ECOLOGICAL DEVELOPMENT OF A MANAGEMENT PLAN FOR REINDEER (*Rangifer tarandus tarandus*) ON ST. GEORGE ISLAND, ALASKA

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A

THESIS

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By

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Abstract

Management of an herbivore production system requires a working knowledge of the components and processes of the targeted grazing system. Land owners and stakeholders wish to develop a management plan for reindeer on St. George Island, Alaska. The foci of this study were to determine seasonal diet composition (including forage preference); evaluate nutritional content of *Angelica lucid*, a potential alternative winter forage; estimate lichen biomass; and estimate reindeer abundance, annual production, and sustainable stocking density. Lichens were the preferred reindeer forage throughout the year, however significant seasonal dietary shifts occurred across the seasons. Forbs and grasses were consumed in significantly greater proportion in spring and summer diets, sedges greater in the fall diets, and mosses greater in the winter diets. *Angelica lucida* was found in reindeer diets throughout the year. The nutritional profile and available biomass suggest this species may serve as an important forage for growth and maintenance of the reindeer. Both the reindeer population and calf:cow ratio increased from 2007 (290 individuals; 48:100 ratio) to 2008 (320 individuals; 57:100 ratio). The estimated total lichen biomass for the island was ~ 5.4 million kg dry matter which could support a population of 217 reindeer or 2.4 reindeer/ km^2.

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List of Abbreviations and Acronyms

ADF	Acid Detergent Fiber
BLM	Bureau of Land Management
cm	centimeter
Co	Cobalt
CP	crude protein
Cu	Copper
Fe	Iron
g	gram
GNSC	Great Northern Safari Company
GPS	Global Positioning System
K	Potassium
kg	kilogram
km	kilometer
LARS	R.G. White Large Animal Research Station
M	meter
Mg	Magnesium
Mn	Manganese
Mo	Molybdenum
Na	Sodium
NDF	Neutral Detergent Fiber
NOAA	National Oceanic and Atmospheric Administration

NPS	National Park Service
NRC	National Research Council
NRCS	Natural Resources Conservation Service
NRPH	National Range and Pasture Handbook
oz	ounce
P	Phosphorus
S	Sulfur
Se	Selenium
UAF	University of Alaska Fairbanks
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
Zn	Zinc

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1 General Introduction

Reindeer (*Rangifer tarandus tarandus*) are domesticated animals that have been introduced to a diversity of grazing environments with varying degrees of success. Reindeer have been introduced to 31 islands around the world including Greenland, Iceland, Newfoundland, Scotland, South Georgia, Kuriles (Japan), and many others (Leader-Williams, 1988). Of these 31 introductions, 10 occured on islands in Alaska: Atka, Hagemeister, Kodiak, Nunivak, Stuart, St. Lawrence, St. Matthew, St. Paul, St. George, and Umnak (Swanson & Barker, 1992). Many of these introductions were conducted by the U.S. government to provide food for Alaska Natives, while others occurred during World War II to provide food for the military (Klein, 1959). Some populations declined precipitously after an initial irruption, but many populations exhibited a single irruptive burst with progressive declines to a stable state (Riney, 1964; Leader-Williams, 1988).

Examples of irruptive reindeer populations followed by a rapid decline include St. Matthew and St. Paul Island. Peak densities were 18 animals/ km^2 on St. Matthew (Klein, 1968) and 19 animals/ km^2 on St. Paul (Wilke & Hajny, 1965). However, large population declines (>30% mortality) have also occurred at lower densities on other islands (i.e. Bathurst Island; Gunn & Dragon, 2002). These crashes are believed to have been caused by a combination of insufficient winter lichen resources and climatic factors such as harsh winters (Scheffer, 1951; Klein, 1987; Miller & Gunn, 2003).

Introduced island populations of reindeer demonstrating population stability include Hagemeister and South Georgia Island. The Bureau of Indian Affairs introduced 71 animals to Hagemeister Island in 1965. The population increased to 1,000 animals in only 6 years. The population then oscillated between 590 to 953 animals for the next 15 years before peaking at 1,530 animals in 1991. The herd was extirpated by government officials starting in 1992 (Stimmelmayr, 1994). South Georgia reindeer populations, including Busen and Barff, have remained fairly stable as well. The Busen reindeer population was introduced in 1925, increased to 800 animals by 1973, and has since remained steady (Moen & MacAlister, 1994).The Barff population was introduced in 1911 with 11 animals and peaked in 1957 with 3,000. Since then, the population has declined to 2,000 animals (Bell & Dieterich, 2010).

Both abiotic and biotic factors have been promoted as limiting island reindeer populations. Abiotic factors, such as snowfall and temperature, can influence reindeer populations in part through affecting access to forage and energy balance. Behnke (2000) addressed arctic grazing systems as non-equilibrium consumer-resource systems. He suggested there are three abiotic factors that drive vegetation production: rainfall, snow cover, and temperature (Behnke, 2000). Solberg *et al.* (2001) agreed that climatic variation is directly related to reindeer population density and growth rates. Tyler (1987) noted that harsh winters (i.e. deep snow and icing) caused large fluctuations in reindeer population size, independent of the population density. Miller *et al.* (2005) questioned Klein's (1968) conclusion that the population crash on St. Matthew Island was caused by density-dependent limitation on winter lichen forage. Because the crash occurred in a short time period, they believed it was not related to density or nutritional state but to deep, dense snow and icing conditions that restricted access to forage (Miller *et al.*, 2005). Gunn *et al*. (2003) stated abiotic factors (i.e. snow and ice) caused reindeer populations to crash on five of the nine Alaskan islands. Icing may have caused steep population declines by preventing access to winter forage (Miller *et al*., 1982).

