Kerndt, 1990). Lapps were also permitted to slaughter their reindeer for personal consumption, whereas apprentice Alaska Natives were not (Olson, 1969).

By 1905, the average herd size was 59 head for Alaska Native owners, and 238 head for Lapps (Olson, 1969). Reindeer husbandry techniques, including proper animal care, stock selection, and pasture usage, were not yet standardized. Many reindeer herders found herding neither as dependable nor as straightforward as anticipated (Simon, 1998). Substantial yearly changes in supervisors, apprenticeship terms, and ownership qualifications caused discontent among many Alaska Native herders (Olson, 1969). Many Alaska Natives questioned who benefited most from the reindeer industry.

Gold mining created a large local market for reindeer, beginning in 1897. Reindeer were managed for meat and hide production as well as for transport, hauling, and mail delivery (Postell, 1990). The larger herds, primarily mission or Lapp owned herds, were more commercially productive (Olson, 1969). This resulted in a federal effort to put more reindeer into Alaska Native ownership. Prospective Alaska Native herders were heavily recruited, and mission and government herds were loaned out to the new herders (Kerndt, 1990; Olson, 1969). The number of herders increased, but the average herd size remained small, and herds were kept close to villages and coastlines for easier management (Kerndt, 1990).

Reindeer Management in Alaska: Reindeer Fairs and Collective Ownership (1915-1941)

Government sponsored reindeer fairs began in 1915, and are commonly seen as marking a successful period in the history of reindeer herding. The fairs created an opportunity for Alaska Native herders to gather and discuss changes and problems with reindeer herding (Kerndt, 1990). It was at the reindeer fairs that the Board of Education first suggested that Alaska Native owners form herd associations to set prices and allocate market portions (Postell, 1990). Herd associations advocated open herding based on the Great Plains ranching model, which would allow for higher population growth amid large groups of undisturbed reindeer. Many herders at the time were already finding it difficult to keep growing herds separated on adjoining ranges, and welcomed the open herding method (Kerndt, 1990). Joint stock companies were created, allowing one share of stock per reindeer owned (Postell, 1990). Cows and bulls were valued equally, causing disputes in later years regarding what animals were owed to what herders (Simon, 1998).

From 1914 to 1929, the non-Alaska Native Lomen family acquired 14,023 reindeer from missions and non-Alaska Native owners. It was the Lomen's public policy to leave the local market to the Alaska Native herders, and to concentrate instead on exports to the 'lower 48' (Olson, 1969). This arrangement worked well for a short time, and reindeer herds grew in size while interest in joint stock companies was high (Kerndt, 1990).

The period of the joint stock companies (1915-1944) resulted in less active herding, with harvesting being the primary interaction between herder and herd (Simon, 1998). Ownership of reindeer became detached from the live animals, separated from the annual subsistence cycle, and instead a matter of paperwork; herders more often dealt with reindeer numbers on paper than with the live animals in corrals. Harvesting and handling were infrequent and populations not closely monitored. The herds became large, wild, and mixed, with many unmarked animals (Olson, 1969). Association policy restricted access to reindeer products, relying on outdated tallies of general stock ownership rather than on live-birth ownership records. The limited access, poor record keeping, and undervalued stock frustrated and alienated many herders (Simon, 1998).

Toward 1925, the gold rush slowed, and the local demand for reindeer dropped creating large herds, no market, and little grazing land (Postell, 1990). The Lomens began buying the Alaska Native-owned reindeer at $2/head. This renewed tensions between Alaska Native and non-Alaska Native herd owners. Alaska Native reindeer owners again began to question who benefited from the reindeer industry. Many Alaska Native herders lost interest, and often abandoned their herds. Loose management, combined with heavily stocked and grazed ranges, caribou problems and increased predators, resulted in a sharp decline in reindeer numbers over the next 30 years, from a peak of 640,000 animals in 1930, to 25,000 in 1950 (Stern *et al.*, 1980).

Unrest among Alaska Native reindeer herders led to a federal government investigation into the matter during the 1920's. In 1929, the Secretary of the Interior reassigned the regulation of the reindeer industry to the Alaska governor, ending the Bureau of Education's involvement (Postell, 1990). The governor of Alaska recommended that federal agencies reorganize the administration of the reindeer industry and continue direct involvement only until Alaska Native herders could manage alone. After this, it was recommended that government agencies play an advisory role only (Postell, 1990).

The legality of the Lomen operation also came under investigation during this period. In 1937, the Federal Reindeer Act was passed, which prohibited non-Alaska Native ownership of Alaskan reindeer. By 1940, all non-Alaska Native owned reindeer had been purchased by the federal government and redistribution to Alaska Native herders had begun. However, disputes over interpretation of the Reindeer Act would delay the complete reorganization of the reindeer industry for nearly a decade (Stern *et al.*, 1980).

Reindeer Management in Alaska: Reorganization and Re-privatization (1944-1960)

The Division of Forestry and Grazing within the Bureau of Indian Affairs (BIA) assumed responsibility for the reindeer industry in 1941. A report was published on the status and management of reindeer in Alaska with five suggested steps for improved reindeer herd management:

> 1) Constant herding; 2) An intensive campaign for the control of wolves; 3) Improved corral handlings; 4) Improvement in methods of handling and slaughter

> of deer; and 5) Research on range and stock management, the control of parasites, and the utilization of meat, skins, and slaughter by-products, (Stern *et al*, 1980).

The BIA initiated a program in 1944 to improve management on the Seward Peninsula based on the 1941 report (Stern *et al.*, 1980). The program focused on reintroducing constant, intensive herding, improving methods of handling and slaughtering, and identifying realistic stocking densities based on range carrying capacity. Constant herding required herders to live and travel with their herd, while intensive herding required herders to monitor herd location closely with the aim of controlling herd movements and interactions.

The re-privatization of herds involved the establishment of a limited number of moderately stocked reindeer ranges (Simon, 1998). Seventeen new herds were started on the Seward Peninsula (Stern *et al.,* 1980). By 1948, herds contained an average of 1000 reindeer each. The interdependency between herder and community was reestablished and the importance of close herding was reiterated (Simon, 1998). Herd management occurred in concert with family and subsistence needs. The period of re-privatization and new herd establishment (1944-1960) resulted in the formation of several relatively stable herds (Stern *et al.*, 1980). The primary market during this period was local, but by the 1950's, government sales within Alaska and to the 'lower 48' became increasingly important (Olson, 1969).

In 1951, by request of the BIA, the U. S. Fish and Wildlife Service (USFWS) and the Alaska Native Service jointly undertook a second survey to determine the state of the reindeer industry on the Seward Peninsula (Stern *et al.*, 1980). The survey concluded that there was still sufficient demand and quality range for a reindeer industry on the Seward Peninsula. The survey also noted that in order to prevent future overgrazing and population explosions, a limit should be kept on the number and size of herds and ranges. This supervision of reindeer ranges was later assigned to the U. S. Bureau of Land Management (BLM) in 1968 (Stern *et al.*, 1980).

Reindeer Management in Alaska: Snow machine Herding and New Markets (1960-1971)

During the 1960's, a new form of herd management emerged that was based on the open herding of the collective ownership period, but which included mechanized transport (Simon, 1998). The snow machine came into common use circa 1960 and revolutionized herd management. Combined with a good working knowledge of herd and range characteristics, snow machines allowed for less time spent with the herds, while still intensively managing herd location (Simon, 1998). The undisturbed reindeer were more prolific and the more efficient management fit well with family and subsistence needs. The introduction of snow machines for herd management was followed by an increase in winter herding (Simon, 1998).

A further change in reindeer management during the 1960's occurred at the federal level. A 1968 cooperative agreement between the BLM, the BIA, and the State of Alaska established a division of labor and responsibility in matters relating to the reindeer industry. The BLM, which had been issuing 10-year grazing permits since 1962, was made responsible for assessing range quality and carrying capacity by performing range utilization checks and setting stocking densities throughout the 4 million hectares of reindeer range (Stern *et al.*, 1980). The U. S. Department of Agriculture Soil Conservation Service (NRCS) and the University of Alaska, Fairbanks (UAF) also contributed range survey work. The BIA, which had managed the training and ranching aspects of reindeer herding, was put in charge of distributing any remaining government owned reindeer and re-loaning any returned reindeer (Stern *et al.*, 1980). For every 1000 reindeer loaned, 1000 reindeer were to be repaid. The loan program ceased in 2004 when substantial numbers of loaned reindeer were lost to the migrating Western Arctic Caribou Herd. Herders could not repay the reindeer and the BIA had no budget to replace the lost animals (Warren Eastland, BIA, personal communication).

At the state level, the Department of Commerce and Economic Development assisted the City of Nome in the construction of a reindeer slaughtering and processing facility in Nome in 1969, and began maintaining economic statistics on the reindeer industry (Kerndt, 1990). The state in general assumed responsibility for the guidance and promotion of reindeer processing and marketing. Additionally, research and experimental projects, both independent and cooperative, were begun at UAF, resulting in improved herd management (Kerndt, 1990).

Herding practices changed during the 1970’s and 1980’s. Asian markets for velvet antler products began to open up in 1969, which resulted in more frequent summer handlings. Antler harvesting was found to be a particularly profitable endeavor, as the antlers are a renewable resource and their harvesting does not require the slaughtering of reindeer. The increased use of helicopters to round up and corral reindeer for antler harvest changed traditional herding practices by further increasing management efficiency, allowing herders to diversify their work lives while retaining intensive control of their herds.

Reindeer Management in Alaska: Land Ownership and Management Plans (1971-1989)

The passage of the Alaska Native Claims Settlement Act in 1971 and the Alaska National Interest Lands Conservation Act in 1980 caused much confusion regarding land ownership status (Kerndt, 1990). Rangelands became a mosaic of land ownership (Stern *et al.*, 1980). Rather than a single entity, rangelands came under the supervision of several state, federal, private, and corporate agencies. These agencies included village and regional Alaska Native corporations, the National Park Service, the BLM, and the State of Alaska. Each agency had its own attitudes, policies and regulations for herding, and often objectives were conflicting on adjoining properties (Stern *et al.*, 1980). Obtaining permits and approval for land use was frequently difficult, especially for large tracts of land spanning several ownership areas. The typical reindeer range on the Seward Peninsula is 0.2 to 0.5 million hectares in size, and includes lands owned by 6 to 8 different agencies. Many herders saw the change in land ownership as a complication and a hindrance to reindeer herding.

The formation of the Reindeer Herder's Association (RHA) in 1971 by the BIA, through a grant to Kawerak, Inc. to help gather statistics on the reindeer herds, served to unite the herders in their vision for the reindeer industry (Bader & Finstad, 1999). The herders could meet formally to discuss herding problems and possible solutions (Kerndt, 1990). RHA established a five-year industry development plan in 1979. The goal of the plan was to develop the reindeer industry to provide a stable meat supply and an enhanced economic base to the people of northwest Alaska within a culturally acceptable framework (Stern *et al.*, 1980).

In 1984, with the help of the Soil Conservation Service, coordinated resource management plans (CRMP) were developed to facilitate cooperation amongst the land-owners and the RHA (Kerndt, 1990; AKDNR, 1988). The CRMPs aim to promote sound range management practices. From 1976 to 1983, the NRCS inventoried and mapped soils and vegetation of the Seward Peninsula. These data were used to develop a CRMP for individual herders to graze animals while monitoring range conditions. Other issues addressed by a CRMP include land ownership status, grazing permits, herder goals and objectives, herd expansion, facilities expansion, fire protection, predator control, and reindeer-caribou conflicts (AKDNR, 1988).

During the 1980's, the CRMP for many herders prescribed a 5-7 year rotational grazing system for protection of lichen communities (Swanson and Colville, 1999). The resting period allowed lichens an opportunity to recover after grazing. Rotational grazing required intensive management on the part of the herder, who would move his reindeer each season to a designated grazing area (Swanson and Colville, 1999). Moving and maintaining reindeer in the chosen location often called for frequent monitoring by snow machine. During this period of management lichen production was increasing, range conditions were improving, and herd production and health were high (Swanson and Colville, 1999).

Much of the success in herd productivity during this period might also be attributed to changes in management brought about by collaboration with the University of Alaska, Fairbanks Reindeer Research Program (UAF RRP). The UAF RRP had been established in 1981 to initiate research, improve herd health, and develop herd management strategies. Changes to herding initiated by the UAF RRP include developing a Brucellosis vaccine for reindeer, obtaining approval for the use of Ivermectin in reindeer, establishing a herd record keeping system for research and management needs, and improving reindeer husbandry. The introduction of vaccinations and anti-parasitic medication alone drastically improved herd health and productivity (Dieterich *et al.*, 1981).

The reindeer industry was responding positively to modern management strategies set in place during the two decades leading up to the 1990's. High body weights, high pregnancy rates, and productive ranges were typical (Prichard *et al.*, 1999). It was these same productive ranges, however, that may have enticed the Western Arctic Caribou Herd to winter on the Seward Peninsula during the late 1980's.

An Overview of Technological Advancement in Herd Management

The introduction of new technologies, such as aircraft, helicopters, all-terrain vehicles (ATVs), vaccines, antibiotics, and computers has significantly changed traditional herding practices (Stern *et al.*, 1980). Some technologies, including aircraft and ATVs, have already been so well integrated into management practices, that productive modern herd management requires their usage for success (Bader & Finstad, 1999).

Several herders use ATVs for locating and herding reindeer during summer. However these vehicles do not travel well across tundra or waterways. Other factors may also prohibit the use of ATVs such as high purchase and operating costs, frequent mechanical problems, and detrimental environmental impact (Dau, 2000). Nevertheless, ATVs remain popular with those herders whose ranges are elevated with good drainage.

The introduction of snow machines in the late 1960's caused considerable change in herding methods. Previously, herding was done on foot or by dog team (Dau, 1990). Before the snow machine era, a crew constantly supervised and traveled with the herd even in the worst weather conditions. With the aid of a snow machine, however, herding was a much faster and easier process. By 1969, all herders on the Seward Peninsula used snow machines and new herding techniques were being developed specifically for use with snow machines (Stern *et al.*, 1980). Herders no longer had to remain with their herds, nor supply crews. Instead, herds were visited often on snow machine during the winter, and allowed to range freely during the summer, when travel was difficult.

Reindeer herders began utilizing helicopters to corral reindeer in summer during the late 1970's and early 1980's. Helicopter use was implemented after velvet antler harvesting became common, and offered a more cost-effective and timely method of corralling reindeer when antlers were in prime condition (Stern *et al.*, 1980).

Further technological advancement of the reindeer industry has occurred in the field of computer science. Computers were used at corrallings in the early 1990's

(Renecker & Chetkiewicz, 1991; Blodgett *et al.*, 1993). This has made record keeping faster, more efficient, and has allowed increasing amounts of data to be stored in an electronic format. Records for each reindeer in the corral can be viewed easily, and characteristics such as body weight and medical problems can be compared between years. The UAF RRP maintains a secure online database of reindeer related data that dates back to 1981. The database includes corralling records, vegetation sampling information, and geographic information systems (GIS) data.

Reindeer Management in Alaska: Telemetry and GIS (1989-?)

The most recent technological contributions to reindeer herding are animal location systems using telemetry and a GIS. The potential use of GIS for environmental and ecological studies has become increasingly apparent as mapping systems become more advanced (Stoms *et al.*, 1992). Past research involving a GIS has ranged from vegetation studies and habitat selection analysis to home range identification and wilderness management and planning applications (Chang *et al.*, 1995; Schneider *et al.*, 2000; Joly & Adams, 2003). The bulk of ecological work utilizing a GIS thus far deals with land surveying, habitat use, and impact assessment, with the outcome only presented in supplemental maps. There have been sparse reports of direct GIS application in range management, although the possibilities for GIS use in this field are promising (Gagliuso, 1991; Aebisher *et al.*, 1993). The concurrent explosive development of GIS and the Internet has made Internet mapping applications the natural next step for mapping systems, and for the reindeer industry.

Herders began using VHF telemetry and aircraft in the 1980’s to locate their reindeer on the large, remote ranges. This form of monitoring allows herders to quickly locate reindeer and keep an eye on movements. Efficient location techniques, combined with faster means of rounding up animals (by snow machine or helicopter), decoupled herders from their reindeer by decreasing the amount of time a herder typically spends with his herd. Near real-time herd locations (locations taken within 12 hours of real-time) have become imperative as caribou threaten herds each winter. In response to the reindeer/caribou conflict, the Alaska Department of Fish and Game (ADFG) also makes Western Arctic Caribou Herd location maps available to herders as often as possible during the conflict season, via fax or internet. The caribou are tracked with both VHF and satellite collars. The maps are publicly available on the ADFG website, however, external publication of specific caribou locations is prohibited without ADFG approval (Peter Bente, ADFG, personal communication).

The Western Arctic Caribou Herd (WACH)

In the early 1800’s, caribou were present throughout northern and western Alaska (Stern *et al.*, 1980). The disappearance of caribou during the mid-1800’s led to the introduction of reindeer. During the 1930’s the WACH began returning to eastern portions of the Seward Peninsula where it had not been seen for decades. Many northerly reindeer herds, particularly those north and northeast of the Seward Peninsula, were lost to the caribou between 1930 and 1970 (Stern *et al.*, 1980). The caribou herd peaked at around 250,000 animals before declining to 75,000 animals in the 1970’s (Dau, 2000).

The caribou herd increased dramatically in the 1990's and migrated further into the Seward Peninsula during winter, affecting more resident reindeer herds each year (Finstad *et al.*, 2000). The 2003 estimated population for the caribou herd is slightly fewer than 463,000 animals (Dau, 2000).

Two-thirds of the reindeer herders on the Seward Peninsula have lost over half of their herds to caribou since 1990, through emigration with caribou herds and through predation by wolves associated with the caribou herd. Caribou enter and leave the Seward Peninsula during fall and late spring, when snow machine use is most difficult, and when inclement weather often causes problems (Stern *et al.*, 1980; Dau, 2000; Finstad *et al.*, 2002). Caribou directly affect reindeer in three ways: "1) when reindeer join groups of caribou and leave designated ranges; 2) through competition for food and reduction of range quality through trampling; and 3) by mixing with reindeer and making them difficult to control" (Dau, 2000). Once reindeer join caribou herds, they are considered irretrievable and counted as a loss. Helicopters can be used to separate reindeer from caribou by selecting the shorter limbed and slower moving reindeer. The process requires a skilled pilot and can take hours to accomplish. Upon successful separation, the reindeer can sometimes be herded back to their ranges. Helicopters are unaffordable for many herders though, and those who do use helicopters often have no regions of their ranges free of caribou. In cases where reindeer are recovered, these reindeer have often become wild and must be slaughtered for the herder to maintain control of the rest of the herd. Loss of reindeer to caribou represents not only decreased reindeer numbers and potential income, but also a way of life (Schneider *et al.*, 2000). In hopes of retaining the reindeer industry in Western Alaska, the herders have turned to technology for aid.

Objectives

The primary objectives of this project were to develop new herding techniques using satellite telemetry and the internet, and to recommend changes in range management practices based on an assessment of the impact of increased reindeer browsing on lichen in refugia.

Part one of this study presents new methods in which satellite telemetry and GIS are being developed to minimize the impact of caribou presence on reindeer herds. GIS capabilities were enhanced to create an automated, interactive web-based interface where herders can obtain "near real-time" locations and related data for collared reindeer. The GIS interface is accessible anywhere that the Internet is available, and can provide herders with reindeer herd information such as dates and frequency of locations, seasonal movement patterns, home range location, and habitat use data.

Part two of the project presents the consequences of intensified lichen grazing within reindeer refugia. Preferred lichen biomass, distribution, and utilization were compared with historical biomass values established by the NRCS. The results of the biomass analysis provided information on the potential sustainability of refugia use as a management technique for reindeer in the presence of caribou.