Biotic factors influencing population dynamics of reindeer include quantity and quality of forage. Nutritional requirements of reindeer vary by season, sex, age, and reproductive status. Nutrient requirements are highest in the spring and summer months due to muscle and bone growth, gestation, lactation, and the need to replenish fat reserves (Chan-McLeod *et al*., 1994; Barboza *et al*., 2009). Fiber and nutrient concentrations in plants change throughout the growing season (Buchanan *et al*., 2002), and reindeer shift forages throughout the season to meet current nutritional demands. Shifting of diet throughout the year has been well documented in mainland reindeer populations, where lichens are preferred in winter, graminoids in spring, and shrubs in summer (Luick, 1977; White & Trudell, 1980; Bergerud *et al*., 2008).

During the winter months, lichens are the preferred food source for reindeer and caribou (Pegau, 1970; Gaare, 1986), and its availability can influence body weight, reproduction, and calf mortality (Skogland, 1983; Skogland, 1985, Skogland, 1986; Kojola *et al.*, 1995; Weladji *et al.*, 2002). Thus, the availability of lichen is often thought to be the limiting factor in the reproduction and growth of reindeer (Gaare, 1986; Kumpula *et al.*, 1998).

Currently, U.S. agencies, the Natural Resources Conservation Service (NRCS) and the Bureau of Land Management (BLM), recommend stocking densities of reindeer on grazing allotments based on utilization and the abundance of lichen available for future grazing (BLM, 2007). Therefore, lichen inventories are a key tool in understanding grazing conditions and capacity (Holecheck *et al*., 2004).

However, studies have shown that some stable island populations of reindeer are productive on vascular plants and mosses in winter in the absence of lichens (Klein, 1968; Skogland, 1984; Klein, 1990). For example, South Georgia Island reindeer consume mostly grasses (*Poa flabellate)* during the winter months (Leader-Williams, 1988). Greenland caribou forage predominantly on grasses and sedges in winter (Leader-Williams, 1988-first cited by Thing, 1984), and Svalbard reindeer are largely dependent on mosses and vascular plants (Staaland *et al*., 1993; van der Wal *et al*., 2001). These studies provide evidence that reindeer and caribou are not necessarily limited by availability of lichens during winter (Skoog, 1968; Bergerud, 1974).

Locals have reported St. George Island reindeer consuming *Angelica lucida* (common name: puchki) taproots during the winter months. However, for *Angelica lucida* to be included in a grazing management plan as primary winter forage we must know its nutrient profile, how much is available, and how much is being consumed.

In 2002, the NRCS conducted a lichen survey on St. George Island and found overgrazing on the southeastern side of the island (Sonnen, 2004). Reindeer had also begun to cross to the western peninsula, a previously ungrazed area, where lichen conditions were observed to be excellent. Lichen utilization increased by 2004, during the population peak of ~450-550 reindeer, at which point the NRCS recommended the herd be reduced to 100-150 reindeer (Sonnen, 2004). Additional surveys in 2005 and 2007 showed further decrease in the lichen standing crop across the island and the recommended stocking density was revised to 80-100 reindeer or 1 reindeer/ km^2 (Karin Sonnen, pers. comm.).

Some stakeholders on St. George Island expressed concern about the condition of the lichen range and the size of the reindeer herd. Portions of the western peninsula are owned by the U.S. Fish and Wildlife Service (USFWS) whose main goal is to preserve wildlife and wildlife habitat. The St. George Island Traditional Council has also voiced concern that the lichen ranges have become overgrazed and the reindeer population must be reduced. Concerns about the effects of reindeer on the condition of the lichen range on St. George led to a need for a more detailed assessment of reindeer diet and range status to adequately manage the reindeer and forage resources. The St. George Traditional Council contacted the Reindeer Research Program at the University of Alaska Fairbanks (UAF) in 2006 asking for help in developing a management plan for the reindeer on St. George Island.

Understanding the population demographics is key in developing a management strategy. By linking population dynamics with the forage base we can manage both resources in a sustainable manner. Since the re-introduction of reindeer to St. George in 1980, rough population estimates have been conducted by several entities at various times of the year. However, there has never been a complete census (age, sex, recruitment rates) of the St. George Island reindeer herd. The decrease in the lichen crop is presumably the result of an increasing reindeer population, and is of concern to stakeholders. Coupling population dynamics and range condition is the first towards development of a sound management plan, including a culling regime to optimize age and sex ratios, which is an important part of a good management strategy.

Knowledge of the shifting seasonal forage use of reindeer is key to developing a year round management strategy. Diet composition data can be used to identify the primary seasonal forage in an ecosystem, which in turn can be used collectively to estimate stocking density. Seasonal diet composition data can be used to identify forages, other than lichen, that may be used by reindeer in the winter on St. George Island.

St. George Island ecosystem

St. George Island (56^{o} 36’ N, 169^{o} 32’ W) (~91 km^{2}) is one of the Pribilof Islands, located in the Bering Sea (Figure 1.1). Elevation varies from sea level to 366 m. The climate is maritime with considerable cloudiness, heavy fog, and high humidity throughout the year. Because St. George Island does not have a weather station, weather data from neighboring St. Paul Island, 76 km north, is used to describe the island. The average temperature is 3.9ºC. February is the coldest month (-7.3ºC), while August is the warmest (10.8ºC). Temperatures below -17ºC are extremely rare. Frequent storms are characteristic and gale-force winds are common October through April, with wind speeds reaching 109 kph (NOAA, 2010). Annual precipitation is approximately 61 cm, with average snowfall of 147 cm per year (National Climatic Data Center, 2010). Snowfall occurs October through late June. Average snow depth is 5.1 cm, however, snow depths have been recorded up to 66 cm (NOAA, 2010).

Soils and vegetation

St. George Island was formed nearly 2.1 million years ago and is composed of basaltic lava (Hopkins & Einarsson, 1966). There is very little to no soil underlying the vegetation on the island. In the few areas that do contain soil, it is organic and hydric with the water table close to the surface. Sandy soil is seen along the dunes and ridges (Sonnen, 2005).

There are no trees on the island. The dominant vegetation consists of forbs and grasses in the lowlands to rocky lichen outcroppings at higher elevations. The Natural Resources Conservation Service (NRCS) has identified 22 ecological types on the island, which contain over 100 species of vascular plants and include ten species of lichen (USDA-NRCS, 2007).

Wildlife

Roughly 2.8 million birds representing 210 species nest on St. George Island each year. The Pribilof Islands are also a major breeding ground for the northern fur seal (*Callorhinus ursinus*). St. George Island also provides important habitat for the Steller sea lions (*Eumetopias jubatus*). There are only two native terrestrial mammals on the island; the Pribilof species of arctic fox (*Alopex lagopus*) and the lemming (*Lemmus nigripes*) (Scheffer, 1951). Dogs are not allowed on the island due to possible disease transmission to foxes or seals. There is an ongoing effort to keep the island pristine and free from invasive species such as rats (NPS, 2005).

Human population

Roughly 100 people currently inhabit St. George Island (U.S. Census Bureau, 2010). The island has only one 9.6 km road connecting the village to the airport; the rest of the island is only accessible by foot. While most of the subsistence harvest is from the sea, including marine mammals, fish, sea birds, and eggs (Torrey, 1978), roughly 10 reindeer are harvested per year (Karin Holser, pers. comm.).

St. George Island reindeer population

In 1911, the United States government placed 15 reindeer on St. George Island to provide the native people with a sustainable food source. The reindeer population peaked at 222 animals in 1922, but then rapidly declined, leaving only 60 individuals by 1926, and by 1950, the herd was extirpated by over hunting (Scheffer, 1951). In 1980, 15 reindeer were re-introduced from Umnak Island, forming the existing herd (Swanson & Barker, 1992).

Reindeer population numbers were recorded yearly on St. George Island from the introduction (1911) until the extermination (1950) by the Alaska fur-seal industry (Scheffer, 1951). Since the re-introduction of reindeer in 1980, rough population estimates have been conducted by several entities at varying times of the year (Figure 1.2).

St. George Island reindeer management

Reindeer have undergone little management since their introduction on St. George Island. A reindeer corral was built of stones by an Eskimo herder in the early 20th

century, but was later abandoned (Scheffer, 1951). The remnants of this corral still exist on the eastern end of the island.

In 2003, Tanaq Corporation gave exclusive commercial hunting rights to Great Northern Safari Company (GNSC-owner Corey Rossi). GNSC's main interest was harvesting Boone and Crockett trophy sized males. An estimated 20 trophy bulls were collected each year by their clients (Rossi, 2005 unpublished report). Tanaq Corporation also gave management rights to GNSC to cull the population down to the NRCS's recommended number of ~180 animals (based on lichen availability) in 2004. These were the first steps in managing the herd since their reintroduction. The same year, Tanaq Corporation enticed local residents to shoot reindeer and return the ears for $100 reward in an effort to further cull the reindeer population. One hundred and six animals were harvested in the summer of 2004 in efforts to reduce the population down to 200 animals (Rossi, 2005 unpublished report).

Objectives/ Discussion

The overall objective of this study was to understand the general ecology of the reindeer on St. George Island, Alaska in order to develop a management plan. Specifically, the objectives of this study were to: 1) estimate reindeer seasonal diet composition; 2) estimate seasonal forage preference; 3) estimate *Angelica lucida* taproot biomass on the island; 4) determine *Angelica lucida* taproot nutritional analyses including nitrogen and mineral content, fiber, digestibility, and surface to volume ratio; 5) determine age class (calves, yearlings, adults), sex ratios, and recruitment rates of the reindeer population in 2007 and 2008; 6) estimate lichen biomass; and 7) estimate stocking density based on useable winter lichen.

Island populations provide a unique opportunity for understanding the population dynamics and forage selection in a closed population. Understanding these factors is key in developing a management strategy. Chapter 2 covers the seasonal diet and forage preference of reindeer on St. George Island. In addition, *Angelica lucida* biomass and nutritional characteristics were determined to understand if this plant could be a sustainable winter forage. In chapter 3, total lichen biomass, proportion of lichen in reindeer diet, and herd demographics were estimated to calculate a recommended reindeer stocking density for St. George Island. Finally, chapter 4 discusses the overall results and key findings.

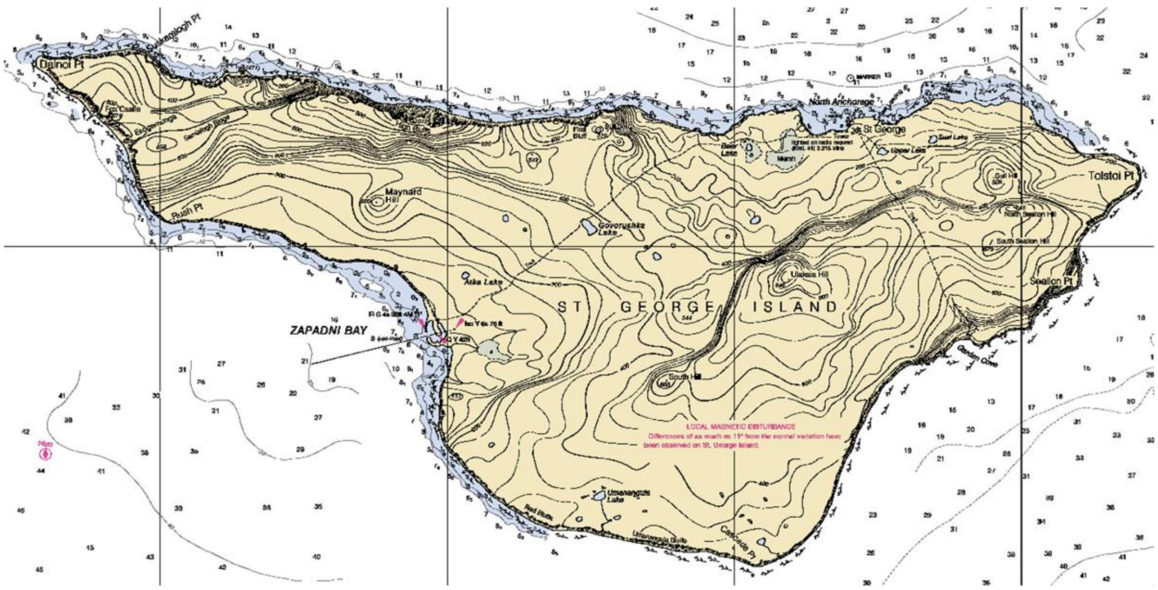

Figure 1.1 Map of St. George Island, Alaska (NOAA, 2011).