Chapter 2: Managing Alaskan reindeer with satellite telemetry and a GIS

Abstract

Historically, the Seward Peninsula of Alaska has been considered prime grazing land for domestic reindeer (*Rangifer tarandus tarandus*) largely because of the abundance of forage and the absence of caribou (*Rangifer tarandus granti*). Recently, the Western Arctic Caribou Herd of Alaska increased in size from approximately 80,000 to over 500,000 animals and shifted its winter range. Since 1996, as many as 225,000 caribou have overrun traditional reindeer ranges. As a result, reindeer are mixing with migrating caribou and leaving traditional ranges. Reindeer herders now must change management strategies and use new technologies to salvage what is left of their herds. Herders need to identify isolated areas, or refugia, on their ranges that provide adequate nutrition, avoid migrating caribou, and allow tighter control of their herds. With the aid of satellite telemetry, GIS mapping systems, and the World Wide Web, herders are able to monitor and move their reindeer relative to the migrating caribou.

Introduction

Satellite telemetry and geographic information systems (GIS) have become an accepted method of determining locations and movements of animals during the past 3 decades (Kenward, R. E., 2001). Telemetry has been used in the range management of both wildlife and domesticated animals (Coulson *et al.*, 1987; Stuth *et al.*, 1990). Caribou research in North America, Asia, and Europe has benefited from the use of satellite telemetry in population, migration, and land utilization studies (Schaefer *et al.*, 1998; Farnell & McDonald, 1990). Domesticated animals studied using these techniques include cattle and sheep (Bleich *et al.*, 1990; Udal *et al.*, 1998). Such studies revealed valuable information on daily to weekly movements, resource utilization, migration paths and distances, and home range size and location. However, few studies have utilized satellite telemetry data in the management of animal distribution.

There are several benefits to utilizing a satellite telemetry system in range and herd management (Keating, Brewster, & Key, 1991). Data recovered in satellite telemetry is near real-time, limited only by data processing time (data is delivered within 12 hours of collection). Additionally, satellite telemetry data is less weather dependent, and more reliable, than tracking from ground or aircraft. The latter can be hindered by overcast and poor weather days, when aircraft and ground vehicles cannot be used to track animals. Producers can easily and quickly locate animals on large and remote ranges. Furthermore, by combining telemetry data with forage data, producers can determine usage and make adjustments to grazing patterns. Lastly, satellite telemetry can promote community involvement in range and herd management in rural areas. The “near real-time” results of a telemetry based management system can offer a community immediate and encouraging feedback on their efforts and participation in range management. Such positive feedback can act as an impetus to increase community participation and support for rural range management (Lewis, 1995).

A disadvantage to satellite telemetry is poor positional accuracy relative to ground-based estimates. Satellites usually receive signals at an angle and therefore contain an element of error. Even the highest quality locations produced by satellite telemetry contain some error. Locations are accurate only to 150 m (Service Argos, Largo, Maryland), even with a high quality transmission. However, locations accurate to within 150 to 500 m may be adequate for reindeer range management applications.

Satellite telemetry is needed for reindeer management on the Seward Peninsula to address three major management difficulties: remote terrain, sensitive forage, and caribou interaction. Reindeer ranges are large and secluded, and the herders have sporadic contact with their animals. Herders once traveled and lived with their herds, but today live in communities with their families. Currently, herding involves the occasional gathering and moving of reindeer by foot, ATV, and helicopter. Isolation from the animals requires herders to have a remote means of monitoring animal locations and movements. In summer, travel across tundra is onerous. Rivers and saturated tundra make ATV use difficult. Although travel can be faster by snow machine during the winter, blizzards and extreme sub-zero temperatures can be prohibitive. Additionally, sufficient snowfall for snow machine usage comes late in some winters (Schneider *et al.*, 2000). Locating and monitoring the movements of reindeer by satellite offers a safer, easier, and more reliable method of monitoring locations and managing reindeer.

Current reindeer management calls for constant monitoring of herd distribution due to range sensitivity to grazing. Lichens, the staple of the winter reindeer diet, recover slowly after grazing. Rotational grazing allows winter ranges to recover between grazing periods. The time spent grazing and resting a winter range depends largely on the amount of lichen within each winter range, as well as the size and number of winter ranges within the herder's permit. In general, reindeer are allowed to graze a winter range only to the extent that the lichens can still grow back fully within a reasonable amount of time after grazing (USDA-NRCS recommends not exceeding 45% of the available forage biomass). Beyond this point, the reindeer must be moved to another winter range while the previous winter range is given a resting period. To ensure that each winter range has sufficient recovery time, reindeer locations must be constantly monitored, and reindeer moved if they stray into resting ranges. Knowledge of current herd telemetry locations helps herders to better enforce their management practices, such as rotational grazing and use exclusion. When reindeer stray from their designated grazing area, herders can know right away and quickly take action to correct the situation.

Reindeer also need to be moved when there is a possibility that they will interact with caribou. Reindeer in the presence of caribou become more difficult to herd and control (Dau, 2000; Klien, 1980; Finstad *et al.*, 2003). A single caribou can change the behavior of a reindeer herd. Reindeer are bred to be sedentary and stay in groups when frightened, but in the presence of caribou, reindeer disperse quickly. Once mixed with caribou, reindeer migrate far off their ranges. To avoid the behavioral problems associated with caribou, reindeer must be herded away from the caribou to refugia (Finstad *et al.*, 2003). Mountains and bodies of water often geographically isolate refugia. Caribou are turned aside by these geographic obstructions and prevented from associating with the reindeer. Reindeer management in the presence of caribou requires up to date location data. Near real-time data allows herders to immediately move their reindeer into the refugia as caribou approach.

Fifteen reindeer range allotments have been directly affected by the annual caribou migrations between 1985 and 2002 (Figure 2.1). Reindeer herds have been lost from 8 of 15 allotments: Walker, Hadley, Henry, Sagoonik, Sheldon, Elim, Karmun, and Goodhope, and herds have been affected on the remaining 7 allotments: Gray, Menadelook, Weyiouanna, Noyakuk, Davis, Kakaruk, and Olanna (Finstad *et al.*, 2003). In 1999, a satellite telemetry system was implemented to aid in managing reindeer, especially those affected by caribou migrating through reindeer ranges. Herders used the data from these collars to manage their herding activities.

Objective

The objective of this paper is to investigate the effectiveness of a telemetry and data transmission system designed to give herders timely location data for their animals when caribou are present.

<u>Methods</u>

Study Area

The Seward Peninsula is located in central western Alaska, along the Bering Strait (between 64°N and 67°N in latitude, and -170°W and -160°W in longitude), and encompasses over 4 million ha of tundra rangeland (Figure 2.2). Perched water tables and permafrost are ubiquitous in the area. Native vegetation consists of a variety of sedges, grasses, forbs, lichens, and mosses. White Spruce (*Picea glauca*) and Paper Birch (*Betula papyrifera*) stands are limited to southeast Seward Peninsula, while much of the remaining region is defined by extensive tussock tundra and sedge drainage ways. Thirty-nine distinct ecological sites have been identified and mapped for the region (Swanson *et al.*, 1985).

Two primary mountain ranges and the Imuruk Basin characterize the region (Figure 2.2). The Imuruk Basin is a large and centrally located water body, providing some herders with summer access by boat to otherwise remote ranges. To the south of the Imuruk Basin, and forming a crescent above the city of Nome, lay the Kigluaik Mountains. Together these two features form a formidable physical barrier around the area west of Nome and south of the Imuruk Basin. The Bendeleben Mountains are located on the eastern portion of central Seward Peninsula. In the south, these give way to the Fish River Flats, a primary river drainage for the area. Road access within the Seward Peninsula is limited, and overland travel is difficult. Travel on the three main roads that branch out from Nome to the east, west, and north is limited by season and maintenance. In some years, roads may be closed and without maintenance from late November to mid-June. Each of the three roads is less than 1500 km in length. There are 16 permitted reindeer grazing allotments on the Seward Peninsula, 6 of which are accessible by road.

Overview

Satellite collared reindeer were tracked, and the location information was made available to herders through Internet, phone, or fax. Locations were typically received on a weekly basis and mapped using a geographic information system (GIS). Herders located their reindeer according to the telemetry data and, when possible, herded them away from incoming caribou to refugia. Refugia are intensively managed, secluded geographic regions selected for their natural barriers, such as mountains and rivers, which may discourage caribou use (Finstad *et al.*, 2003).

Refugia usage required herders to restrict their herds to winter areas that are typically much smaller than the average reindeer range size. This concentrates grazing pressure in the refugia, and can damage important winter forage, particularly lichens, if stocking densities and range utilization are not carefully monitored. The BLM, NRCS, and UAF RRP perform routine utilization checks and adjust stocking density recommendations accordingly. Caribou wintering on the area outside of refugia also deplete rangeland quality and quantity. Utilization checks are done on this area as well, to predict future reindeer range carrying capacity after the caribou have migrated.

Telemetry

Thirty-two platform terminal transmitters (PTTs: Telonics, Inc., Mesa, Arizona) were placed on reindeer from 9 herds, and tracked by satellite (Service Argos, Largo, Maryland) from 1999 to 2003 by the Natural Resource Conservation Service (NRCS), the University of Alaska, Fairbanks Reindeer Research Program (UAF RRP), and the Reindeer Herders Association (RHA). Each collar consisted of heavy machine belting with an attached PTT (Telonics Inc., Mesa, Arizona) and VHF beacon. Collars were tested for accuracy six-weeks prior to deployment. The collars were placed in a tree within the fenced Fairbanks reindeer farm of the University of Alaska. A location was taken using a Garmin global positioning system (GPS) 12 receiver, World Geodetic System 1984 (WGS84) datum, and used as a reference point to compare to telemetry generated locations. Garmin GPS receivers are accurate to within 15 meters on average.

Reindeer were outfitted with satellite collars at handlings, or in the field by using snow machines and net-guns. Females and steers were chosen for collaring because they do not experience the neck expansion and contraction exhibited by reproductive males during the fall breeding season, which often leads to shed collars (Farnell & McDonald, 1990). Females also tend to be less solitary than males, providing for a better representation of herd location when tracking (Paine, 1987; Baskin, 1990). Three collars were programmed to broadcast at 6-hour intervals daily, and 6 to broadcast at 6-hour intervals every 10 days. The remaining collars were programmed to broadcast every 5 days. Each collar was deployed for approximately 2 years before being replaced.

In some cases, the animal died or the battery on the satellite collar was depleted before the collars were retrieved. In the cases of battery depletion or mortality, UAF-RRP staff retrieved the satellite collars in the field utilizing the VHF beacon attached to each collar. Once recovered, the collars were sent to Telonics, Inc for refurbishment, to have their batteries replaced and systems updated if needed. After refurbishment, Telonics, Inc returned the collars, which could then be redeployed on other reindeer.

Collars were allocated to those herders whose herds were at risk to migrating caribou, and who showed the most interest in applying telemetry (Table 2.1). Four collars were initially placed on animals in the herd of Mr. Thomas Gray (White Mountain, Alaska), six collars were placed on animals in the herd of Mr. James Noyakuk

(Teller, Alaska), and one collar was placed on a reindeer in Mr. Roger Menadelook's herd (Teller, Alaska). During the second year of the telemetry program, three more collars were placed on animals in Mr. Menadelook's herd, one more in Mr. Gray's herd, three in Mr. Wilfred Kakaruk's herd (Teller, Alaska), four in Mr. Leonard Olanna's herd (Brevig Mission, Alaska), two in Mr. Clifford Weyiouanna's herd (Shishmaref, Alaska), one in Mrs. Faye Ongtowasruk's herd (Wales, Alaska), and two in the Savoonga IRA herd (Savoonga, Alaska). Additionally, five collars were placed at the end of the study during the fourth winter (2002-2003) in Mr. Larry Davis' herd (Nome, Alaska).

Satellites transmitted collar ID, latitude and longitude in decimal degrees (WGS84), Julian date, time of day, and quality class values to the Argos data retrieval center in Largo, Maryland. The data were decoded and sent via file transfer protocol (ftp) to the UAF RRP for archiving and mapping with a GIS. Only the most recent locations with the highest quality location class (LC = 2 or 3) from each Argos dataset were used for mapping (Keating *et al.*, 1991). Electronic characteristics such as signal strength, signal-to-noise ratios, and geometric dilution of precision were used by Argos to determine location quality (Johnson & Marx, 1998). Argos estimates that LC-3 locations are accurate to within 150 m, and LC-2 locations to within 350 m. LC-3 locations were the most accurate locations provided in the Argos datasets.

GIS workstation

GIS products were utilized during the automation and set up process. Generic Mapping Tools 2.0 (GMT, public domain UNIX software developed and maintained by

Paul Wessel and Walter H. F. Smith, available at http://gmt.soest.hawaii.edu/) was installed on a networked Linux system and run using a UNIX command prompt. GMT provided the framework for map automation.

Arc Internet Mapping Server 3.2, an ESRI development closely related to ArcView, designs and publishes interactive websites based on GIS mapping technology. The initial aim of the automation procedure was to utilize this ESRI product, however, until the required programming integration was met, GMT was utilized as the default system. GMT offers superior integration of UNIX programming commands and command line based mapping tools. It was therefore better suited for GIS automation purposes at the time.

Creating Automated Maps

Automated map creation was accomplished by composing and running a series of linked program scripts. The programs that the scripts were written for are basic utilities of a Linux operating system, commonly used for automating simple tasks. Each script runs through a set of commands to that work sequentially to convert numerical satellite data into maps.

Satellite collar locations are received from Argos each morning and processed three times per day (7AM, 3PM, and 10PM) (Figure 2.3). First, Script 1 is run to archive locations and to call Script 2. Script 1 uses queries to identify whether new data have arrived. If there are no new data, Script 1 ends and no further tasks are followed until the next preset processing time occurs (e.g. 3PM). When there are new data, Script 1 processes a ‘copy command’ to copy the data to an archive file. The original data then serves as a working file. Script 1 moves the working file to a work folder, and then calls Script 2.

Script 2 sorts the collar locations and eliminates erroneous data. The format of the received ARGOS data is preset such that unique signifier sections of the data strings can be identified and eliminated using command language. After removing erroneous data, Script 2 arranges the remaining data as insert statements.

Script 1 then calls the command line monitor program (mySQL) and instructs it to put the insert statements into a temporary database. Script 1 next calls a command line interpreter to run Script 3. Script 3 uses queries to select only the highest quality locations from the temporary database, and then inputs these into a primary database. Finally, Script 1 calls Script 4 (queryloc.php) to create any new maps.

The queryloc.php script (Appendix) involves several steps prior to map output. First, the primary database is queried to find which herders need new maps for the current and previous day. For each of these herders, the database is then queried again to find the latest location for each collar. Next, the script determines how many maps each herder requires, based on each collar’s distance from the herder’s mean collar location. Collars more than a degree away from the mean are placed on a new map. The basemap boundaries are then determined from the mean collar location of each map. GMT uses these values to adjust to the area of each map being plotted. All maps were plotted using the Universal Transverse Mercator Zone 3 projection, North American Datum, 1927.

GMT was used to add coastlines, rivers, contours, labels, collar locations, a scale bar and a legend. Coastline data were provided with GMT in the pscoast module. Rivers and labels were obtained from a United States Geological Survey (USGS) annotation e00 file (anno.e00 and rivers.e00). Converting USGS 1-degree digital elevation model (DEM) files to grid contour files provided contour data for GMT. After executing the GMT commands for each map, the script then converts each map to a 600x480 pixel Joint Photographic Experts Group (JPEG) image, and moves the new images into a secure online database (CMS). Each image is named with the format:

“*herdname*”satcoll_”*date*”_”*mapnumber*”.jpg,

where “herdname” is the first four letters of the herd name, “date” is the date of the most recent location on the map (YYYY-MM-DD), and “mapnumber” is between 0 and 3, depending on the number of maps made for a herd (0=first map, 1=second map, etc). The online database is accessible by password to herders through a primary satellite collar web page.

The web page was created for herders to easily access the most recent maps from the database. It contains links that call up each herder’s most recent maps for viewing, and lists all other maps by date in a pull-down menu. The web page also links by permission to Western Arctic Caribou telemetry maps created by the Alaska Department of Fish and Game (ADFG).

Results

Collar Accuracy

In testing the collars before deployment, there was a mean distance of 281 m (MSE= 20 m, n=32) from the GPS location for collar locations of the highest location class (LC = 3). There was a mean distance of 400 m (MSE= 39 m, n=32) for LC-2 locations. These results are consistent with others found in the literature, and may be affected by changing temperatures, dense vegetation cover, heavy cloud cover, and elevation (Harris *et al.*, 1990; Kenward, 2001).

Winter 1999-2000

Two reindeer had collars by fall, 1999. ID 13168 was on a Gray reindeer, and ID 04997 was on a Noyakuk reindeer. Herders allowed the collared reindeer to range freely during this initial trial of the telemetry, but the reindeer remained on their respective ranges. At this time, herders primarily used location data for monitoring animal movements.

By summer, 2000, more collars had been deployed, and herders were using the collar locations to aid in corralling reindeer. Herders tracked reindeer closely using satellite telemetry before handlings. Herders on ATVs or a chartered helicopter easily located reindeer and herded them to the corrals. Locations from satellites were often used specifically on overcast days, when radio telemetry tracking, or observation using fixed wing aircraft telemetry, was difficult. Furthermore, herders also used the locations to round up reindeer during summer before inclement autumn weather. Herders were able to identify which reindeer were closest to the corrals and which would therefore be most swiftly and easily rounded up. Some herders would even wait to round up their animals until collared reindeer traveled within a few kilometers of corrals (James Noyakuk; Leonard Olanna, herder, personal communications).

Winter 2000-2001

Nine more collars were placed on reindeer by fall, 2000. Three went on Gray reindeer, 5 on Noyakuk reindeer, and 1 on a Menadelook reindeer. There were 11 collars operating on the 3 ranges: 6 on the Noyakuk range, 4 on the Gray range, and 1 on the Menadelook range. These ranges were located at the western front of the caribou wintering grounds, and given priority for collar placement due to the threat of communing with caribou.

The Seward Peninsula experienced a large influx of caribou during winter, 2000-2001 (Figure 2.4) (Peter Bente, Kate Persons, ADFG, personal communications; RHA reports). Herders utilized telemetry locations on a daily basis to monitor reindeer movements. The ADFG made location maps of the Western Arctic Caribou Herd (WACH) available to herders to monitor caribou locations. When caribou moved into areas close to reindeer herds, the herder would travel by snow machine and move his reindeer. Mr. Thomas Gray was able to successfully move his animals out of the way of migrating caribou to a refuge (Figure 2.4B) using a snow machine and the information provided by collar locations.

Thomas Gray selected his refuge based on geographic isolation, proximity to the village and traditional home range, and winter forage availability (Thomas Gray, herder, personal communication). Geographic isolation was sought as a physical deterrent to caribou. Proximity to the village and traditional home range were sought to ease stresses on both reindeer and herder due to increased herding activity. Reindeer will demonstrate fidelity to a traditional home range. The closer the herd remains to the village, the lower the expenses and effort associated with physically locating the reindeer (Stern *et al.*, 1980). Winter forage availability largely determines the number of animals that can be held in a refuge.

Gray monitored caribou movements using the web-based location maps, and he moved his reindeer to the refuge before caribou arrived. Initially the reindeer moved out of the refuge, and had to be herded back on a regular basis. Satellite locations alerted the herder to straying reindeer. Persistent and intensive herding by the herder gradually accustomed the reindeer to their new location, and many reindeer were successfully kept separated from the encroaching caribou. The caribou skirted the refuge, but did not enter, probably due to the mountainous terrain and herder intervention.

Despite intensive herding practices, some reindeer mixed with the migrating caribou during winter, 2000 (Finstad *et al.*, 2002; Swanson *et al.*, 2002), including all 7 of the collared Noyakuk and Menadelook reindeer. Two collared reindeer, ID 19038 (Figure 2.5) and ID 17590, were located, separated from the caribou, and herded back to the appropriate range during spring, 2001. The reindeer collared with ID 17590 died of unknown causes on its home range in late summer, 2001. ID 19038 remained on the home range in the field for another winter before it fell prey to wolves in late spring, 2002 (Greg Finstad, UAF-RRP; James Noyakuk, herder, personal communications).