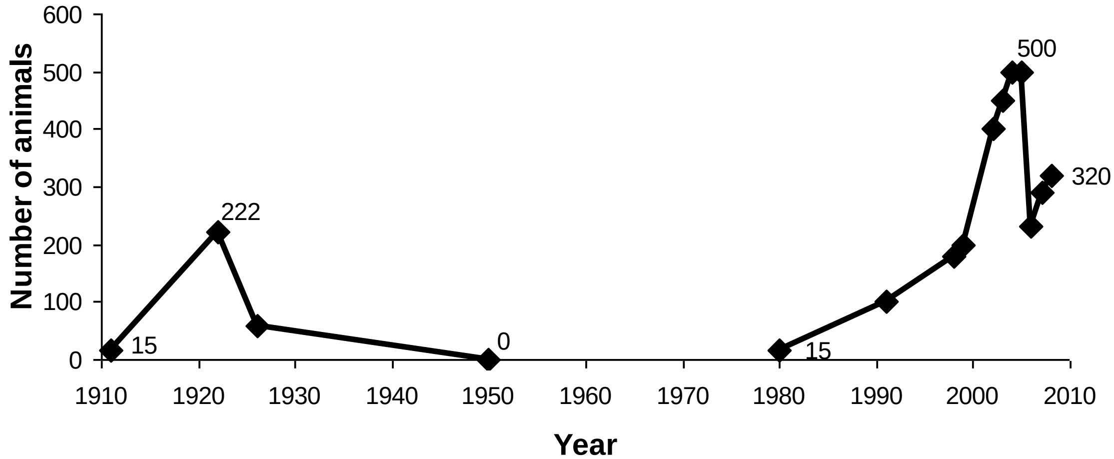

Figure 1.2 Reindeer population size on St. George Island, Alaska, 1911-2007 (Scheffer, 1951; Swanson & Barker, 1992).

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2 Reindeer (*Rangifer t. tarandus*) diet and analysis of a potential alternate winter forage (*Angelica lucida)* on St. George Island, Alaska

Abstract

Management of reindeer grazing systems requires information on the interaction between the forage base and animal foraging behavior. Our objectives were to estimate seasonal diet composition and forage preference of reindeer, and estimate taproot biomass and nutritional profile of *Angelica lucida*, a purported winter reindeer forage on St. George Island. Lichens, the preferred forage throughout the year, made up 51% of the summer and 66% of the winter diet. Reindeer consumed higher percentages of forbs and grasses in the spring and summer, sedges and shrubs in the fall, and lichens and mosses in the winter. *Angelica lucida* was most prevalent in the diet during the spring and early summer months.

Introduction

Reindeer are a highly adaptable species, which allows them to live in diverse habitats, from boreal forests to the high Arctic tundra. Reindeer show strong preferences for certain forage species when they are available, but will also consume a diversity of vegetation reflecting unique local plant communities. Reindeer forage selectively based on quality and quantity of forage, which varies by plant species, plant phenology, and season (Klein, 1990).Generally, reindeer in continental habitats prefer lichens in winter, graminoids in spring, and shrubs and sedges in the summer (Gauthier *et al*., 1989). Nutritional needs are highest during the spring and early summer months due to muscle and bone growth, gestation, lactation, and replenishment of fat reserves (Chan-McLeod *et al*., 1994). High concentrations of nitrogen, carbohydrates, and phosphorus are found in new growth of deciduous shrubs, forbs, and graminoids after snow-melt (Chapin *et al.*, 1975; Chapin *et al*., 1980; Klein, 1990) making these forages highly selected by reindeer at this time. Phenological development of the plant during mid-to-late summer redistributes N, P, K, and Ca back into the stem and roots of some deciduous shrubs and graminoids (Chapin *et al*., 1975; Chapin *et al*., 1980). Also, some graminoids, shrubs (i.e. *Ledum palustre*), and evergreen species have constant, or slight increases in levels of N, P, K, and carbohydrates throughout the growing season (Chapin *et al*., 1980; Klein, 1990) creating a dynamic forage base for reindeer. In late summer to fall, reindeer fat deposition increases along with winter coat production (Chan-McLeod *et al*., 1999). During winter reindeer shift their diet to meet basic energy requirements for maintenance (White *et al*., 1981). Lichens, which are high in carbohydrates and low in minerals, become the main component of the diet in the winter months, along with a few select vascular plants (Klein, 1990).

Reindeer grazing ranges on islands are often composed of atypical plant communities that arise from unique soil and climate conditions. Grazing dynamics are unique, thus creating the need to investigate the mechanisms and processes on the island to develop an ad hoc grazing management plan. For example, Leader-Williams (1988) found grasses (almost exclusively *Poa flabellate*) dominate the winter diet of reindeer on South Georgia, with some seaweed. In the snow-free months, rushes, lichens, and grasses dominated their diets (Leader-Williams, 1988). Winter and summer diets of barren-ground caribou in Greenland consist predominately of grasses and sedges, and include shrubs and rushes (Leader-Williams, 1988-first cited by Thing, 1984). Svalbard reindeer are largely dependent on mosses and vascular plants in winter (Staaland *et al*., 1993; van der Wal *et al*., 2001). Their summer diets consist of mainly grasses, sedges, and even some goose droppings (Orpin *et al.*, 1985; van der Wal & Loonen, 1998). The winter diet of Peary caribou, on Western Queen Elizabeth Islands, Canada, consists mainly of graminoids (sedges and rushes) and moss during the winter (Thomas & Edmonds, 1983). Summer diet of Peary caribou consisted of willows, mosses, forbs, and lichens (Fisher & Duncan, 1976). Coats Island, Canada caribou consume primarily willows (up to 60%) and lichens in winter, as well as shrubs, forbs, and sedges. Their summer diets are almost exclusively willows, but include some forbs (Adamczewski *et al.*, 1988). St. Paul Island, Alaska summer diets are almost exclusively *Angelica lucida* (puchki) and *Pedicularis verticillata* (whorled lousewort). Fall diets consist mainly of grasses, specifically *Elymus mollis* (American dunegrass), and some crowberry (*Empetrum nigrum*) (Scheffer, 1951). Although lichens are the preferred forage (Garmo, 1986) and are considered the most important winter forage for reindeer when available (Pegau, 1968), these studies suggest forages other than lichens are primary forages in winter.