Five collared reindeer remained mixed with caribou during winter 2000 - 2001 (Figures 2.4, 2.6). Two (ID 05504 and ID 19041) of these died within one year of leaving the range, and two (ID 17589 and ID 17591) others went offline due to battery depletion. Handlers observed these collars on live reindeer at a Davis handling just outside of Nome, approximately 100 km from their deployment location (Rose Fosdick, RHA, personal communication). Collar locations of reindeer that mixed with caribou indicated that several reindeer remained near the Bendeleben Mountains when the caribou herd rapidly left the Seward Peninsula in May (Figures 2.7, 2.8). Some of these reindeer later returned to their ranges after the caribou left (Figures 2.5, 2.7). A hunter mistook the reindeer with ID 05504 for a caribou and shot it while it was off range (Rose Fosdick, RHA, personal communication). Wolves killed the reindeer bearing ID 19041 within two weeks of the ID 19038 reindeer (Greg Finstad, UAF-RRP; James Noyakuk, herder, personal communications). Locations for ID 19041 indicated that this reindeer died just outside of its range. The fifth collared reindeer that mixed with the caribou, ID 04997, was tracked off of the Seward Peninsula into the Brooks Range, until data transmission ceased a year and a half later, in late 2002, presumably due to battery depletion (Figures 2.6, 2.9).

Winter 2001-2002

Herders were alarmed by the devastating losses brought about by the caribou presence on western ranges during winter, 2000-2001 (Finstad *et al.*, 2002). By fall, 2001, 16 more satellite collars were placed on reindeer. In total, there were 25 active collars in 8 herds by early September 2001 (two collars, ID 19089 and ID 20953, were inactive due to battery depletion and mortality). At this point, all remaining herders on the Seward Peninsula were using satellite telemetry.

Of the reindeer with collars deployed from 1999-2001, only those belonging to herder Gray were still on range at the beginning of the 2001-2002 winter. The reindeer with collar ID 19039 was killed by a bear on the Gray range during the summer of 2001 (Thomas Gray, herder, personal communication). The collar was redeployed the following spring on another Gray reindeer. Collar ID 28557 was added to the Gray herd in spring, 2001. During winter 2002, caribou again wintered on the Gray range, forcing him to move and hold his herd on the refuge.

The Noyakuk collars, aside from collar ID 19038, either were off range with caribou, or went offline due to dead batteries by winter. However, locations from reindeer collared during later winters (2002-2003), showed a successful utilization of a Noyakuk refuge with a small, intensively managed herd.

Caribou overran the Menadelook range in winter, 2001. The reindeer herd completely mixed in with the caribou. Three collars were placed by net-gun on Menadelook reindeer while on their home range during early spring, 2001. Two of these reindeer died during late spring and early fall of unknown causes, while mixed with caribou. Collar ID 05504 was redeployed on a Menadelook reindeer in summer, 2001, while on the Noyakuk range. This collared reindeer later wandered further off-range.

Additional collars went to western herds during spring, 2001. All but one of these collared animals survived the winter and avoided caribou. Collar ID 20953, belonged to the Kakaruk herd and was on an off-range animal on the Davis range. A bear killed it during summer, 2001, while it was still on the Davis range (Greg Finstad, UAF-RRP, personal communication). The remaining collars were placed and remained on the appropriate ranges throughout the winter (Figure 2.10).

Many collars were refurbished and redeployed during 2002. The website for herders became completely automated in spring, 2002. Before that time, maps were updated daily by hand and transferred to the website within a few hours of receiving new data. The automated maps are continuously being refined to provide the best maps possible to the herders. Several new collars were scheduled for placement on reindeer during 2003.

Discussion

Herder Response

When first introduced, the satellite telemetry program was not easily accepted. Many herders were reluctant to apply an expensive and unproven new technology for management purposes. However, the initial phase of satellite telemetry had successfully demonstrated its value to herders as a reliable and useful management tool.

Noyakuk indicated that satellite collars were essential in enabling him to cost-effectively round up his herd for a handling (James Noyakuk, herder, personal communication). Locating reindeer on the remote terrain in a timely manner was critical to successful management. Before the availability of satellite collar data, he was not able to justify corralling his reindeer for several years due to the prohibitive costs of locating his herd by aircraft (James Noyakuk, herder, personal communication).

Reindeer herder Larry Davis indicated that satellite collars had become fundamental to successful reindeer herding. “Without satellite collars I don’t think there would be any reindeer on the Seward Peninsula anymore. Without satellite collars, I wouldn’t be able to herd reindeer anymore. I have 6 collars now and I wish I had sixteen more” (Larry Davis, herder, personal communication). Davis also mentioned that having the technology only helps if it is used as part of an overall management strategy. “With the satellite collars we can find the reindeer right away and know they are nearby in the general area of the collar location. But even with a helicopter and the satellite collars, you still have to use them or they won’t help” (Larry Davis, herder, personal communication).

Herders were able to use collar locations for management purposes, despite the poor positional accuracy of satellite telemetry estimates relative to ground-based estimates. The telemetry system allowed the herders to see when caribou began migrating out of the Seward Peninsula, and which reindeer were sufficiently close to their ranges to justify retrieval expenses. Without the telemetry system, herders may not have had this management option, and all of the reindeer that had left with the caribou would have migrated with the caribou or died in the attempt.

Reindeer that went off range often became mortalities. As semi-domesticated animals, the reindeer were not physically built to migrate the long distances that caribou travel annually (Klein, 1980). The reindeer quickly became easy targets for predators and hunters that trailed the caribou. Wolves were particularly indiscriminant in reindeer and caribou kills, attacking both animals, regardless of what range they were on.

Many factors combined to work against the herders' efforts to maintain their herds during winter, 2000. Herders were not prepared as caribou swept into the Seward Peninsula much faster than expected and in larger numbers. Sufficient telemetry locations were not yet consistently updated and forwarded to herders in a timely manner. Furthermore, collar locations did not indicate how many reindeer or caribou were present with a collared animal, or if that animal was at the edge or the center of its herd. In addition, Gray's refuge was exceptionally isolated as part of a coastal range. It was located on a peninsula and barricaded by a series of imposing ridges. The refugia of the inland ranges of Noyakuk and Menadelook were not as inaccessible to caribou, and may not have provided as much protection. Refugia identified on these ranges consisted of open, low-lying areas protected only on one side by the Imuruk Basin.

Nonetheless, both Gray and later Noyakuk had success in intensively managing their reindeer in refugia with the use of satellite telemetry. Few reindeer were lost when the herders monitored their herds closely. More herders began using telemetry to help corral reindeer for handlings, and to reinforce site fidelity by ensuring that the reindeer did not stray far from their ranges or refugia. Some herders reduced their herds to promote close herding. They hoped to retain a core group of stock reindeer from which to start up a new herd once the caribou changed migration routes again (Larry Davis, herder, personal communication).

Funding

Currently, reindeer herders are not paying for satellite collars, ARGOS time, or the automated mapping system. The telemetry system is supported financially and logistically by the collaborative efforts of several state, federal, and tribal organizations, namely UAF, RHA, individual herders, NRCS, and BIA. UAF-RRP contributes support for all aspects of the program. NRCS contributes through the Grazing Lands Conservation Initiative to fund collar tracking and refurbishment. BIA contributes funds for collar purchase and tracking. Kawerak RHA contributes funds earned from grants to support satellite collar tracking. Individual herders help by placing and recovering collars, as well as by returning collars no longer transmitting to satellites. Without the funds and technical services provided cooperatively by these entities, herders will have difficulty maintaining the program due to small herds and low profits. Herders may need to find an alternate means of funding should current financial support cease.

Automated Maps

The maps produced by GMT are simple and efficient, though not without room for improvement (Figure 2.11). Initially labels on these maps were not equally distributed throughout the Seward Peninsula, and some regions displayed more landmarks than others. Several geographic locations and landmarks had to be entered into the feature data files by hand, possibly due to the remote location and small scale of the region under study. The GMT script is constantly being customized and developed to provide more detailed automated map creation.

Conclusions

Automating the mapping system has given herders “near real-time” location data, limited only by processing time, to make successful management decisions. The few hours saved by automation represent a few more kilometers between caribou and reindeer, and a few less dollars or hours spent looking for reindeer, by air or land. The faster locations are relayed to herders, the sooner and more reliably the reindeer can be physically located and herded. Herders have overwhelmingly adopted satellite telemetry as a management tool, hoping to expand the program to include more satellite telemetry collars. Many herders have proclaimed satellite telemetry to be “the best thing since snow machines.” In a time and place where nomadic herding is no longer a practical option, satellite telemetry offers a reliable and efficient means of maintaining intensive herding practices.

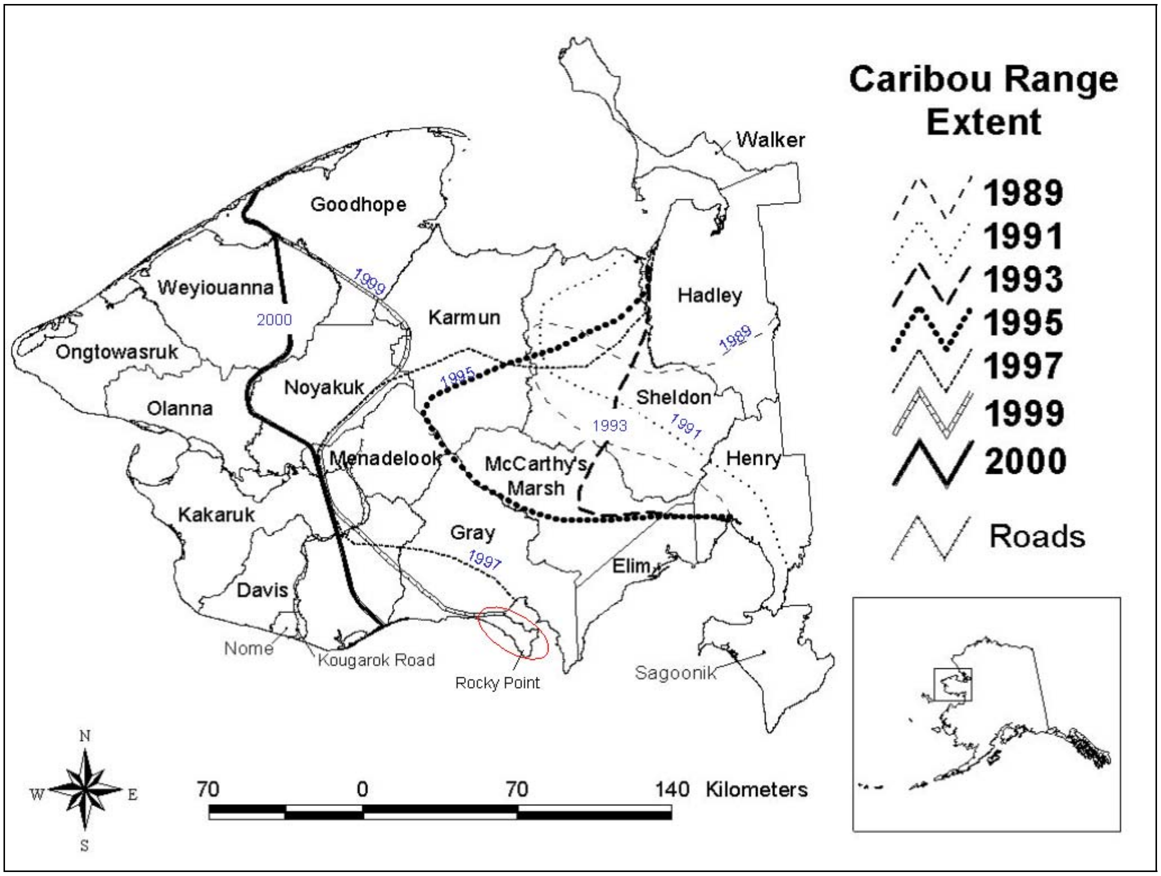

Figure 2.1 Seward Peninsula reindeer ranges occupied by caribou, 1989-2000. The red circled region represents the Gray refuge near Rocky Point, Alaska.

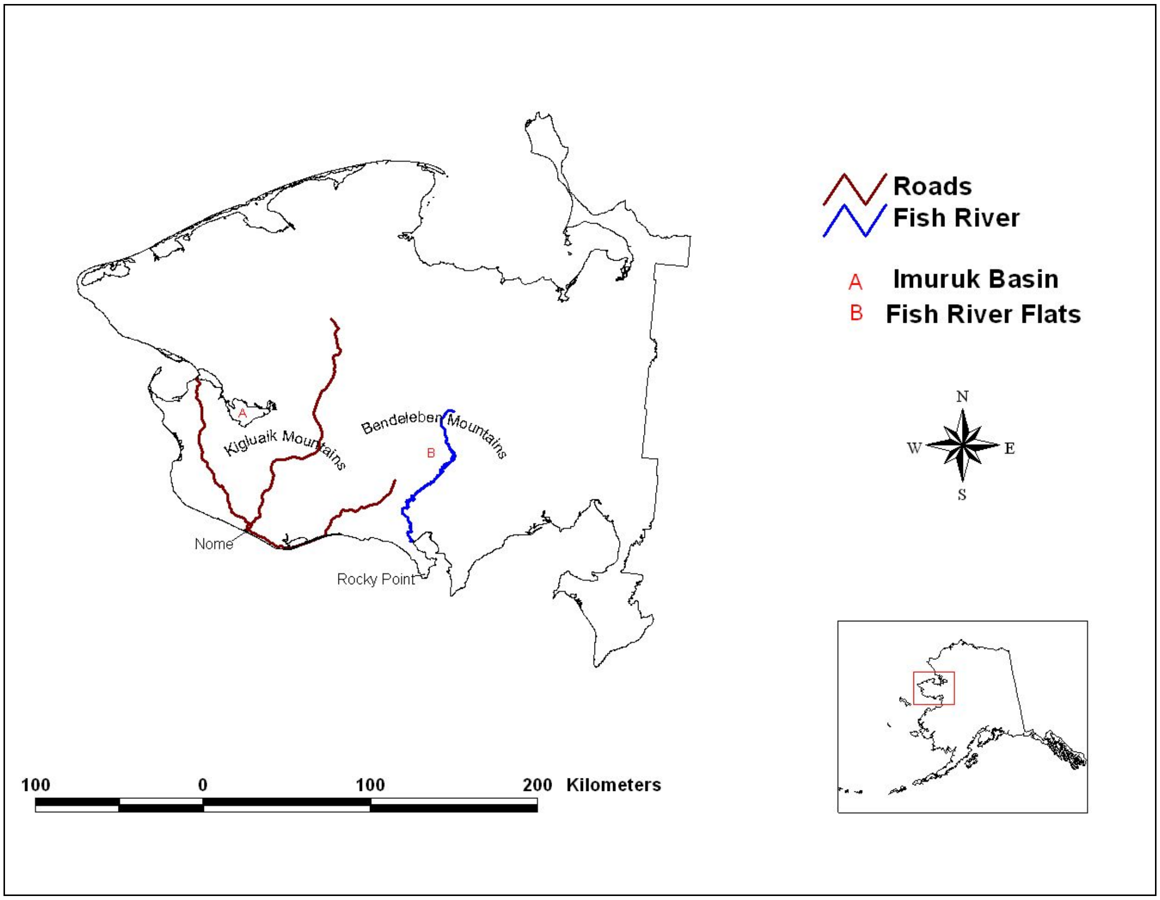

Figure 2.2 Some major geographic features of Seward Peninsula, Alaska.

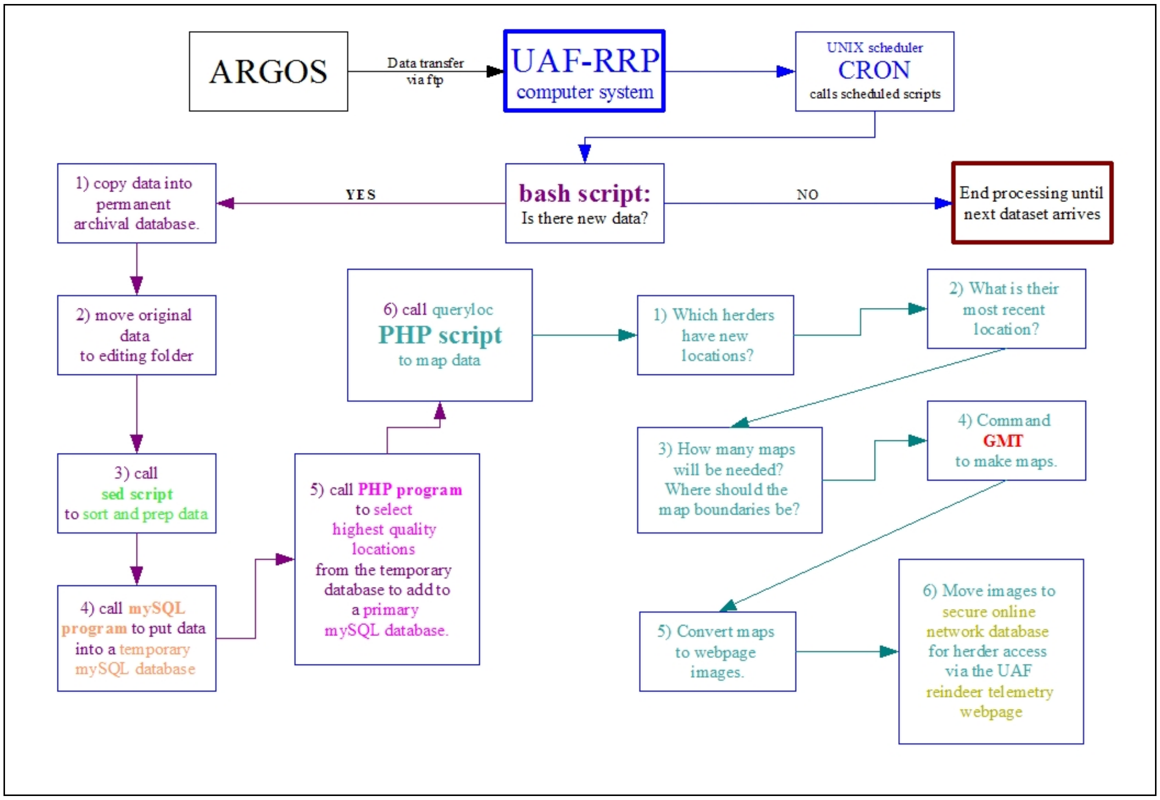

Figure 2.3 Overview of the automated mapping process for reindeer locations. The automated maps remotely provide herders with current reindeer locations. The UNIX scheduler CRON runs three times a day and commands the bash script (Script 1) to run. The bash script (purple) is programmed to execute six sequential tasks, including calling a sed script (Script 2) to sort the satellite data, a short PHP script (Script 3) to select the highest quality locations, and the longer queryloc.php script (Script 4). The queryloc script (teal) executes six additional tasks to create and post new satellite collar maps to the reindeer telemetry webpage.