St. George Island

Reindeer have undergone large population fluctuations on St. George Island since being introduced in 1911. The initial introduction of 15 animals peaked at 222 animals in 1922, declined sharply to 60 animals by 1926 and was extirpated by 1950 (Scheffer, 1951). A second introduction of 15 animals in 1980 peaked at ~450-550 animals in 2004 and then declined to 230 by 2006. Reindeer diet composition on St. George has not previously been assessed, but the impact of reindeer grazing on lichen range has been recorded intermittently. Lichen ranges on St. George were assessed to be in good condition following extirpation of reindeer in 1950 and in excellent condition in 1991 following the second reintroduction (Swanson & Barker, 1992). The first signs of overgrazing were seen in a survey in 2002, which found that lichen on the southeastern side of the island was heavily utilized (Sonnen, 2004). Assessments by the NRCS in 2005 and 2007 showed further decreases in the lichen standing crop on the island (Sonnen, 2005). Concerns about the effects of reindeer on the condition of the lichen range on St. George led to an interest by stakeholders to develop a range management plan for the island to promote sustainable use of the rangeland, which is discussed in chapter 3.

Local residents have reported St. George Island reindeer consuming *Angelica lucida* (puchki) taproots during the winter months. This forage may contribute energy and nutrients to meet nutritional requirements in. We will investigate the nutritional profile and availability of *Angelica lucida* for potential use as a winter forage. The purpose of this study is to gather information on the interaction of reindeer grazing behavior and the forage base as the basis for a grazing management plan.

Objectives

The specific objectives of this study are to: 1) estimate reindeer seasonal diet composition; 2) estimate seasonal forage preference; 3) estimate *Angelica lucida* taproot biomass per ecological site; and 4) determine *Angelica lucida* taproot nutritional values including nitrogen and mineral content, fiber, digestibility, and surface to volume ratio.

Although reindeer diet composition has been well documented on mainland populations (i.e. Alaska, Finland, Norway, etc.), this is the first time a seasonal diet analysis has been conducted for reindeer on St. George Island. This information will form the basis of a range management plan, allowing managers to identify seasonally important forages and move animals to habitats rich in these forages, thus optimizing animal production while maintaining range resources.

Study Site

St. George Island (~91 km^2) is located in the Pribilof Islands in the Bering Sea (56^o 36’ N, 169^o 32’ W). Approximately 100 people currently inhabit the island (U.S. Census Bureau, 2010). The island has only one 9.6 km road connecting the village to the airport; the rest of the island is only accessible by foot. The island has a maritime subarctic climate with temperatures varying little throughout the year from -4.4 to 11.1^{o}C (Alaska CIS, 2008). The island was formed by volcanoes roughly 2.5 to 1 million years ago. The elevation varies from sea level to 309 m (Hopkins & Einarsson, 1966).

The U.S. Geological Survey (USGS) has classified the St. George Island ecosystem as moist tundra (USGS, 1997). The vegetation on the island consists of grassy-herbaceous communities in the lowlands and dunes to rocky lichen outcroppings in higher elevations. There are no trees on the island and shrubs do not exceed two feet in height. The Natural Resources Conservation Service (NRCS) has classified the vegetation communities of the island into 22 ecological types, which contain over 100 species of vascular plants and ten species of lichen (USDA-NRCS, 2007) (Figure 2.1). Twenty five percent of the island is classified as Rocky Crowberry Lichen Upland (i.d. number 136) (Table 2.1) which is dominated by shrubs (72%), particularly *Empetrum nigrum* (crowberry), graminoids (17%) including *Carex sp*. (sedges), and forbs (11%) *Artemesia arctica* (boreal sagebrush), *Artemesia globulari* (purple wormwood), and *Angelica lucida* (puchki). Mosses and lichens are also present. Forb Tundra (i.d number 57) sites make up nineteen percent of the island. These ecological sites are found at lower elevations and consist almost exclusively of forbs (55%), particularly *Angelica lucida* (puchki), and graminoids (45%) including *Leymus mollis ssp. mollis* (American dunegrass). Other major ecological sites include, Crowberry Forb/ Grassy Tundra (i.d. numbers 135-198) (~9%) and Boulder Mixed Tundra (i.d. number 187) (~9%) (Table 2.1). Based on the forage composition of the entire island, lichens dominate the island

(48%), followed by graminoids (23%), forbs (21%), and shrubs (8%) (USDA-NRCS, 2007).

Methods

Seasonal diet composition of reindeer

Reindeer fecal samples were collected opportunistically once per month from May 2007 to May 2008. A composite sample was collected for every 10 reindeer within a group, up to a maximum of three composites per group. Each composite sample consisted of 6 pellets from 10 different fecal piles, for a total of 60 pellets per sample. The pile was "marked" by stepping on the pile to prevent repeated sampling.

Fecal pellets were frozen until they could be processed. Fecal pellets were cleaned of all non-fecal contaminants while frozen and dried at 60ºC for 48 hours. Once fully dried, they were placed into a clean bag and sent to the Wildlife Habitat Laboratory, Washington State University, for a microhistological 50 view, level A diet composition analyses. This analysis estimated diet composition based on identification of undigested plant fragments in the feces at the genus and species level.

Reindeer diets were categorized by season; spring (April and May), summer (June, July, August), fall (September, October, November), and winter (December, January, February, March). The diet composition data was adjusted for digestibility using digestibility correction values from Finstad (2008). Seasonal differences in diet were determined by a one-way ANOVA after transforming the diet composition data using an arcsine transformation to normalize the data. If a significant difference in the diet was found, a Tukey test was conducted to determine which of the seasons were significantly different (R project 2.7).

Forage preference

Geographic waypoints were recorded using a Global Positioning System (GPS; Garmin eTrex®) during each fecal collection, as well as recording general site description, date, and sex of the herd (i.e. all male herd, all female herd, or mixed male and female herd). These waypoints were downloaded into ArcView 9.0® and overlaid on the digitized vector ecological site map of the island produced by the NRCS (Sonnen, 2005; USDA-NRCS, 2007).

Forage preference was estimated as the percentage of the forage found in the diet compared to the percentage found in the grazing area using Ivlev's Electivity Index (Strauss, 1979):

$$E = (r - p)/(r + p)$$

Where:

r = percentage of forage found in the diet

p = percentage of forage found in the grazing area

Ivlev's index ranges from -1 to +1, where negative values indicate avoidance and positive values indicate selection.

Forage preference was estimated for the same seasons as diet composition: spring, summer, fall, and winter. Forage preference was analyzed at two different spatial scales of the island. The regional scale divided the island into the western peninsula and the main body of the island, using the west end of the airport runway as a division line because reindeer generally stay away from this area (Figure 2.3). While it is not an impermeable barrier, based on local knowledge, the reindeer stay in this area and do not cross for a few months out of the year. The larger scale was the entire island. We looked at two spatial scales because the herd splits into two populations for most of the year. One population moves around the main body of the island while the other population stays consistently on the western peninsula. For analysis at the larger scale, the whole population was considered one herd with a whole island range. Forage availability was determined for the appropriate scale.

The NRCS estimated annual production for both vascular and non-vascular species of forage for each ecological site. Because the NRCS lumped grasses, sedges, and grass-like plants into one category "grasses", all grass and sedge/rush values in the diet composition data were combined into one category for consistency. Also, because the NRCS did not estimate moss production within each ecological site, the diet composition was corrected by removing moss in the reindeer's diet and adjusting the diet proportion for the remaining species.

Angelica lucida nutritional analyses

Taproot biomass

The sampling area was comprised of ecological sites containing *Angelica lucida*. To estimate *Angelica lucida* biomass, the number of *Angelica lucida* plants were counted along transects in each ecological site. At each site, at least six 100 m transects were laid using randomly generated X and Y coordinates and bearings. On each transect the total number of *Angelica lucida* plants were counted within 2 meters on the right side of the transect. Initial sampling (38% of total transects) included 10 transects per ecological site polygon. However, after conducting a bootstrap statistical analysis, 6 transects were determined to be statistically sufficient, therefore subsequent sampling included only 6 transects per ecological site polygon.

To estimate taproot biomass, 18 plants from four different ecological sites (Sandy Beach, Coastal Tundra, Rocky Crowberry Upland, and Crowberry Lowland) across the island were arbitrarily collected. The taproot was cut to the depth (roughly 40 mm) at which reindeer could be expected to access the plant. These depths were estimated based on personal visual observation of reindeer foraging activity in the area. Plant wet weights were recorded, and the bagged plants were immediately shipped to the University of Alaska Fairbanks to be dried. The taproots were cut into smaller pieces, dried at 60ºC for 48 hours, and weights recorded. The mean dry weight of the 18 taproots was multiplied by the average number of plants per ecological site to estimate total *Angelica lucida* taproot dry matter per ecological site.

<u>Nutritional content</u>

Fiber analyses

Three to six *Angelica lucida* taproots were randomly collected in 5 different ecological sites across the island during the spring, summer, and fall months for a total of 56 plants. The samples were oven-dried, cleaned of all non-taproot contaminates, and re-dried at 60ºC for 24 hours. Dried samples were ground in a Wiley Mill™ using 20 mesh

(.85 mm) screen. The ground samples were thoroughly mixed and partitioned into two subsamples. One subsample was used for nitrogen and mineral analyses, while the other subsample was used for fiber (Ankom method) and digestibility (In SACCO) analyses (Person *et al*., 1980; Vogel *et al*., 1999; Ihl & Barboza, 2007).

Nitrogen and mineral content

Samples to be analyzed for nitrogen and mineral content were sent to the UAF Palmer Research and Extension Center (Palmer, AK) for crude protein (N x 6.25), P, K, Ca, Mg, S, Na, Co, Cu, Fe, Mn, Mo, Se, and Zn analyses. The samples were digested with a perchloric-nitric acid mixture (HN03-HC104) then run on an ICP Optima 3000 XL spectrometer for the mineral analyses or a CHN 1000 Elemental Analyzer for nitrogen analysis. A one-way ANOVA test was conducted in R to determine if there were any significant differences in nitrogen or mineral concentrations across seasons.

Fiber

Fiber determinations were made on an ANKOM 200 Fiber Analyzer at the University of Alaska Fairbanks using the ANKOM technique for the NDF, ADF, and lignin procedures (Vogel *et al*., 1999). A 0.500 gram (± 10%) taproot sample was added to an Ankom F57 bag.

Rumen digestion

Three reindeer with rumen fistulas were used at the R. G. White Large Animal Research Station (LARS), Fairbanks, Alaska from December 17 to 24, 2008 to estimate digestibility within the rumen (protocol no. 08-40 of the University of Alaska Fairbanks Institutional Animal Care and Use Committee). One gram *Angelica lucida* taproot was added to permeable nylon bags, which were attached to a weighted polypropylene rope and inserted in the rumen. After 48 hours, they were removed and dried. Digestibility was calculated as the proportion of final dry matter to original dry matter. A replicate of each sample run was assigned to a different animal to reduce between-animal variability.

Acid-Pepsin digest

Following the rumen digestion, the samples were put through an acid-pepsin digestion using the methods of Ihl & Barboza (2007). The procedure was modified due to limitations imposed by laboratory equipment. Modifications included randomly dividing samples into groups of three, incubating in 115 ml of acid- pepsin solution in a 8 oz canning jar, and agitating in an incubator at 38ºC for 24 hours. Three 1 gram samples of casein were included as a standard.