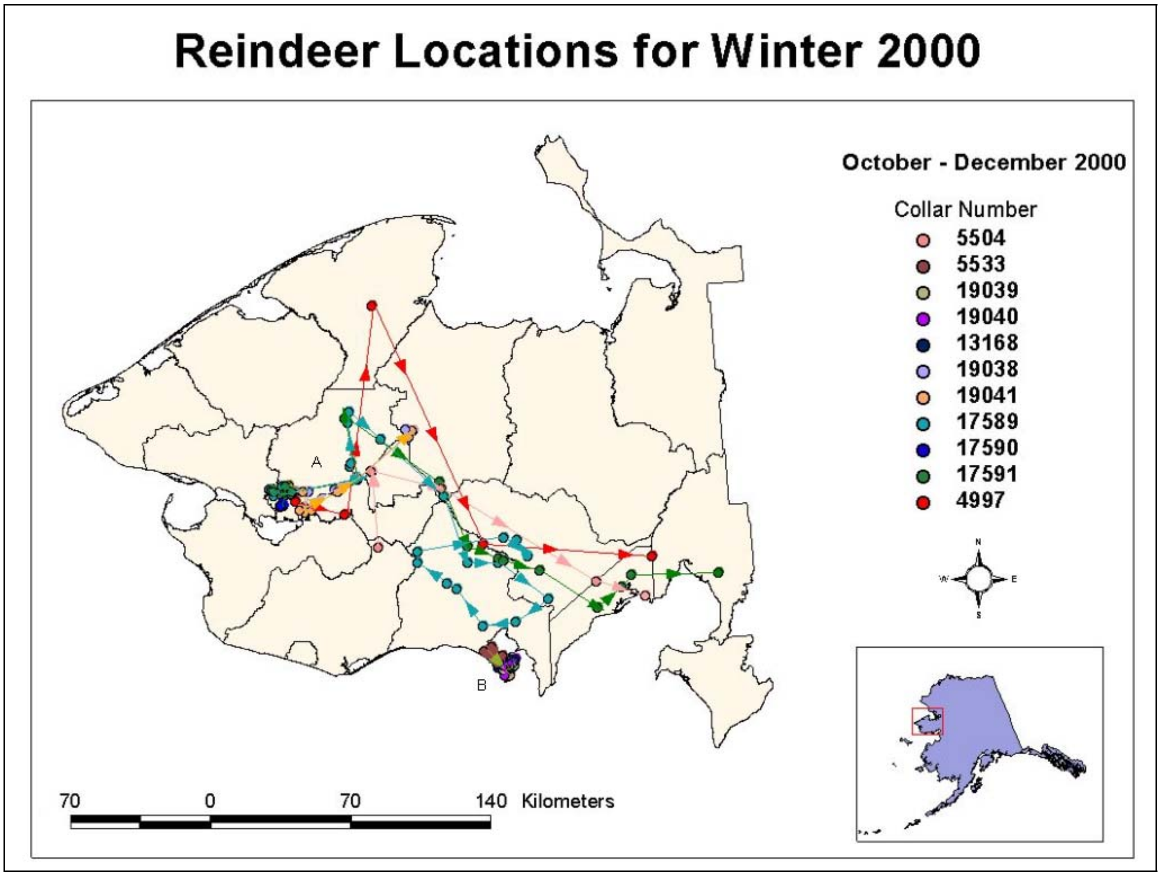

Figure 2.4 Reindeer (A) dispersal with caribou and (B) concentration in a refuge. Movements of satellite collared reindeer, Seward Peninsula, Alaska. (A) Dispersal of reindeer (ID's 5504, 19038, 19041, 17589, 17590, 17591, 4997) associating with caribou and (B) concentration of reindeer herded into a refuge (ID's 19039, 19040, 13168).

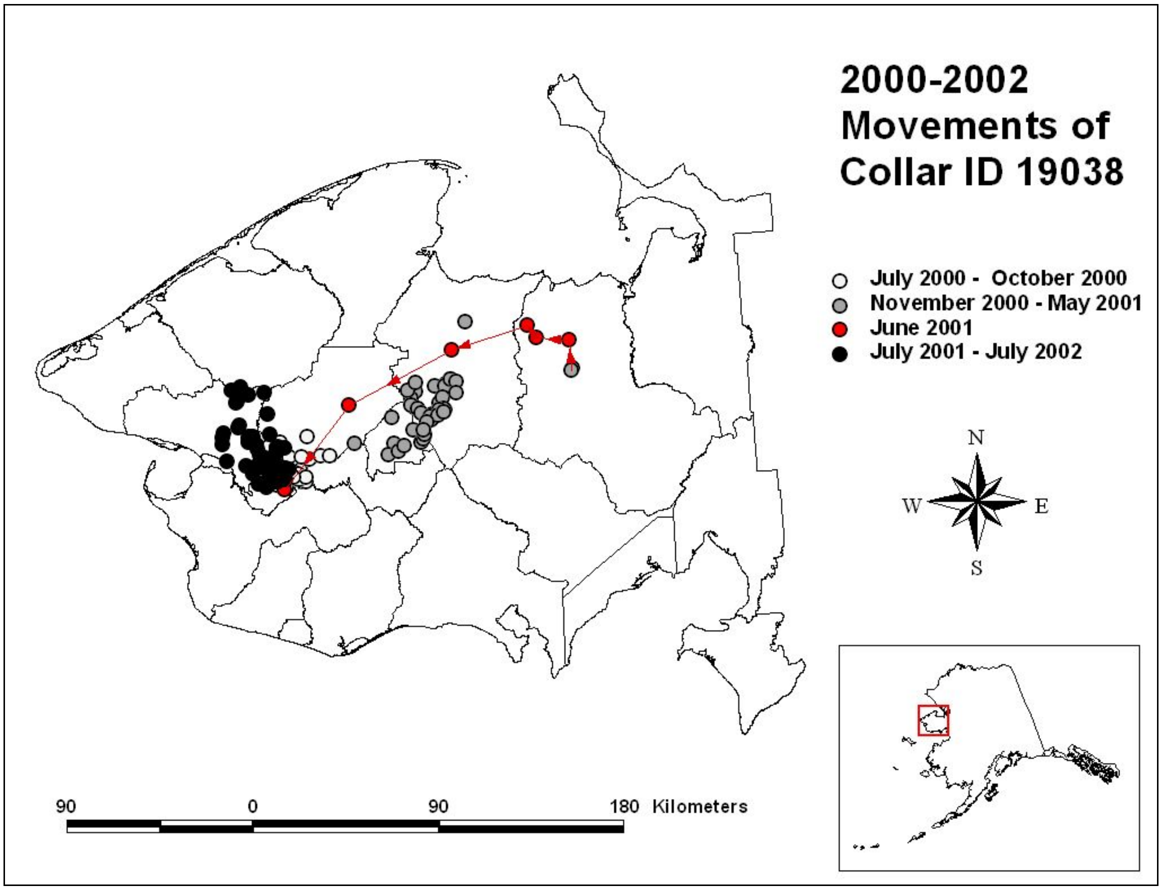

Figure 2.5 Movements of Noyakuk reindeer, collar ID 19038, 2000-2002. Seward Peninsula, Alaska.

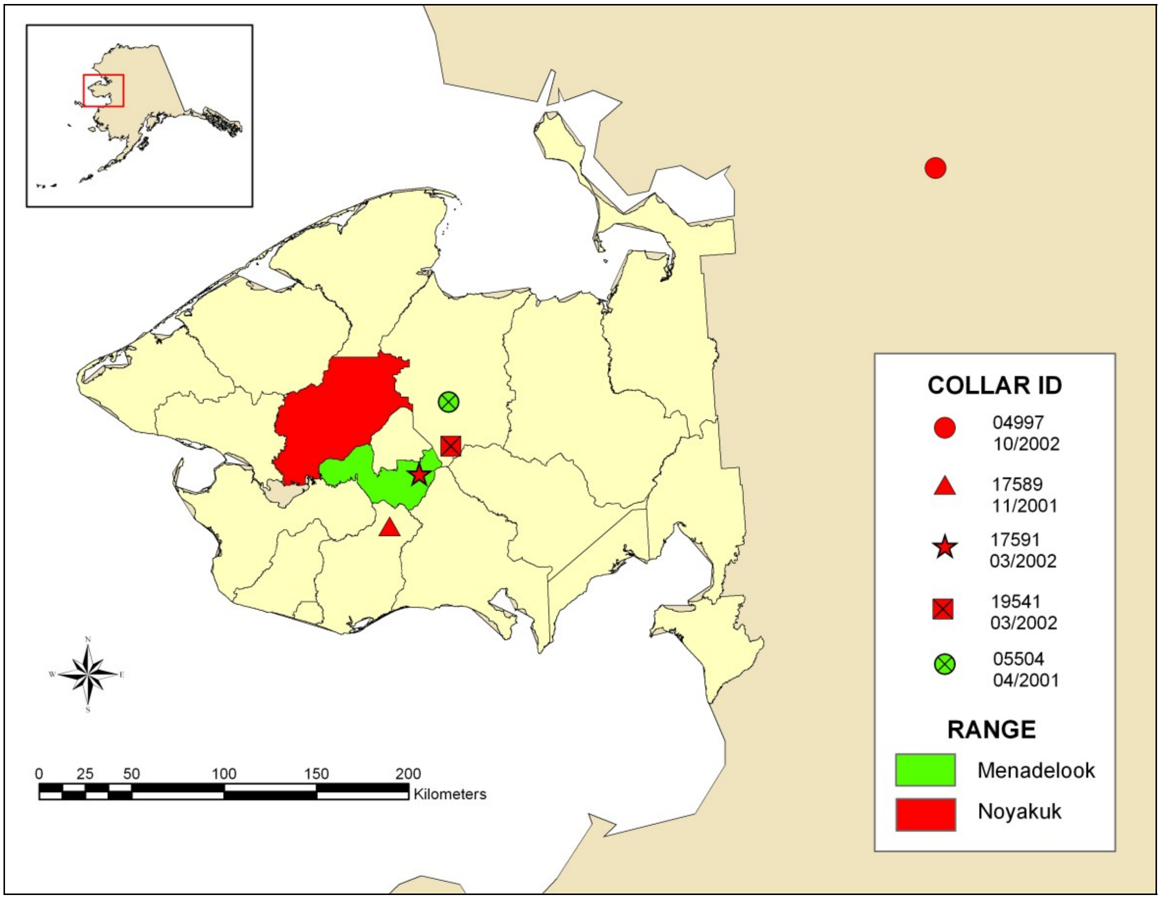

Figure 2.6 Last locations for reindeer not on traditional ranges, 2000-2001. Seward Peninsula, Alaska. Locations marked with an 'x' were mortalities. Other locations had battery failure on the dates indicated.

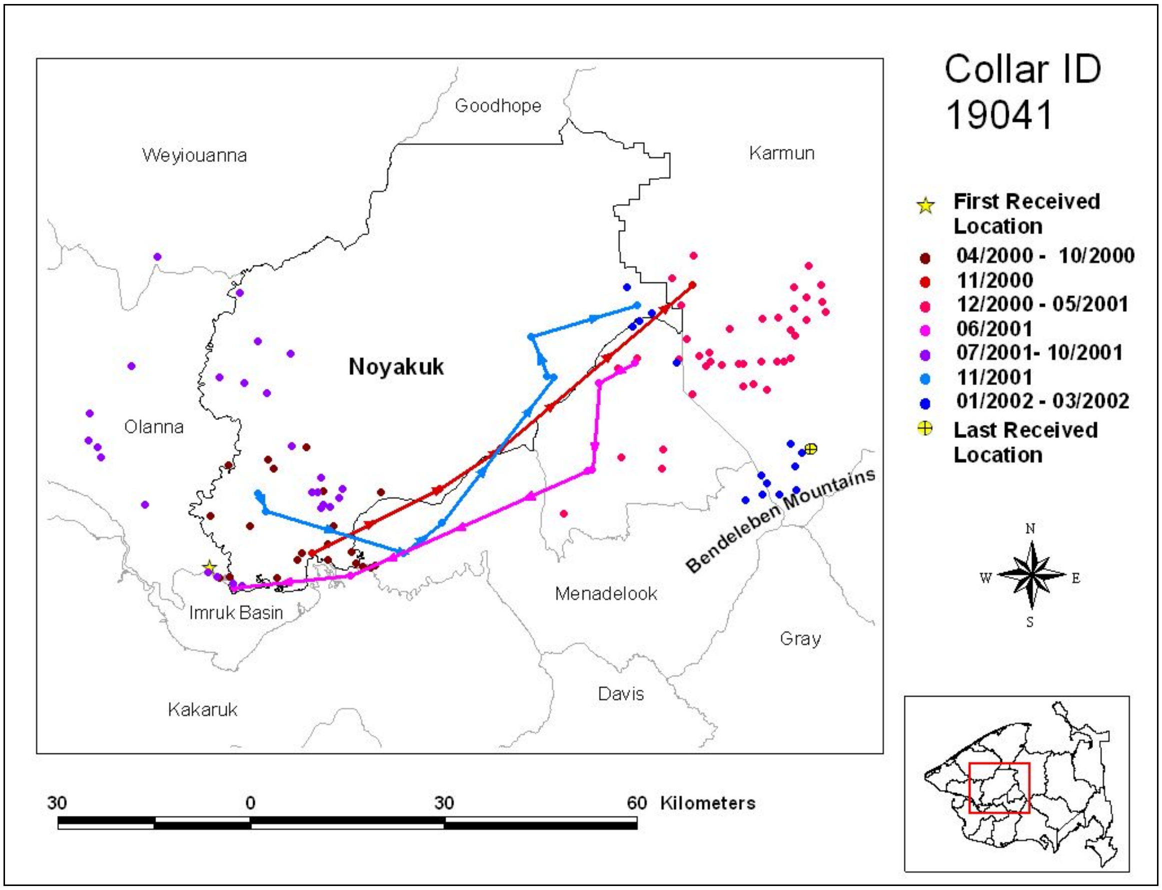

Figure 2.7 Movements of Noyakuk reindeer, collar ID 19041, 2000-2002. Seward Peninsula, Alaska. It left the Noyakuk range in November, 2000, returned in June, 2001, left the range again in November, 2001, and was killed by wolves in the Bendeleben Mountains in March, 2002.

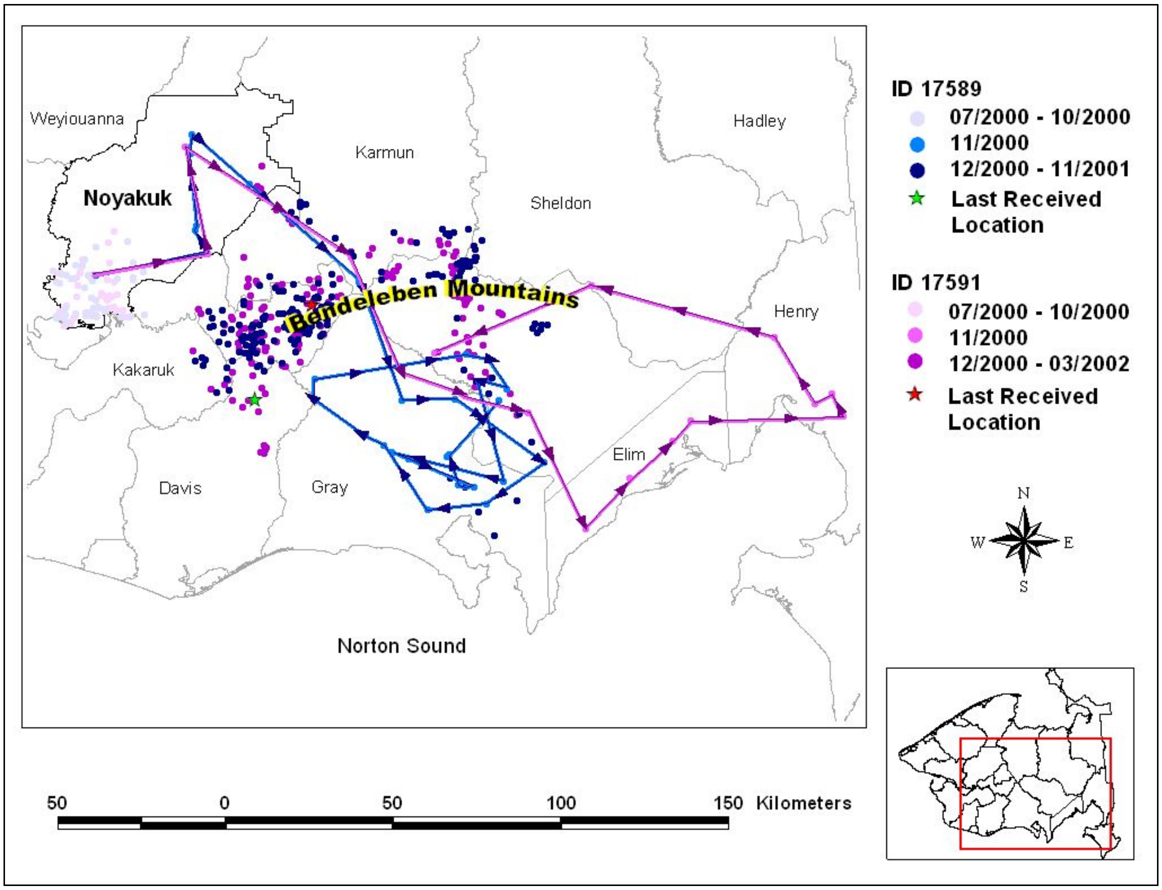

Figure 2.8 Movements of Noyakuk reindeer, collars ID 17589 and ID 17591, 2000-2002. Seward Peninsula, Alaska. After leaving the Noyakuk range and wandering the Seward Peninsula during November, 2000, the reindeer settled in the Bendeleben Mountains in December, 2000.

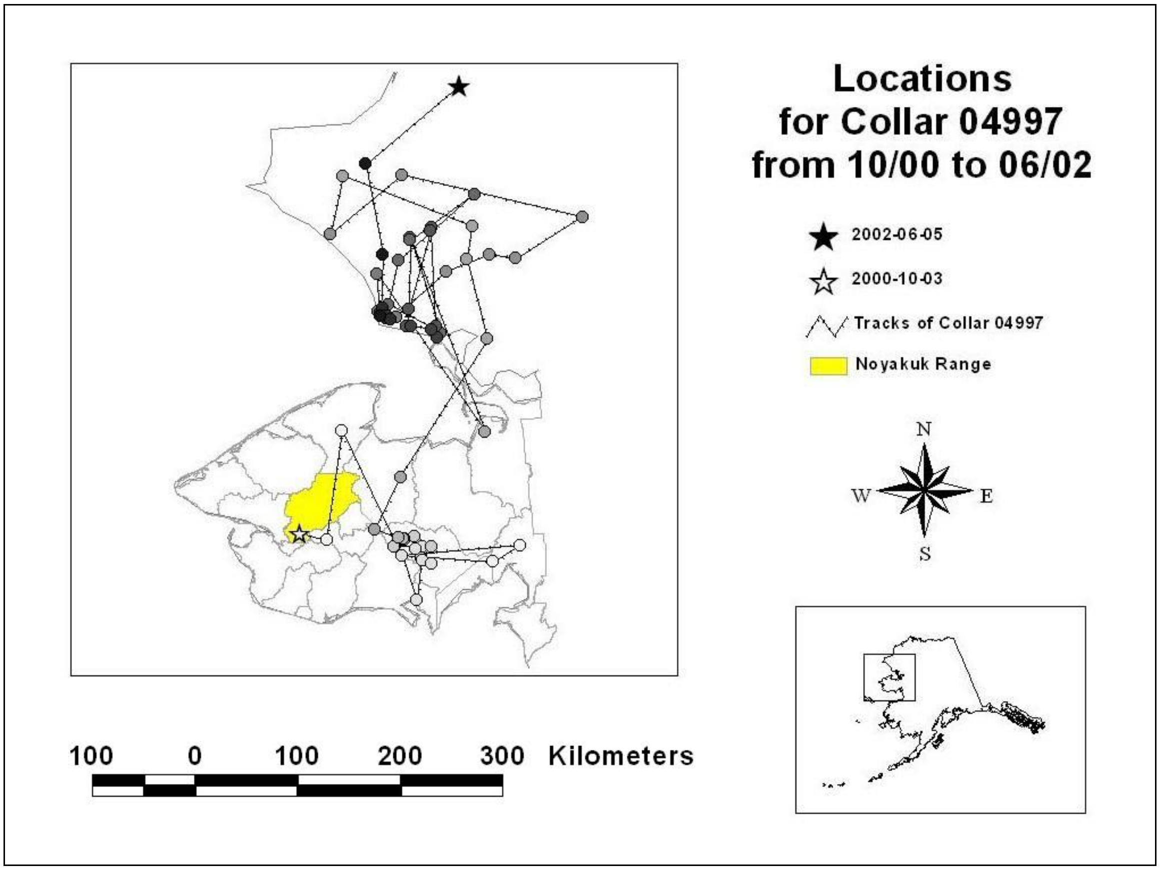

Figure 2.9 Movements of Noyakuk reindeer, collar ID 04997, 2000-2002. Seward Peninsula, Alaska. The reindeer left the Noyakuk range in October, 2000, and its fate is unknown due to battery depletion in 2002.

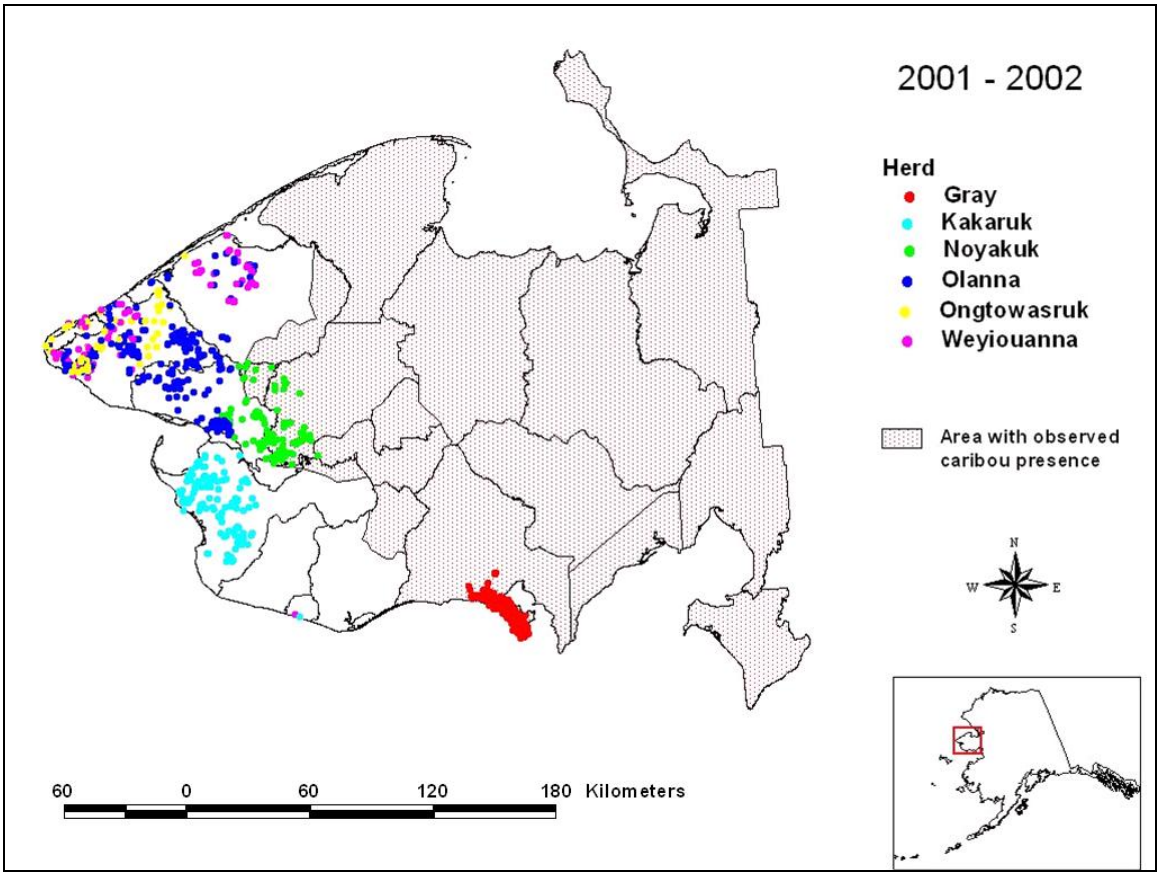

Figure 2.10 Satellite locations of viable reindeer herds, 2001-2002. Seward Peninsula, Alaska. Reindeer in the Davis herd were collared late in this period (04/2002) and are not shown. The shaded area indicates where caribou were observed in 2000-2001 (Finstad, UAF-RRP, personal communication).

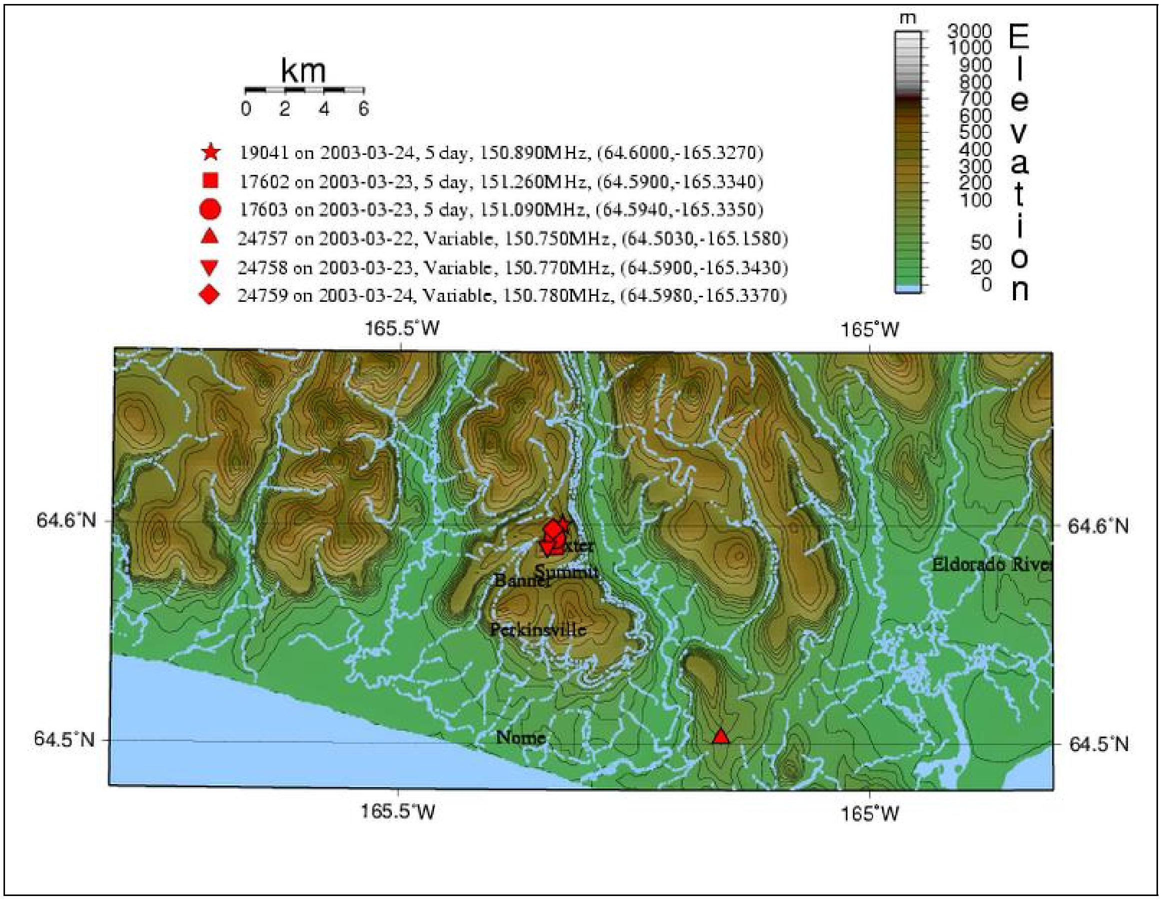

Figure 2.11 Automated map created with Generic Mapping Tools (GMT). Seward Peninsula, Alaska. This map is for six satellite collared Davis reindeer, identification numbers 19041, 17602, 17603, 24757, 24758, and 24759. For each collar, the transmission date, duty cycle, VHF frequency, and location in decimal degrees is provided in addition to the mapped location. A duty cycle of five days indicates that collar locations are received once every five days. A variable duty cycle indicates that collar locations are received once every five days throughout the year, except during the month of June, when the collar broadcasts daily to aid herders in corralling reindeer. Davis was the first herder to try the variable setting.

Table 2.1 Satellite telemetry collar placement history on reindeer, (1999 – 2003). Seward Peninsula, Alaska. (n=32).

Reindeer Collar Placement History (1999 - 2003)

	First Placement			***Second Placement***	
Collar ID	**Date**	**Herd**	**Status as of Feb-03**	**Date**	**Herd**
13168	May-99	Gray			
4997	Jun-99	Noyakuk	(M/B) **Oct-02; retrieval needed**; off range.		
5004	Dec-99	Menadelook	(M) shot Apr-01 while with caribou off range. (R) Jun-01.	Jul-01	Menadelook
5533	Jan-00	Gray			
19039	Jan-00	Gray	(M) Jun-01; (R) Jan-02; died on range; never left.	Mar-02	Gray
19040	Jan-00	Gray	(B) **Mar-02; retrieval needed**; on range.		
17589	Feb-00	Noyakuk	(B) **Nov-01; retrieval needed**; off range.		
17590	Feb-00	Noyakuk	(M) **Jul-01; retrieval needed**; died on range; never left.		
17591	Feb-00	Noyakuk	(B) Mar-02; (R) Jan-03; **sent in for refurbishment 02/03.**		
19038	Jun-00	Noyakuk	(M) Mar-02; (R) Mar-02; died on range after returning from caribou.	Mar-02	Noyakuk
19041	Jun-00	Noyakuk	(M) Mar-02; (R) Mar-02; died off range.	Mar-02	Davis
28556	Feb-01	Menadelook	(M) Sep-01; (R) Nov-01; died off range.	Jul-02	Ongtowasruk
20953	Feb-01	Kakaruk	(M) Aug-01; (R) Jan-02; died off range.	Apr-02	Stebbins
20952	Feb-01	Menadelook	(M) May-01; (R) Jan-02; died off range.	Apr-02	Gray
28542	Mar-01	Olanna			
28543	Mar-01	Olanna			
28544	Mar-01	Olanna			
28545	Mar-01	Olanna			
28557	Mar-01	Gray			
28555	Jul-01	Menadelook	(M) Oct-01; (R) Jan-02; died on range; never left.	Nov-02	Noyakuk
28547	Jul-01	Kakaruk			
28546	Jul-01	Weyiouanna			
28554	Jul-01	Weyiouanna			
28548	Jul-01	Ongtowasruk			
28549	Jul-01	Savoonga IRA			
28550	Jul-01	Savoonga IRA			
28551	Jul-01	Kakaruk			
17602	Jan-03	Davis			
17603	Jan-03	Davis			
24757	Feb-03	Davis			
24758	Feb-03	Davis			
24759	Feb-03	Davis			

Key: (M) mortality; (B) battery depleted; (R) retrieval.

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Appendix

```
#######   APPENDIX 1.0: PHP script for the automated mapping of
#######                 reindeer satellite locations.  (9 pages)

<?php

# this module uses the temp table to get the $best collar location from
# however many there are for a given day
# it then puts this in the main Location Table

  $dbcnx = @mysql_connect("localhost","root","WaliayS1");
  if (!$dbcnx) {
    echo("<p>Unable to connect to the ".
       "database server at this time.<p>");
    exit();
  }

# We are using the collars Database
  if (! @mysql_select_db("collars") ){
    echo( "<p> Unable to locate the database".
          " at this time ");
    exit();
  }

# Format Dates and Times
  #get current date (need the year here)
  $currentdate=getdate();
  $yesterday=$currentdate['yday'];
  $nextupdate5=$currentdate['yday']+6;
  $nextupdate10=$currentdate['yday']+11;
  $nextupdate1=$currentdate['yday']+2;
  # get the Unix time for jan 1 of this year
  $basedate = gmmktime(0,0,0,1,1,$currentdate['year']);
  $yesterday = 60*60*24*$yesterday;
  $nextupdate5=60*60*24*$nextupdate5;
  $nextupdate10=60*60*24*$nextupdate10;
  $nextupdate1=60*60*24*$nextupdate1;
  $currentdate = $currentdate['year'] . "-".
                    str_pad($currentdate['mon'],2,"0","STR_PAD_LEFT") .
"-".
                    str_pad($currentdate['mday'],2,"0","STR_PAD_LEFT");
  $yesterday = $basedate + $yesterday;
  $nextupdate5 = $basedate + $nextupdate5;
  $nextupdate10 = $basedate + $nextupdate10;
  $nextupdate1 = $basedate + $nextupdate1;

  $yesterday = date("Y-m-d",$yesterday);
  $nextupdate5 = date("Y-m-d",$nextupdate5);
  $nextupdate10 = date("Y-m-d",$nextupdate10);
  $nextupdate1 = date("Y-m-d",$nextupdate1);
#  echo($nextupdate5);
```

```
#  echo($nextupdate10);
#  echo($nextupdate1);


#  $wday = $currentdate['wday'];


# Find Herds with new locations from last 2 days.
  $sqlNEW = "select distinct Collars.Range from Collars,Locations".
          " where (Collars.ID = Locations.ID) and ".
          "(Locations.Date1 = '$currentdate' or ".
          "Locations.Date1 = '$yesterday')";

  $herdinfo= mysql_query($sqlNEW);
  if (!$herdinfo){
    echo("<P> Error Performing query: " .
    mysql_error() . "</p>");
    exit();
  }


# big loop starts here
  while($thisherd = mysql_fetch_array($herdinfo)){
###### Make our Database connection
    $dbcnx = @mysql_connect("localhost","root","WaliayS1");
     if (!$dbcnx) {
       echo("<p>Unable to connect to the ".
            "database server at this time.<p>");
       exit();
     }

#    We are using the collars Database
     if (! @mysql_select_db("collars") ){
       echo( "<p> Unable to locate the database".
             " at this time ");
       exit();
     }
######################################################

### Get the list of  ALL distinct collar ID's for this particular herd
     $sqlID = "select distinct Collars.ID".
          " from Collars,Locations where (Collars.ID = Locations.ID)
and ".
          "(Collars.Range = '$thisherd[0]') and (Collars.Status =
'active')";
     $allcollars = mysql_query($sqlID);
     if (!$allcollars){
         echo("<P> Error Performing query: " .
         mysql_error() . "</P>");
         exit();
     }
############################################################
```

```
#  Initalize our arrays that will hold this herds collar information &
counter for indexing
     $lat = "";
     $long = "";
     $date = "";
     $ID = "";
     $count = 0;

##############    Now Process each collar(thisID[0]) of this herd to
get its latest location

     while($thisID = mysql_fetch_array($allcollars)){
       $sqlLOC = "select
Locations.Latitude,Locations.Longitude,Locations.Date1,".

"Collars.ID,Collars.Range,Collars.Frequency,Collars.DutyCycle ".
                 "from Collars,Locations where (Collars.ID =
Locations.ID) and ".
                 "(Collars.ID = '$thisID[0]') order by Locations.Date1
DESC";

       $latlong = mysql_query($sqlLOC);
       if (!$latlong){
          echo("<P> Error Performing query: " .
          mysql_error() . "</P>");
          exit();
       }

##########  Store in parallel arrays: lat, long, date,ID,freq,
cycle,Range

       $results = mysql_fetch_array($latlong);
       $lat[$count] = $results['Latitude'];
       $long[$count] = $results['Longitude'];
       $date[$count] = $results['Date1'];
       $ID[$count] = $results['ID'];
       $freq[$count] = $results['Frequency'];
       $cycle[$count] = $results['DutyCycle'];
       $Range[$count] = $thisherd[0];
       $count++;
     }

#  At this point we have the latest locations for all active collars in
this herd.
#  Now we need to see if more than one map is required.
#  Mapping, multiple maps when collars too far apart
#  we have an array of collar locations
herd[n],id[n],Date[n],lat[n],long[n],Quality[n],Duty[n]
#  Now we need to sort collars for each herder into maps based on
distance from each other

    $mapndx=0;
    $maxmaps = 1;
    $collarndx=0;
```

```
    $mapdata ="";
    $label ="";
    $sumlat = "";
    $sumlong = "";
    $n = "";
    $labelcount=0;
    # Different Symbols for Each collar, should reset when more than 5
collars on a map
    $symbol[0] = "a";
    $symbol[1] = "s";
    $symbol[2] = "c";
    $symbol[3] = "t";
    $symbol[4] = "i";
    $symbol[5] = "d";
##############  Process each collar in our  array of collars
ID's($ID[N])
    while ($ID[$collarndx]){
      $location = "notmapped";
/* boolean type initialized to notmapped */
      if ($collarndx == 0)  {
/* first collar, initializes first map */
        $mapdata[0][0] = $collarndx;
/* first collar of first map */
        $sumlat[0] = $lat[$collarndx];
/* initialize latitude sum */
        $sumlong[0] = $long[$collarndx];
/* initialize longitud sum */
        $n[0] = 1;
/* initialize our n value to 1 */
######## Initialize $ids which are our map points to plot, and $label
which is legend information
######## with our first collars data.
        $ids[$mapndx] =
"$long[$collarndx],$lat[$collarndx],$symbol[$collarndx]" . "\n";
        $label[0][0] = "\"$ID[$collarndx] on $date[$collarndx],
$cycle[$collarndx], $freq[$collarndx]MHz\"";
        $labelcount = 1;
      }
      else{                             /* Already have one collar We
need to do comparison(s) */
        $mapcounter = 0;                /* To see if it fits on this
map, or we need a new map */
        while(($location == "notmapped" &&  $mapcounter <= $maxmaps)){
/* try and fit into existing map */
          $counter = 0;
          $last = sizeof($mapdata[$mapcounter]);
          while(($location == "notmapped" && $counter <= $last)){
            $tempndx = $mapdata[$mapcounter][$counter];
            $latdist=abs(($lat[$tempndx] - $lat[$collarndx]));
            $longdist=abs(($long[$tempndx] - $long[$collarndx]));
            if (($latdist   <    .1 ) && ($longdist <  .5)){   /** IT
FITS INTO THIS MAP! */
```

```
              $ids[$mapndx] = $ids[$mapndx] .
"$long[$collarndx],$lat[$collarndx],$symbol[$collarndx]" . "\n";
              $label[$mapndx][$labelcount] = "\"$ID[$collarndx] on
$date[$collarndx], ".
                                              "$cycle[$collarndx],
$freq[$collarndx]MHz\"";
              $labelcount++;

              array_push($mapdata[$mapndx],$collarndx);
              $sumlat[$mapcounter] = $sumlat[$mapcounter] +
$lat[$collarndx];
              $sumlong[$mapcounter] = $sumlong[$mapcounter] +
$long[$collarndx];
              $n[$mapcounter]++;
              $location = "mapped";
            }
            else{
              $counter++;
            }
          }
          $mapcounter++;
        }                               /** Either location is mapped,
or */
        if ($location == "notmapped") { /* we need a new map */
          $mapndx++;                    /* Increment the number of maps
& initialize new map with first collar*/
          $ids[$mapndx] =
"$long[$collarndx],$lat[$collarndx],$symbol[$collarndx]" . "\n";
          $label[$mapndx][0] = "\"$ID[$collarndx] on $date[$collarndx],
$cycle[$collarndx], $freq[$collarndx]MHz\"";
          $labelcount=1;
          $mapdata[$mapndx][0] = $collarndx;
          $sumlat[$mapndx] = $sumlat[$mapndx] + $lat[$collarndx];
          $sumlong[$mapndx] = $sumlong[$mapndx] + $long[$collarndx];
          $n[$mapndx] = 1;
          $maxmaps++;
          $location = "mapped";
        }
      }
      $collarndx++;
    }

# Now we have processed all data into map arrays: ids, label,sumlat,
sumlong
# now we need to find mean values for latitude and longitude in each
map
# we use those means to get the R-values(basemap size) for the GMT
commands


#second major while statement. counter for rest of document.
  $count=0;
  $labelcount=0;
  $symbolcount=0;
```

```
  while ($count < $maxmaps){
    $meanlat[$count]=$sumlat[$count]/$n[$count];
    $meanlong[$count]=$sumlong[$count]/$n[$count];
    $R0[$count] = $meanlat[$count] + 0.1;
    $R1[$count] = $meanlong[$count] + 0.5;
    $R2[$count] = $meanlat[$count] - 0.1;
    $R3[$count] = $meanlong[$count] - 0.5;
# Set lat/long for scale bar
    $SBlat = ($R0[$count]+0.12);
    $SBlong = ($R3[$count]+0.2);

# Set up coastline in UTM zone 3, with a scalebar, political borders,
# full data resolution, all rivers, tickmarks every 0.5, green land,
blue water,
# outline features, and without ending code:
# This is our command for the intial coastline plot(command executed
later)
    $pscoast = "pscoast -
R$R3[$count]/$R1[$count]/$R2[$count]/$R0[$count] -Ju3/1:210000 -
Lf$SBlong/$SBlat/64.3/6m -Na -Df -Ia/0.25p/153/204/102 -B0.5/0.1g0.1 -
G153/204/153 -S153/204/255 -W -K >  $thisherd[0]$count.ps";

#
    $labelcount = 0;
    $legendsymbol = "";
    $legendlabel = "";

# Create

    while($label[$count][$labelcount]){     /*$label holds our label
data for this particular map */
#      $symbolcount = $count + $labelcount;
      $labelLat = $SBlat - $labelcount*0.013 - 0.03;
      $symbolLong = $SBlong -0.1;
      $legendsymbol = $legendsymbol .
"$symbolLong,$labelLat,$symbol[$symbolcount]\n";
      $labelLong = $symbolLong + 0.03;
      $legendlabel = $legendlabel . "\n$labelLong"  .
                     " " . " $labelLat" . " " . "14" .
                     " " . "0" . " " . "4" . " " . "ML" .
                     " " . $label[$count][$labelcount];
      echo("\n".$symbolcount . ">". $legendsymbol . "\n");
      $labelcount++;
      $symbolcount++;
    }

#   command to Add contour data.

    $grdcontour = "grdcontour spdem.grd -
R$R3[$count]/$R1[$count]/$R2[$count]/$R0[$count] -Ju3/1:210000 -Csp.cpt
-A- -L0/5000 -O -K >>  $thisherd[0]$count.ps";

#  Commands to plot other data sets we have obtained/created .
```

```
    $people = "pstext people.csv -
R$R3[$count]/$R1[$count]/$R2[$count]/$R0[$count] -Ju3/1:210000 -
D0.1/0.1 -S0.1 -H -O -K >>  $thisherd[0]$count.ps";

    $rivers = "psxy rivers.csv -
R$R3[$count]/$R1[$count]/$R2[$count]/$R0[$count] -Ju3/1:210000 -S0.06c
-O -K   -G102/153/204 >>  $thisherd[0]$count.ps";

    $savorivers = "psxy savorvrpts.csv -
R$R3[$count]/$R1[$count]/$R2[$count]/$R0[$count] -Ju3/1:210000 -S0.06c
-O -K   -G102/153/204 >>  $thisherd[0]$count.ps";

    $bay = "pstext bay.csv -
R$R3[$count]/$R1[$count]/$R2[$count]/$R0[$count] -Ju3/1:210000 -S0.1 -H
-O -K  >>  $thisherd[0]$count.ps";

    $capes = "pstext capes.csv -
R$R3[$count]/$R1[$count]/$R2[$count]/$R0[$count] -Ju3/1:210000 -S0.1 -H
-O -K  >>  $thisherd[0]$count.ps";

    $chnnl = "pstext chnnl.csv -
R$R3[$count]/$R1[$count]/$R2[$count]/$R0[$count] -Ju3/1:210000 -H -S0.1
-O -K  >>  $thisherd[0]$count.ps";

    $islnd = "pstext islnd.csv -
R$R3[$count]/$R1[$count]/$R2[$count]/$R0[$count] -Ju3/1:210000 -H -O -
S0.1 -K  >>  $thisherd[0]$count.ps";

    $lakes = "pstext lakes.csv -
R$R3[$count]/$R1[$count]/$R2[$count]/$R0[$count] -Ju3/1:210000 -H -O -K
-S0.1  >>  $thisherd[0]$count.ps";

    $local = "pstext local.csv -
R$R3[$count]/$R1[$count]/$R2[$count]/$R0[$count] -Ju3/1:210000 -S0.1 -H
-O -K  >>  $thisherd[0]$count.ps";

    $mtns = "pstext mtns.csv -
R$R3[$count]/$R1[$count]/$R2[$count]/$R0[$count] -Ju3/1:210000 -H -S0.1
-O -K >>  $thisherd[0]$count.ps";

    $seas = "pstext seas.csv -
R$R3[$count]/$R1[$count]/$R2[$count]/$R0[$count] -Ju3/1:210000 -S0.1 -H
-O -K  >>  $thisherd[0]$count.ps";

    $streams = "pstext streams.csv -
R$R3[$count]/$R1[$count]/$R2[$count]/$R0[$count] -Ju3/1:210000 -S0.1 -H
-O  -K >>  $thisherd[0]$count.ps";


##  Command to  Set up legend.

    $pstext = "echo \"$legendlabel\"|pstext -
R$R3[$count]/$R1[$count]/$R2[$count]/$R0[$count] -Ju3/1:210000 -H -O -K
-N >>  $thisherd[0]$count.ps";
```

```
    $psxySymbol = "echo \"$legendsymbol\"|psxy -
R$R3[$count]/$R1[$count]/$R2[$count]/$R0[$count] -Ju3/1:210000 -O -K -
S0.3c -G255/0/0 -N >>  $thisherd[0]$count.ps";


# Set up locations layer and overlay on coastline.
    $psxy = "echo \"$ids[$count]\"|psxy -
R$R3[$count]/$R1[$count]/$R2[$count]/$R0[$count] -Ju3/1:210000 -O -
S0.3c -G255/0/0 -N  >>  $thisherd[0]$count.ps";

# Convert and store
    $filename="$thisherd[0]satcoll_".$currentdate."_".$count.".jpg";
    $convert = "/usr/local/bin/convert -resize 950x800 -rotate 90
$thisherd[0]$count.ps $filename";



#    $count++;
#    echo ("\nPSCOAST:" . $pscoast . "\n");
#    echo ("\nCONTOUR:" . $grdcontour . "\n");
#    echo ("\nPSXY" . $psxy . "\n");


# MAKE MAPS!
    $output=exec($pscoast);
    if (($thisherd[0] != "grayold") && ($thisherd[0] != "savo")){
      $output=exec($grdcontour);
    }
    $output=exec($rivers);
    if (($thisherd[0] == "savo")){
      $output=exec($savorivers);
    }
    $output=exec($bay);
    $output=exec($capes);
    $output=exec($chnnl);
    $output=exec($islnd);
    $output=exec($lakes);
    $output=exec($mtns);
    $output=exec($seas);
    $output=exec($streams);
    $output=exec($people);
    $output=exec($local);
    $output=exec($pstext);
    $output=exec($psxySymbol);
    $output=exec($psxy);
    $output=exec($convert);



#################     UPDATE CMS
   # make our database connection
      $dbcnx2 = @mysql_connect("localhost","apache","waliays");
      if (!$dbcnx)  {
```

```
        echo("<p>Unable to connect to the".
             " database server at this time.<p>");
        exit();
      }

# connect to the cms database
      if (! @mysql_select_db("cms") ){
        echo("<p> Unable to locate the database".
             " at this time ");
        exit();
      }

# First need to check if we already have a file with this name

      $sql = "select FileName from Files where FileName ='" . $filename
."'";
      $result= mysql_query($sql);
      $row = mysql_fetch_array($result);
      if ($row){                   /*  File is already in the database
go on to the next */
          $count++;
      }

      else{    /* Add file to the cms database and move it into
position */

        $sql = "insert into Files set
FileName='$filename',Description='',Class='completed',".

"Type='Image',Format='image/jpeg',Location='/Completed/Images/',Submitt
er='auto',Date='$currentdate'";

        if((mysql_query($sql))){
          # Move the file into its proper Directory if the name or
location has been changed.
 # moved this function to updatemaps script
 #         $source="/home/data/Heather/". $filename;
 #         $target="/home/www/cms/files/Completed/Images/". $filename;
 #         echo($source);
 #         echo($target);
 #         copy($source,$target);
 #         unlink($source);
        }
        else{
          echo("<P> Error adding file to the database: " .
          mysql_error() . "</p>");
          exit();
        }
      $count++;
      }
    }
 }

?>
```