Surface to volume ratio

The microhistological procedure used to determine diet composition is based on the presence of epidermal cells of the forage (Davitt & Nelson, 1980). Plants differ in the surface to volume ratios depending on growth form. Lichens, shrubs, forbs, and mosses have high surface to volume ratios (Brown, 1970; Sylvester & Wein, 1981) while grass surface to volume ratios are approximately equal (Dengler *et al*., 1994; Gibson, 2009). In plants or plant parts with small surface to volume ratios, such as tubers and taproots, proportion in the diet can be severely underestimated (Marti, 1982). *Angelica lucida* taproots are bulky and have a small surface to volume ratio, which may lead to underrepresentation in the diet composition by microhistological analysis. The surface to volume ratio of *Angelica lucida* taproot was calculated to estimate the volume of non-epidermal cells not accounted for in microhistological procedure and was used to adjust diet composition. The mathematical equation for the volume of a cylinder was used:

$$V=\pi r^2 h$$

Where;

r = radius (average of the minimum and maximum diameter).

h = height measured from the top of the root to the natural breaking point.

The natural breaking point was defined as the first major lateral root that branched off of the taproot (Figure 2.2). Based on personal visual observations of reindeer foraging, this was determined to be the best indicator of the depth to which they forage on *Angelica lucida*.

Results

<u>Seasonal diet composition of reindeer</u>

Dietary components were grouped into 6 categories including shrubs, grasses, sedges/rushes, forbs, lichens, mosses, and ferns. *Salix*, *Vaccinium*, *Rubus*, *Empetrum*, and *Cornus* were grouped as shrubs. *Carex*, *Eriophorum*, *Juncus*, and *Luzula* were grouped as sedges/rushes. *Saxifraga*, *Polygonum*, *Pediculars*, *Lathyrus*, *Stellaria*, *Silene acaulis*, *Fritillaria camschatcensis*, and *Angelica lucida* were included as forbs.

Spring 2007 (May)

Lichens dominated the spring diet (65%), followed by mosses (9%), grasses (9%), forbs (7%), sedge/rush (> 5%), and shrubs (5%) (Table 2.2, Figure 2.3).

Summer 2007 (June-August)

The top three dietary components of the summer diets are lichens at 51% followed by forbs (16%) and grasses (14%). Percentage of mosses in the diet was 7% followed by sedge/rush (7%) and shrubs (5%) (Table 2.2).

Fall 2007 (September-November)

Percentage of lichen increased to 58% in the fall diets and there was a shift away from grasses (3%) and forbs (5%) to mosses (14%) and sedges/rushes (13%). The percentage of shrubs in the fall diet remained approximately the same as the summer (6%) (Table 2.2).

Winter 2007-2008 (December-March)

Lichens (66%) and mosses (20%) comprised the majority of the reindeer diet in the winter. Percentage of grasses doubled (6%) while percentage of forbs (1%), sedge/rush (3%), and shrubs (4%) declined in the reindeer diets from fall to winter (Table 2.2).

Spring 2008 (April-May)

Spring 2008 results were similar to the spring of 2007. Lichens (57%), mosses (12%), and grasses (13%) were the predominant forages. Percentage of forbs (12%)

increased in spring 2008, while percentages of sedge/rush (3%) and shrubs (3%) decreased (Table 2.2).

Summer 2008 (June only)

No comparison can be made between the summer seasons of 2007 and 2008 because fecal collections only occurred during one month in 2008. Lichens (67%) dominated the diet, while forbs (15%), grasses (9%), and mosses (6%) made up a large portion of the diet. Sedge/rush (2%) and shrubs (<1%) also made up a small percentage of the diet (Table 2.2).

Seasonal comparison

We excluded data in the analysis for the spring of 2007 and summer of 2008 due to incomplete sampling. There was no significant difference in the mean percentage of shrubs ($p = 0.61$) or lichens ($p = 0.24$) in the reindeer diet among the seasons. Grasses and forbs were a significantly higher percentage of the diet in spring and summer (13.5, 14.1%; and 11.7, 16.2% respectively) compared to fall and winter (3.5, 5.8%, and 5.2, 0.6%). Sedge/rush percentages were significantly greater in the fall (12.9%) compared to the winter and spring (3.1 and 2.8% respectively). Mosses were significantly higher in winter (20.4%) than in summer (6.9%) (Table 2.2).

Forage preference

Overall, the forage preferences were very similar at both the whole island scale and the regional scale (east vs. west). Shrubs were always avoided. Lichens were selected in all seasons at both scales except at the whole island scale for summer 2007 and the eastern regional scale for spring 2008. In these two cases, grasses and forbs were selected instead of lichen, although the preference was weak at both scales (Figures 2.4 and 2.5).

Angelica lucida

Taproot biomass

Twelve unique ecological site types were sampled for a total of 215 transect locations. The average number of *Angelica lucida* plants per transect was 12.9. The average taproot dry weight was 9.36 g (±1.23 S.E.). The estimated taproot biomass for the island is 344,140 kg (Table 2.3).

Nitrogen and mineral content

In general, the concentrations of individual nutrients in the taproot were highest in the spring and lowest in the summer. Crude protein, P, S, and Zn, were significantly higher in the spring (Tables 2.5 and 2.6). Of all the nutrients analyzed in the taproot (CP, P, K, Ca, Mg, S, Na, Co, Cu, Fe, Mo, Se, Zn), there was no significant difference in Co, Fe, and Mn among seasons (Table 2.6).

Fiber

The fiber content (NDF, ADF, and lignin) varied by season (Table 2.4). Fall taproots contained the highest amount of fiber, followed by spring and then summer (Table 2.4). The only significant difference was lower lignin content in the summer.

InSacco

After rumen digest and pepsin wash, *Angelica lucida* taproot digestibility was 74.4% (± 2% S.E.).