Chapter 3: The utilization of lichen stands in a reindeer refugia on the Seward Peninsula, Alaska

Abstract

In response to the recent influx of caribou (*Rangifer tarandus granti*) onto the reindeer (*Rangifer tarandus tarandus*) ranges of the Seward Peninsula, Alaska, herders have attempted to segregate their reindeer herds from migrating caribou by holding them in "refugia". Herders are utilizing "near real-time" satellite locations of collared reindeer and caribou to monitor and concentrate their animals in a location whose topographical features isolate them from migrating caribou. A herder on the southern Seward Peninsula established a reindeer refuge in 1999 when caribou immigrated to his reindeer range. The refuge rangeland had not been in use since 1985. Reindeer utilized the refuge year-round from 1999 to 2002. Lichen stands within the refuge are being intensively grazed, which can detrimentally affect the region's vegetation communities and suitability as reindeer habitat. Of the 18 lichen sites that were sampled, 7 showed heavy utilization (>80% lichen disturbance), 6 showed moderate to heavy utilization (60-80% lichen disturbance), 4 showed moderate utilization (40-60% lichen disturbance), and 1 site showed light to moderate utilization (0-40% lichen disturbance). The successful implementation of refugia is dependent on adjusting the stocking density of reindeer. A stocking density of 1 reindeer per 2.1 km^2 at 5% annual lichen utilization is recommended for the Gray refuge.

Introduction

Rangifer sp. tend to concentrate winter grazing in areas of abundant palatable lichens, and revisit these areas in subsequent years (Bailey *et al.*, 1996). Light to moderate grazing over large areas encourages lichen growth, while intense grazing can stunt current growth, severely deplete both grazed and ungrazed lichens, and constrain regrowth (Gaare, 1986). Cases of lichen depletion as a consequence of sustained heavy grazing and trampling have been well documented (Klein, 1973, 1987; Henry & Gunn, 1991), and can take up to 50 years to regrow (Pegau, 1969b; Gaare, 1986). Heavy grazing and associated defecation can also alter soil mineral concentrations, thereby changing environmental conditions for lichen species. For example, increased soil concentrations of urea and ammonium are known to deter the growth of some forage lichens, while promoting growth of other, often unpalatable, species. *Parmelia spp.* and *Peltigera spp.* are two of the less palatable species that thrive in nitrogen rich conditions (White & Trudell, 1980). An abundance of these unpalatable species is often viewed as a sign of prolonged heavy grazing (Swanson & Barker, 1992).

Preferred lichens, such as those fruticose lichens of the *Cladonia* and *Cladina* genera, are high in starch but low in protein content and comprise 75-90% of all lichens eaten by reindeer (*Rangifer tarandus tarandus*) (Pegau, 1969b)**.** The most highly preferred lichens include *Cladina rangiferina, Cladonia alpestris, Cladina sylvatica, Cetraria nivalis, Cladina mitis, Cladina stellaris, Cetraria cucullata, Cladina arbuscula, Cladonia uncialis, Cladonia amaurocraea, Cetraria andrejevii, Cetraria crispate, Cetraria islandica, and Cladonia subfurcata* (White & Trudell, 1980; Gaare, 1986;

Pegau, 1969b; Swanson & Knapman, 1985; Swanson & Barker, 1992). Unfortunately, preferred lichens are particularly susceptible to the problems of increased foraging and trampling (Kumpula *et al.*, 2000).

Lichens, the primary winter forage, can be used in estimating carrying capacity and stocking densities (Gaare, 1986; Sveinbjornsson, 1990; Kumpula *et al.*, 2000). Stocking densities of reindeer herds in Alaska were established using lichen reserves of individual ranges (Swanson, 1985). Each reindeer unit (one adult bull, or a female with a calf) requires 1.5 kg of lichen on a dry matter basis per day (Kumpula *et al.*, 2000). A reindeer range containing 450 kg of lichen per hectare supported stocking densities of up to 3.1 reindeer per km^2 with good to excellent production (Finstad & Prichard, 2000). Based on this usage, a conservative estimate of range carrying capacity can be made from preferred lichen biomass, although carrying capacity can also be influenced by other factors, such as predation, total forage availability, and climate variability (Swanson *et al.*, 1985; Gunn & Skogland, 1997; Post & Klein, 1999; Ferguson & Messier, 2000; Finstad & Prichard, 2001).

Caribou (*R. t. granti*) have been shifting their winter range across the Seward Peninsula reindeer ranges annually since the late 1980's (Finstad *et al.*, 2000). High caribou densities can cause severe deterioration of winter reindeer range (Messier *et al.*, 1988; Klein, 1980; Henry & Gunn, 1991), and reduce preferred reindeer stocking densities. Traditionally, reindeer herders practiced extensive herding where stocking densities were low, and ranges were in excellent condition (Finstad & Prichard, 2000).

As caribou began entering the Seward Peninsula, reindeer were lost through emigration and rangelands could be impacted by increased grazing.

Caribou presence on the Seward Peninsula also affected rangeland by prompting a marked change in reindeer management. Reindeer herders are no longer using their entire ranges but instead are holding their animals in small isolated areas, “refugia,” to avoid co-mingling with migratory caribou (Finstad & Prichard, 2000). Foraging by reindeer is concentrated in refugia. Concentrated foraging behavior can contribute to changes in surface albedo and associated environmental conditions (Vare *et al.*, 1996; Finstad *et al.*, 2003). This can alter the ecological diversity of the rangeland and affect the health and grazing patterns of caribou and reindeer (Gunn & Skogland, 1997).

Objectives

The objective of this study is to determine the effect of intensive grazing by reindeer on lichen biomass in a small localized area (refuge). The site of the refuge, on the Rocky Point peninsula, is the sole region remaining on herder Thomas Gray’s range allotment that has not been used by caribou. A refuge stocking density will be recommended based on the current biomass of preferred lichens and a lichen consumption rate of 1.5 kg/day/reindeer. The hypothesis is that preferred lichen biomass within the refuge is below historical levels.

<u>*Methods*</u>

Study Area

The study area is a reindeer refuge established in 1999 on a peninsula on the southern coast of the Seward Peninsula. The peninsula, Rocky Point, is a 20 km long by 8 km wide southern extension of the Gray reindeer range, near White Mountain, Alaska. It is surrounded by Golovin Lagoon to the east and Norton Sound to the south and west (Figure 3.1). The northwest portions of the Rocky Point peninsula abut the Fish River delta of Council Landing, which opens into Golovin Lagoon. The Western face of the Rocky Point peninsula is comprised of hills and mountains, whereas the eastern half is made up of sedge drainage ways and tussock tundra. The highest mountain on the Rocky Point peninsula is Mt. Iknutak (514.5 m above sea level), found at the southern end. Beyond this mountain, there is a small valley and a few lower hills near Rocky Point itself.

Vegetation on Rocky Point consists of shrubs (*Betula nana, Salix spp.*), forbs (*Rubus chamaemorus, Equisetum spp., Vaccinium spp., Ledum spp.*), grasses (*Eriophorum spp., Carex spp., Calamagrostis spp.*), mosses (*Hylocomnium spp., Polytrichum spp., Sphagnum spp., Hypnum spp.*), and lichens (*Cetraria spp., Cladonia spp.,* and *Cladina spp.*). Plant species composition and cover, annual plant productivity, live lichen biomass, moss biomass, and tree species, diameter, height, and cover are available for the Seward Peninsula in the Range Survey of the Seward Peninsula data set, conducted by the United States Department of Agriculture (USDA), Soil Conservation Service (Swanson *et al.*, 1985). Thirty-nine ecological sites across the Seward Peninsula were identified and mapped in the data set, based on high altitude infrared color photography. The ecological sites are unique, mapable areas on the landscape characterized by specific soils, topography, precipitation, and temperature that produce a particular vegetative community.

The Rocky Point peninsula has 18 lichen-dominated (25-50 or more percent lichen coverage) ecological sites (Figure 3.2). Five of these are mixed ecological sites, with the lichen type dominating the mix (two-thirds or more lichen dominated ecological site). Portions of the mixed sites not covered by lichen, contain sedge species. Lichen site types (site ID number) found on the peninsula include: Upland shrub-lichen (44), Tussock tundra lichen (60), Lichen meadow (61), Lichen mat (66), and Lichen granitic slope (70) (Swanson *et al.*, 1985).

Sampling Design

A stratified random sampling design was used with random sampling from each of the 18 lichen dominated ecological sites within the Rocky Point reindeer. During summer 2002, 200 m transects were set up at random distances and directions from the center of each lichen dominated ecological site. For most sites, which were roughly circular, a random number less than the given ecological site's radius was first selected for the distance from the center of that ecological site. A second random number was selected for direction of travel from the center based on 360 degrees from magnetic north. A third random number was selected for the bearing of the transect itself. For non-circular sites, the ecological site was divided into a grid. A random direction (east or west) was selected from the center of the ecological site, along with a random distance less than the radius of the ecological site in that direction. After traveling this first distance, a second random direction (north or south) and distance were chosen. The transect direction was then randomly selected, and the transect laid out, after traveling the second distance.

A 200 m tape was extended in the direction of the random bearing. Ten 0.25 x 1.0 m plots were randomly placed along the transect line. Overall transect lichen biomass conditions were observed and recorded, based on parameters established by White and Trudell, 1980 (Table 3.1).

All lichen biomass palatable to reindeer was removed by hand, while other vegetation was left intact. Preferred lichens were chosen as an indicator of potential carrying capacity (Pegau, 1969b). The following preferred species were identified and collected within the refuge area: *Cladina rangiferina, Cetraria nivalis, Cladina mitis, Cladina stellaris, Cetraria cucullata, Cladina arbuscula, Cladonia uncialis, Cetraria crispate, Cetraria islandica,* and *Cladonia subfurcata*. Dry plots were sprayed with water from a water bottle before sampling to reduce lichen fragmentation. Samples were placed in paper bags labeled with the transect name, date of sampling, and plot number. Bags from all plots were collected in larger bags labeled with the transect name. Samples were frozen as soon as possible after collection until sorted.

Sample Processing

Lichen samples were hand-sorted using tweezers and a dissecting microscope. Dry lichen was sprayed with water for easier sorting and to reduce fragmentation. Live and dead parts of lichen podetium were visually distinguished by color and structural differences (Swanson & Knapman, 1985). All dead material and lichens unpalatable to reindeer were set aside.

Samples were initially dried at room temperature for 5 days before weighing to determine air-dry weights (Kumpula *et al.,* 2000). Temperatures ranged from a minimum of 18.3º C to a maximum of 21.1º C during the drying period. After air-dry weights were obtained, the samples were dried in an oven at 60º C for 48 hours and weighed again. Lichen air-dry weights were used to compare average current preferred lichen biomass in each site to the 1985 baseline biomass values. Baseline biomass refers to live lichen biomass values typical of a site prior to grazing by reindeer (Swanson *et* al., 1985; Meyers, 1995). Stocking recommendations were based on a comparison in preferred lichen biomass.

Utilization Mapping

Percent lichen utilization values were obtained by determining the ratio of current preferred lichen biomass to baseline lichen biomass for each ecological site. Baseline lichen biomass values of the ecological sites were taken from the USDA Range Survey of the Seward Peninsula data set (Swanson *et al.*, 1985). The percent lichen utilization was then mapped in ArcView 3.2 over satellite collar distribution data from 3 years (1999-

2002) at 70% home range use. Seventy percent values were chosen to illustrate average range use as the median between 90%, which shows total area utilized (excluding outliers), and 50%, which better indicates where reindeer locations likely occurred most frequently.

Collar distribution data were established using the ESRI ArcView 3.2 Animal Movement extension with kernel analysis. The data incorporated a location error of 281 m (n=32, MSE=20 m), based on the accuracy testing results of stationary collars (Oleson, 2005). Fixed kernel density and a least squares cross-validation smoothing parameter (Silverman, 1986) were used to create contour shapefiles. Fixed kernel estimates using least squares cross validation have produced results with very little bias and lowest error in comparison to other statistical analyses (Worton 1995, Seaman & Powell 1996).

Home range analysis for this study was conducted on satellite telemetry data from 1999 to 2002 for 5 female reindeer in the Gray herd instrumented with Telonics (Mesa, AZ) PTT’s. The total sampling interval was made larger than the anticipated time required by the reindeer to travel the home range boundary, thus minimizing concern about autocorrelation (Otis, 1999). The time interval between successive observations was kept constant for all individuals, reducing any existing autocorrelation, and allowing for home range comparison among individual reindeer (Desolla *et al.*, 1999).

Stocking Recommendations

Stocking density values were obtained using the formula:

$$\frac{((\text{Total Lichen kg}) * x\%) / (531 \text{ kg/AU/yr})}{250 \text{ km}^2}$$

where x% is the desired range utilization percentage, and the average reindeer animal unit (AU), weighing approximately 130 kg, consumes 2% of its body weight per day in dry matter (2.6 kg), of which an average of 56% is lichen, or 1.5 kg lichen/day (531 kg lichen/year) (Reindeer Research Program, unpublished data; Holechek *et al.*, 2001). The size of the Gray refuge area is approximately 250 km^2. Stocking densities were evaluated for 1%, 5%, and 10% range utilization. The USDA Natural Resources Conservation Service (NRCS) recommends a 5% utilization rate when rotational grazing is not practiced (Karin Sonnen, USDA-NRCS, personal communication).

Results

Visual estimates indicate heavier lichen utilization towards the southern end of the Rocky Point peninsula (Figure 3.3). Also, pure lichen sites appeared to be more heavily utilized than mixed ecological sites. Lichen meadows (61) were the ecological site type most heavily utilized. Six sites were classified as lightly utilized, 5 sites were classified as moderately utilized, 3 sites were classified as moderately to heavily utilized, and 4 sites were classified as heavily utilized. Fragmented lichens, severe mat disturbance, and an abundance of unpalatable lichen species characterized these sites.

Lichen utilization results from the sample data indicated a more even distribution of heavily utilized sites along a western corridor on the Rocky Point peninsula (Figure 3.4). Only one sample site was found to have less than 40% lichen utilization, whereas 7 of the sample sites were found to have over 80% lichen utilization (Figure 3.5). Six sites had between 60 and 80% lichen utilization, and the remaining 4 sites were 40 to 60% utilized.

With home range set at utilizations of 90%, the entire Rocky Point peninsula was used during all years between 1999 and 2002 (Figure 3.6). Further home range utilization analysis indicated core regions of 50% home range use near the southern tip of the Rocky Point peninsula during 2000-2001 and 2001-2002. The period 1999-2000 showed a more northerly core region.

Stocking density estimates varied little between air-dry and oven-dry lichen weights (Tables 3.2, 3.3). A stocking density of 1 AU/2.1 km^2, or 120 reindeer, is recommended for the Gray reindeer refuge.

Discussion

Herding practices and land use patterns of Seward Peninsula reindeer herders have changed since 1996 in response to the presence of migratory caribou. Reindeer that once foraged over large areas are now being held in small isolated refugia. The Gray herd has historically grazed several areas within the Gray range (Figure 3.7). A new area was grazed each year between 1996 and 2000. Beginning in 1999, however, the herd was confined to the refuge of the Rocky Point peninsula for 4 years to avoid caribou interaction. This new strategy in herd management increased range utilization and altered range conditions within the refuge area.

Results obtained from the sampling data (Figure 3.4) show heavier overall range utilization than visual inspection indicated (Figure 3.3). This discrepancy may be due in part to inaccuracies inherent in visual estimation by those inexperienced. In addition, sites that appear to have abundant lichen stands in comparison to other sites may actually have depleted lichen stands relative to the historical biomass values for the site in question. Such is the case for sites like 66-54 and 44-52 (Figure 3.5). Similarly, sites that appeared to support only minimal lichen stands may have been underestimated, with true historical biomass values much higher than expected. Sites 70e and 70w provide an example here (Figure 3.5).

Both visual estimates and sampled utilization data correspond with changing home range patterns. Visual estimates of utilization correlated to changes in home range location at 50% distribution (Figure 3.3, 3.6), whereas the sampled data followed broader changes in home range location at a scale of 70-90% distribution (Figure 3.4, 3.6). During the 3 years of home range observation, most activity was observed on the western side of the Rocky Point peninsula (Figure 3.4). Likewise, the heaviest lichen utilization appears in a corridor along the western side, where most sites show a minimum of 65% lichen utilization (Figure 3.4, 3.5). Also, Mt. Iknutak, located at the southern tip of the Rocky Point peninsula, was used for grazing during all 3 years of home range observation. Four of the 7 most heavily grazed sites (>80% utilization) were found on or near Mt. Iknutak (Figure 3.4). Site 61ik, which was located on Mt Iknutak itself, showed moderate to heavy grazing.

Stocking densities based on the lichen sample data (oven and air dry) suggest that less than 125 reindeer can be conservatively supported on the Gray reindeer refuge (Tables 3.2, 3.3). Estimates indicate a current Gray reindeer herd size of about 300-400 animals. If the herd continues grazing in the Mt. Iknutak area, herd size will need to be reduced to conserve lichen stands and quality range conditions. Otherwise, it would be prudent to have the herd moved to a less intensively utilized area, such as sites 60, 60-54S, or 60-55.

Implications for reindeer herding on the Seward Peninsula

Production and range studies have indicated that the population and nutritional status of reindeer on the Seward Peninsula has been very good (Finstad *et al.*, 1999). The Seward Peninsula reindeer have had a high level of nutrition and correspondingly high growth and reproductive rates. As many as 40% of calves became pregnant during some years, indicating the availability of high quality range resources on the Seward Peninsula (Finstad *et al.*, 1999). Abundant seasonally important forage materials, including lichen and vascular plants, have been observed on the Seward Peninsula. This local rangeland, especially the lichen stands, is threatened by both the intensive grazing of large numbers of caribou and a change in reindeer grazing practices.

The increasing presence of caribou on the Seward Peninsula has already changed grazing patterns and altered the ecological composition on reindeer rangeland. The ranges on the Seward Peninsula cannot sustain increased grazing without a decline in rangeland condition, affecting the potential profitability and success of future herding on the Seward Peninsula (Finstad *et al.*, 2002). Increased grazing in lichen areas can result in permanent vegetation shifts towards communities dominated by small dwarf shrubs, bare soil, and unpalatable cup lichens (den Herder, 2003; Olofsson *et al.*, 2001, 2004).

Bare soil areas resulting from heavy grazing may decrease surface albedo and cause widespread permafrost thaw and settlement (USARCPTF, 2003).

Carrying capacity of the ranges will drop for any future reintroduction of reindeer should lichen reserves be overgrazed (Finstad *et al.*, 2002; Swanson & Barker, 1992). Several reindeer herders have already suffered herd losses between 75 and 100 percent due to co-mingling and out-migration with wild caribou. This loss of over 12,000 reindeer represents an economic value of nearly 13 million dollars, at $550/head (Finstad *et al.*, 2002).

Refugia are an effective way of avoiding conflict and competition between reindeer and caribou on the Seward Peninsula. Both Gray and Noyakuk had success in using intensive herding to implement the refugia management strategy. If lichen utilization within the Gray refuge is a viable indicator, however, the sustainability of reindeer herds within refugia is endangered when stocking densities are not adjusted. Revised stocking densities for each refuge should be evaluated prior to use to prevent overgrazing. Although herd size may need to be reduced in the short-term to accommodate the smaller grazing area within a refuge, long-term goals are maintained by preserving a core herd to restock the range at a later date. In addition to monitoring utilization, efforts should be made to evaluate environmental conditions, such as wind, snow depth, and ice formation, at refuge sites. These factors also contribute to range utilization. Sites that have abundant lichen but are covered with ice or deep snow during much of the winter offer poor foraging areas. Herders should reduce herd sizes to a level based on the sustainable use of range resources, while relocating their herds to alternate areas when caribou are not present.

Alternative strategies may also be considered. One strategy is to provide supplemental feed on refugia (Swanson & Barker, 1992; Finstad *et al.*, 2003). This ensures that the reindeer always have an available food source and will not starve due to a lack or unavailability of lichen. However, the reindeer would need to be trained to accept the feed as a food source. This process would take time. Additionally, the supplemental feed might attract unwanted scavengers including bears and foxes. Further investigation into the possibilities of supplemental feed is required to fully clarify the feasibility of such an endeavor.

Another strategy might be to reduce reindeer lichen reliance through breeding (Leonid Baskin, personal correspondence). Herders in Russia and Scandinavia have successfully bred reindeer to subsist on other forage than lichen during the winter. This strategy too would take time and research to implement.

There is also the possibility that the Western Arctic Caribou Herd's migration pattern will shift as the caribou change their habitat selection (Messier & Rettie, 2000; Ferguson & Messier, 2000). Areas of high lichen availability, especially, are a factor in caribou migration patterns (Finstad & Kielland, 1999). When caribou have sufficiently depleted lichen on the Seward Peninsula, there is the chance that the caribou migration pattern will shift away from the reindeer rangeland. Herders will be able to gradually reintroduce reindeer herds according to available forage.

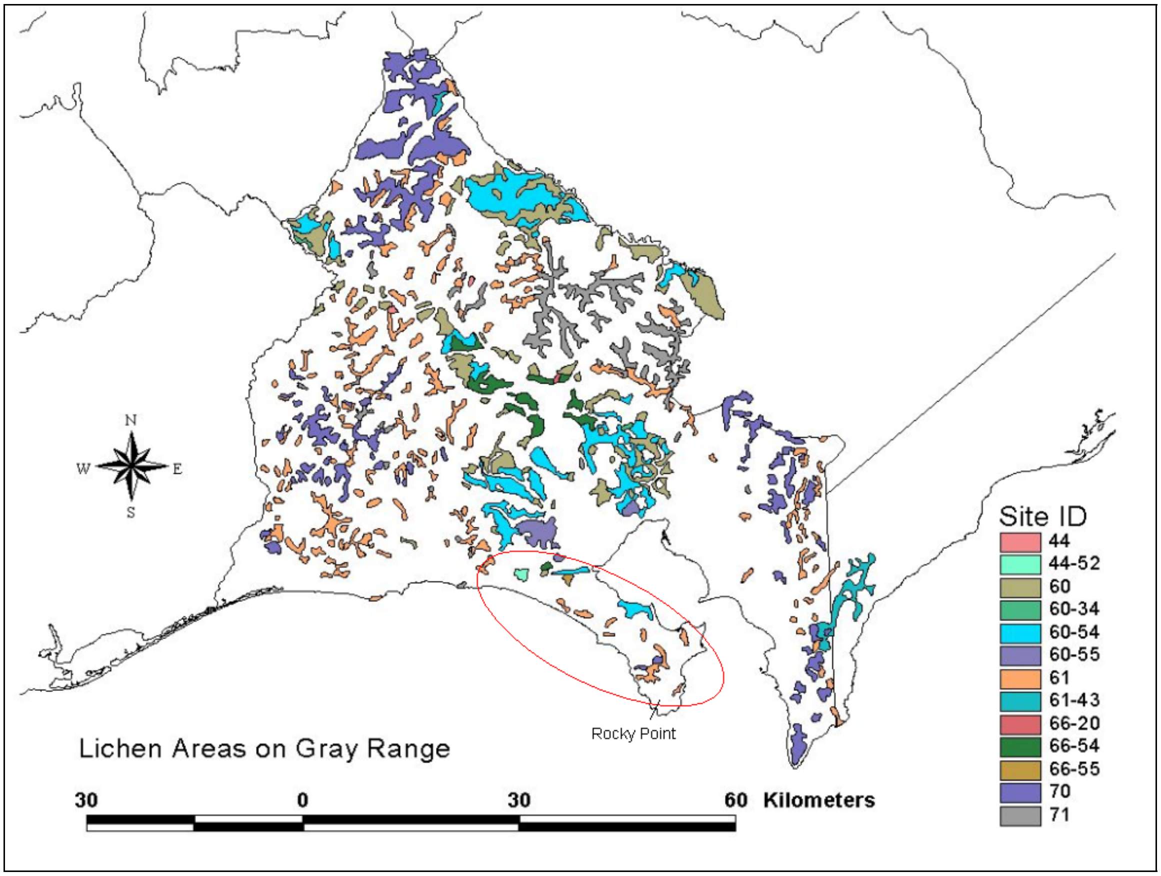

Figure 3.1 Lichen ecosites on the Gray reindeer range, Seward Peninsula, AK. Site IDs are based on the index established by Swanson *et al.*, 1985. The circled area represents the Gray refuge on Rocky Point peninsula.

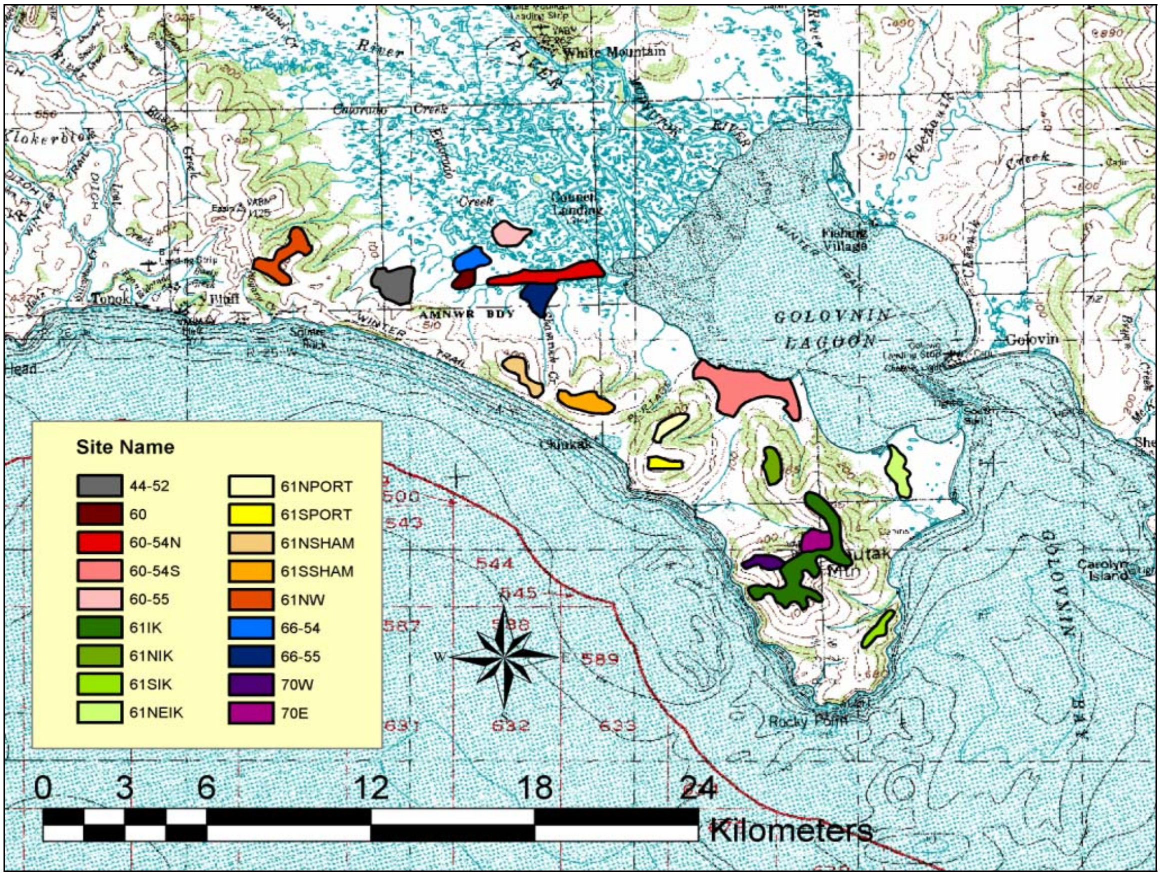

Figure 3.2 Lichen sampling sites on the Gray range. Rocky Point, Seward Peninsula, AK. Site names are based on the ecosite index established by Swanson *et al.*, 1985.

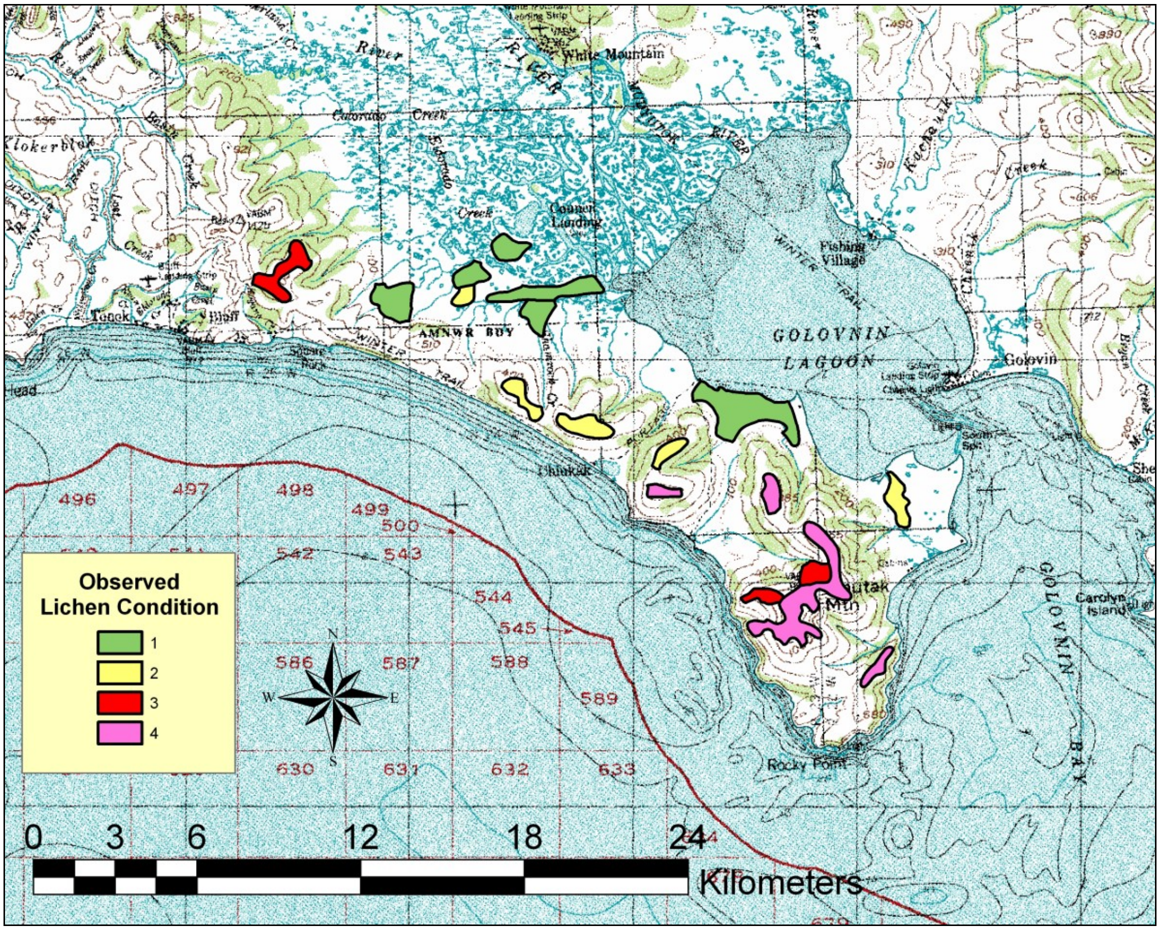

Figure 3.3 Lichen utilization based on visual observation on the Gray range. Rocky Point, Seward Peninsula, AK. Class 1 indicates light to moderate grazing, class 2 indicates moderate grazing, class 3 indicates moderate to heavy grazing, class 4 indicates heavy grazing.

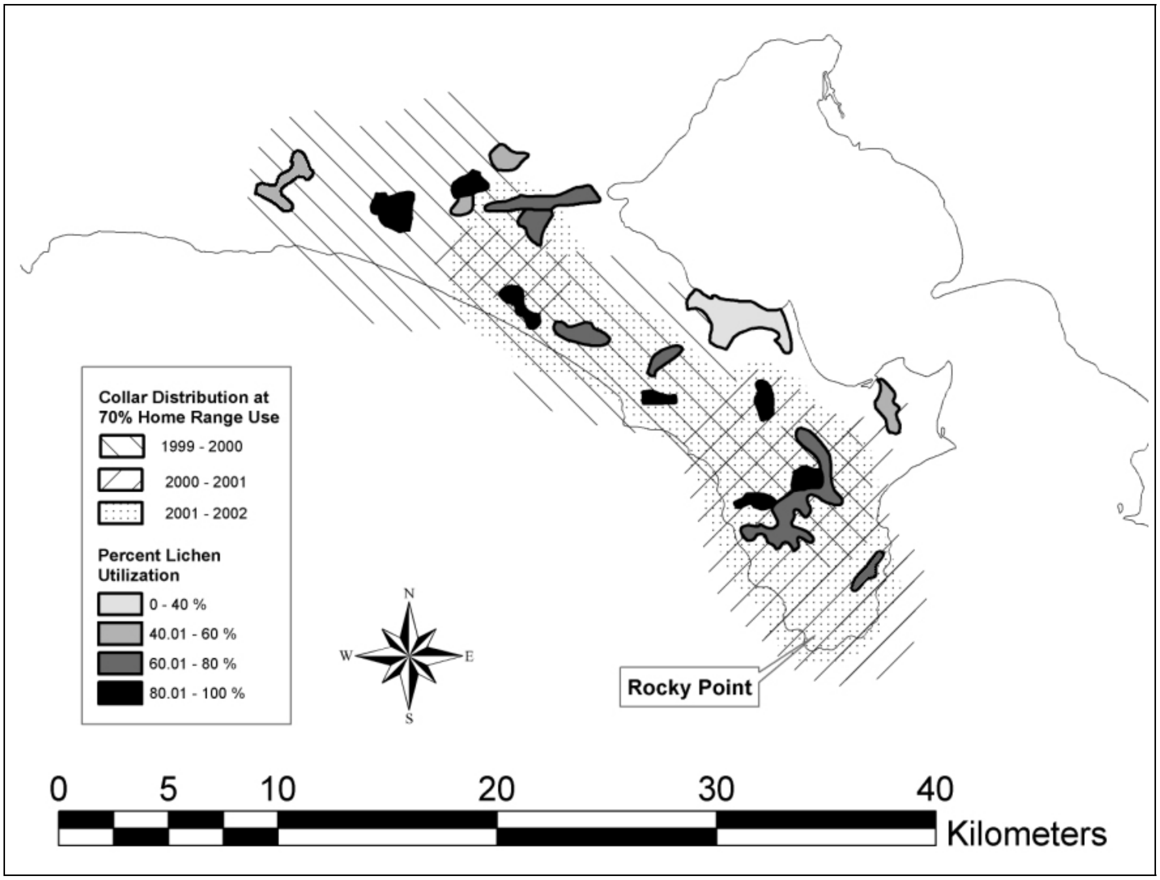

Figure 3.4 Lichen utilization and home range location on the Gray range. Lichen utilization, based on a comparison between lichen sample data from 2001-2002 and historical preferred lichen biomass values, and home range location at 70% use for 1999, 2000, and 2001 on the Rocky Point peninsula of the Gray reindeer range, Seward Peninsula, AK.

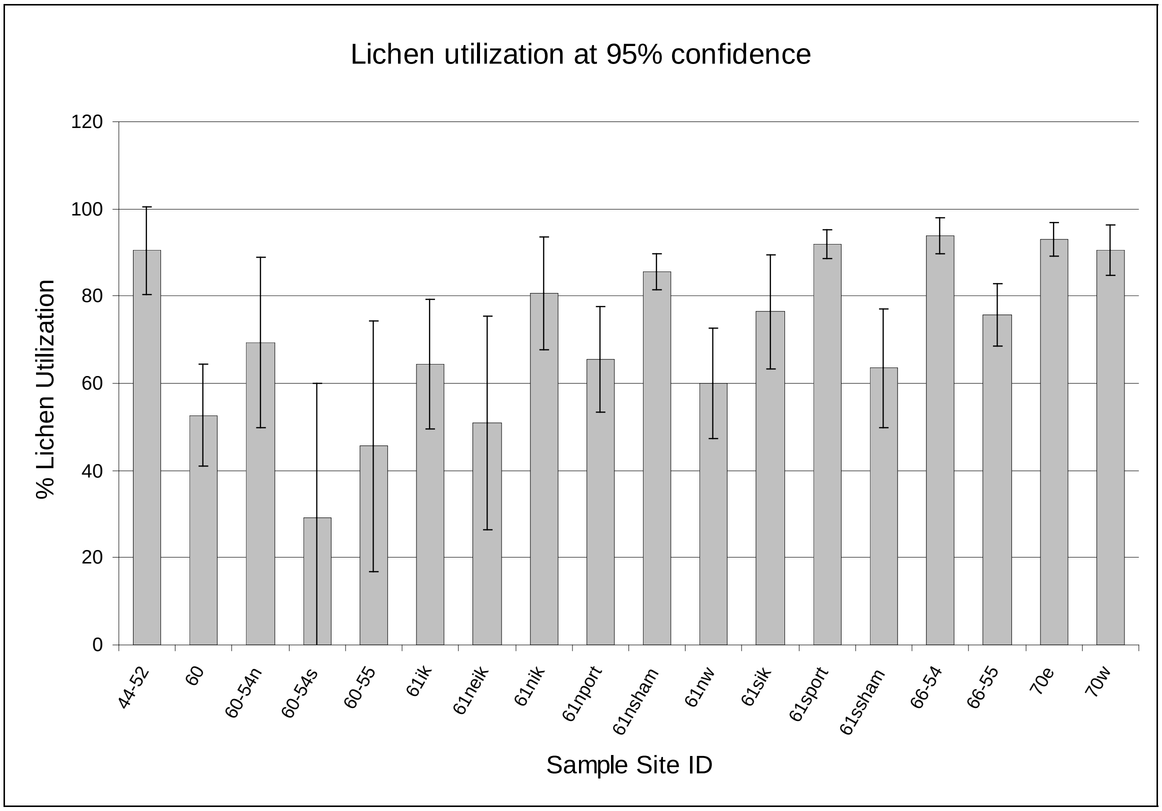

Figure 3.5 Percent lichen utilization at 95% confidence for 18 sample sites. Rocky Point peninsula of the Gray reindeer range, Seward Peninsula, AK. Values are based on air-dry lichen weights.

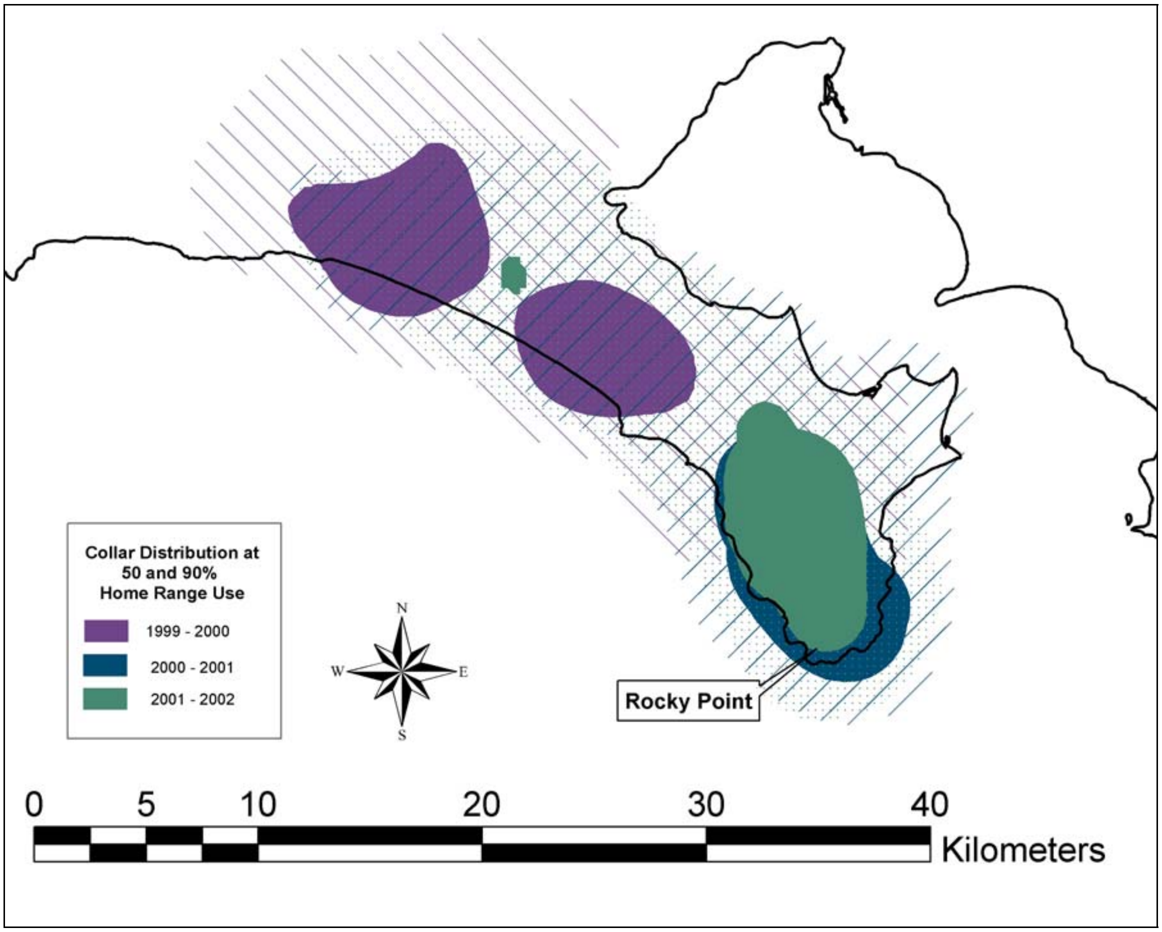

Figure 3.6 Home range core regions of 50 and 90% use. Gray reindeer herd, for the years 1999, 2000, and 2001 on the Seward Peninsula, AK.

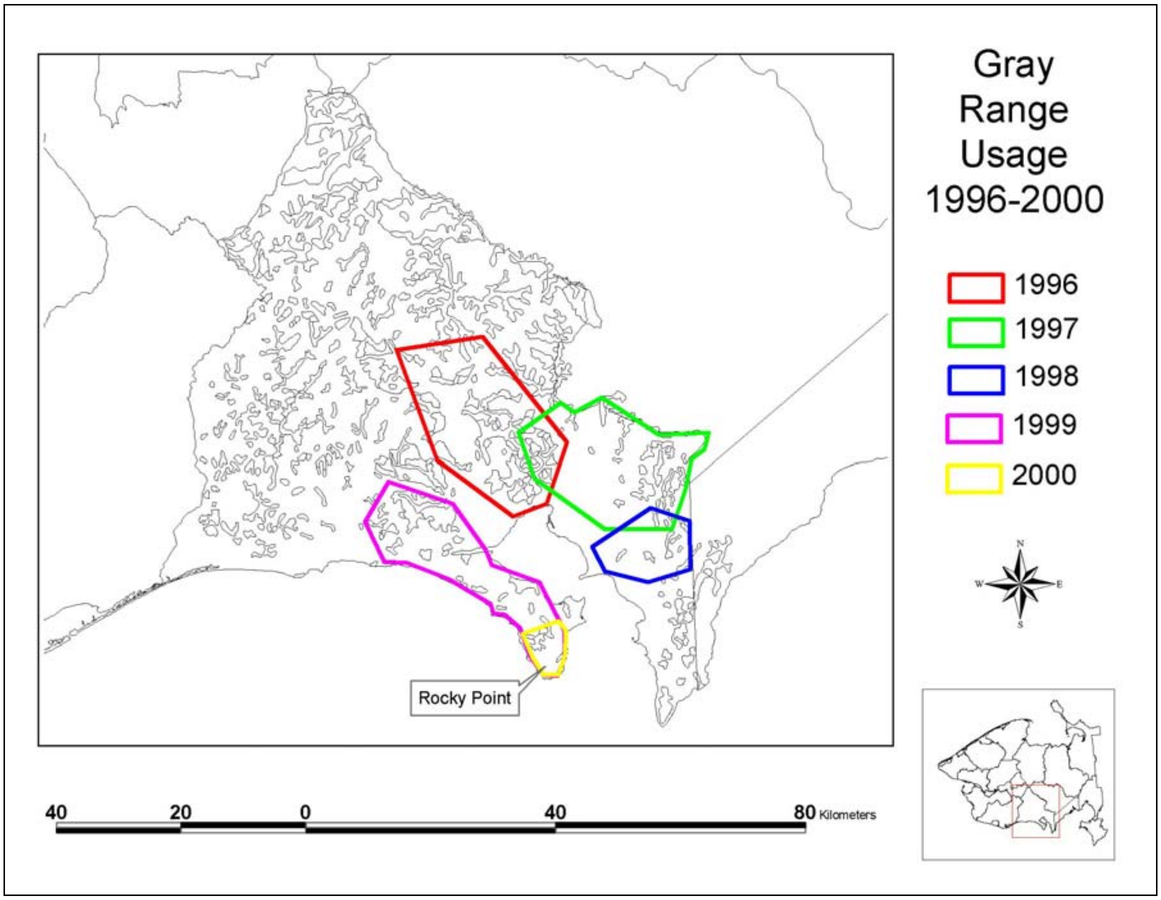

Figure 3.7 Gray range usage, 1996-2000. (Thomas Gray, herder, personal communication). Seward Peninsula, AK. Lichen ecosites within the Gray range are outlined in black.

Table 3.1 Parameters used to calculate an index of grazing intensity. Established by White & Trudell, 1980, and Swanson & Barker, 1992.

Grazing Intensity Score	Site Description	Overall Lichen Condition
0 – 1	Lichen beds intact; Cladonia, Cetraria, and Stereocaulon undisturbed in the moss layer	Excellent; Light Utilization (0-40% lichen disturbance)
1 – 2	Some lichens removed from the moss bedding	Good; Moderate Utilization (41-60% lichen disturbance)
2 – 3	Many lichens lying loose on the surface	Fair; Moderate to Heavy Utilization (61-80% lichen disturbance)
3 – 4	Most lichens loose on the surface; obvious disturbance to the moss layer.	Poor; Heavy Utilization (81-100% lichen disturbance)

Table 3.2 Stocking density values for air-dry lichen biomass from 18 sample sites. Rocky Point peninsula of the Gray reindeer range, Seward Peninsula, AK, 2002. (n=10).

Site ID	Mean air dry lichen weight (g)	Standard Deviation (g)	Mean biomass (kg/ha)	area (ha)	Total lichen (kg)
44-52	4	7	173	249	43155
60	13	5	523	68	35592
60-54n	4	4	169	292	49325
60-54s1	6	6	247	313	122540
60-54s2	13	11	536	313	
60-55	8	7	323	132	42724
61ik	14	9	544	645	351142
61neik	19	14	748	157	117409
61nik	7	8	293	110	32308
61nport	13	7	527	94	49462
61nsham	5	2	220	129	28275
61nw	15	7	611	244	148804
61sik	9	8	360	85	30594
61sport	3	2	122	67	8194
61ssham	14	8	557	180	100378
66-54	5	5	194	123	23848
66-55	19	9	777	155	120127
70e	1	1	58	119	6974
70w	2	2	80	87	6943
			Lichen sites:	3249	1317794
			Refuge totals:	24940	1317794

Refuge Stocking density:

$$\frac{(\text{TotLicKG} * x\%) / (531 \text{ kg/AU/yr})}{250 \text{ km}^2}$$

Refuge Estimates

x	**Stocking density**	Carrying capacity
1%	1 AU / 10.1 km²	25 AU
5%	**1 AU / 2.0 km²**	124 AU
10%	1 AU / 1.0 km²	248 AU

Table 3.3 Stocking density values for oven-dry lichen biomass from 18 sample sites. Rocky Point peninsula of the Gray reindeer range, Seward Peninsula, AK, 2002. (n=10).

Site ID	Mean oven dry lichen weight (g)	Standard deviation (g)	Mean biomass (kg/ha)	Site area (ha)	Total lichen (kg)
44-52	4	7	169	249	42043
60	13	5	509	68	34583
60-54n	4	4	162	292	47253
60-54s1	6	6	240	313	119723
60-54s2	13	11	525	313	
60-55	8	6	307	132	40616
61ik	13	8	525	645	338844
61neik	18	14	732	157	114992
61nik	7	7	277	110	30503
61nport	13	7	528	94	49565
61nsham	5	2	208	129	26795
61nw	15	7	584	244	142356
61sik	9	8	356	85	30214
61sport	3	2	115	67	7731
61ssham	13	8	537	180	96779
66-54	5	5	188	123	23051
66-55	19	9	744	155	114980
70e	1	1	60	119	7117
70w	2	2	78	87	6748
			Lichen sites:	3249	1273893
			Refuge totals:	24940	1273893

Refuge Stocking density:	*x*	Stocking density	Carrying capacity
		Refuge Estimates	
	1%	1 AU / 10.4 km²	24 AU
$\frac{(TotLicKG * x\%) / (531\ kg/AU/yr)}{250\ km^2}$	**5%**	**1 AU / 2.1 km²**	120 AU
	10%	1 AU / 1.0 km²	240 AU

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Chapter 4: Conclusions

Reindeer management strategies on the Seward Peninsula have progressed during the 20th century, adapting to cultural, technological and ecological changes. In particular, the presence of the Western Arctic Caribou Herd on the Seward Peninsula has caused a revision of reindeer management techniques. Herders have adjusted their management strategies in response to reindeer emigration and to resource competition caused by caribou on reindeer rangeland. Modern reindeer management now can incorporate satellite telemetry, an automated GIS, and intensively monitored refugia as strategies for dealing with unwanted caribou presence.

Culturally, reindeer herding evolved from the nomadic activity of a subsistence lifestyle, to the methodical efficiency of a commercial enterprise. Herders began using range conservation plans and keeping records of reindeer numbers, health, reproduction, and lifespan. That which began as a means to both ‘civilize’ Alaska natives and provide a stable food source, grew into an important capitalizing tool for the regional economy. Additionally, caribou, traditionally valued by subsistence standards, are now seen as an obstacle to the reindeer industry. Maximizing the profit generated by reindeer herding while balancing the cultural value of caribou requires herders to take full advantage of technological progress in their management strategies.

Technologically, herders adopted a satellite telemetry system, in conjunction with an automated GIS, for the near real-time (locations taken within 12 hours of real-time) monitoring of reindeer herds. Previously, herds were monitored first by foot and later by snow machine and aircraft. Advances in technology have made circumstances increasingly less practical for herders to remain with their herds year-round. The convenience of automotive machines, and recently satellite technology, has allowed herders to manage their herds from a distance and to diversify their work lives. Technology has changed reindeer management strategies. The use of snow machines marked a substantial shift in management from intensive nomadic herding to loose sporadic herding. The use of satellite telemetry and refugia resulted in a second shift in management practices. The near real-time locations of satellite telemetry allowed herders to find their herds quickly, while refugia required herders to begin intensive herding by snow machine to keep their animals within the refugia.

Ecologically, reindeer herders have had to alter management strategies in response to the increased grazing pressure on their rangeland. Utilization of rangeland by caribou reduces the carrying capacity of the land for future herding practices, and the use of refugia requires that herders concentrate their herds on a small area of land. As a consequence, reindeer herd size must be adjusted according to refugia forage resource availability. Smaller herds can be maintained in the refugia for longer periods of time. If the caribou problem subsides, the reindeer herd size may then be increased to match the new carrying capacity of the range.

Meeting the challenges of reindeer herding in a harsh northern environment requires that Alaskan herders be open to and readily adaptive of new management techniques. Herd and range management in subarctic regions presents many unique difficulties that temperate herders and ranchers may not deal with. The subarctic offers not only a distinctive climate and ecosystem, but also a wilderness that is both large and remote. Ranges are commonly half a million hectares or larger in size, and are often more akin to parkland than controlled rangeland. Few roads and no fences transect the ranges, and wild species roam the area freely. These characteristics combine to provide a challenging environment for prospective herders, where the correct management techniques can be crucial to herd survival.

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