Surface to volume ratio

The average surface to volume ratio of 14 various-sized taproots was 11% (±.003 S.E.) or a ratio of 1:9. Assuming digestibilities are equal for epidermal and non-epidermal cells, microhistological analyses may have underestimated puchki in the diet by up to 89% as a result of only identifying epidermal cells.

Discussion

Reindeer on St. George Island consumed a diversity of forages and the proportions consumed shifted with season. Lichen was the predominant forage in the diet during all seasons, particularly during winter. Although lichen is currently the main winter forage, results from this study suggest reindeer are also consuming at least small quantities of *Angelica lucida* taproot during these time periods.

Lichens were the preferred forage throughout the year (Table 2.2). The lowest percentage of lichens was found in the summer diet (51.3%) and the highest in the winter diet (66.2%), with spring and fall values 57.3% and 58.2% respectively. The highest percentage of lichen was found in the segregated all-male group in June, 2007 at 80%. This high percentage of lichens in the diet coincides with the high quantity of lichens on the western end of the island where males spend most of their time. However, it is not clear whether this is purely a geographical effect or whether male reindeer are driven there by nutritional needs, and this question warrants further investigation.

Mosses were a substantial component of the diet in fall and winter (14.1% and 20.4%, respectively). It is not clearly understood why reindeer consume moss, however high moss consumption (up to 56.1%) has been reported in other studies (Thomas *et al*., 1976). It is unclear whether moss is ingested intentionally or as a result of consuming winter forage (Ihl, 2010). Moss has low protein and very high fiber content, but contains higher concentrations of minerals than lichens (Staaland *et al*., 1988; Ihl & Barboza, 2007), which may provide some important minerals to reindeer in winter. Because the NRCS did not estimate moss plant production, we do not have availability data for moss and therefore could not determine if there was a preference for this forage.

Seasonal diet shifts occurred on St. George Island, likely to support changing reindeer nutritional requirements and reflecting nutritional characteristics of forages. Energy, CP, Ca, and P requirements are highest in the spring and summer months due to muscle and bone growth, gestation, lactation, and replenishment of fat reserves (Thompson & McCourt, 1981). Significantly higher percentages of forbs and grasses were consumed in the spring and summer diets during this period of high demand (Chan-McLeod *et al*., 1994). These forages (including forbs, *Angelica lucida*, and *Lupinus sp*. and grasses, *Arctagrostis sp*., *Poa sp*., and *Phleum sp*.) contain high amounts of CP (Bergerud, 1971) and P (Klein, 1990) and are highly digestible during this time (Tomlin *et al*., 1965; Finstad, 2008).

Advancing plant phenology during the fall induces changes in the fiber and mineral content in plants (Buchanan *et al*., 2002), resulting in reindeer selecting for less fibrous and more nutritious plants. Sedges are relatively high in digestible energy, compared to other forages at this time (Larter & Nagy, 2001; Finstad, 2008). The proportion of sedges (*Carex spp*.) increased in the fall likely to support fat deposition (Chan- McLeod *et al*., 1999).

While lichens dominated the winter diet, mosses and grasses contributed up to 25% of the winter diet. Although protein requirements in reindeer are reduced in the winter (White *et al.*, 1981), mosses and grasses may help meet maintenance demands better than lichen alone (Storeheier *et al*., 2002). While lichens provide energy (carbohydrates), grasses have higher concentrations of nitrogen and minerals in the winter, which could help in reducing the negative nitrogen balance that results from consuming only lichen (Danell *et al*., 1994; Storeheier *et al*., 2002). Increased protein nutrition in the winter can help maintain carcass mass (Mathiesen *et al*., 2000; Storeheier *et al*., 2002) and could explain the high productivity and high antler growth of St. George reindeer.

<u>Diet comparison with Alaska continental population</u>

Continental reindeer populations in Alaska, such as those on the Seward Peninsula, demonstrate seasonal diet similarities and differences compared to the St. George Island population. Lichens dominated the annual diet of both St. George Island and the Seward Peninsula reindeer, supporting other work demonstrating that lichen is a preferred forage. Both populations also had a large percentage of moss in the spring diet

(Davis herd 10.4 ± 1.1 S.E., Gray herd 8.6 ± 1.3 S.E. and St. George Island 12 ± 6.9 S.E. respectively) (Finstad, 2008). However, the St. George Island herd showed much higher seasonal variability in the diet. The top three diet components of the Seward Peninsula population were lichens, sedges, and shrubs in all seasons (Finstad, 2008). Although sedges were a major part of the diet of the St. George Island herd in July and in the fall, mosses, grasses, and forbs occurred at much higher percentages than for the Seward Peninsula population and at differing percentages among seasons. This variation is likely a result of differences in the vegetation communities available to the reindeer.

Diet comparison with other island populations

Caribou and reindeer are considered to be the most versatile feeders in the cervid family (Skoog, 1968; Bergerud, 1974). Mathiesen *et al*., (1999) found the gastro-intestinal tract (GIT) was extremely plastic and highly adaptive based on his comparison of diets of South Georgia (graminoid diet year-round) to Norwegian (lichens in winter; diverse in summer) reindeer. One commonality across most island populations is the amount of moss in the winter diet (Thomas & Edmonds, 1983; van der Wal *et al*., 2001). On islands that had little to no lichen, the summer diets of *Rangifer,* in general, were dominated by willows (shrubs), grasses, sedges, and forbs (Orpin *et al*., 1985; Adamczewski *et al*., 1988; Leader-Williams, 1988-first cited by Thing, 1984). However, if lichens are available, they are the preferred forage (Pegau, 1968). Because St. George Island has lichens, they are preferred and remain a large percentage of the diet.

Angelica lucida

When *Angelica lucida* was found in a fecal sample, it made up an average of 66% (± 4% S.E.) of the forbs in the diet, which appears to be a preferred forb. This analysis likely underestimates the true amount of *Angelica lucida* in the diet because it is based on epidermal tissues of the taproot and not the whole structure. On average, *Angelica lucida* was most prevalent in fecal samples during the spring and early summer months. Similar behavior of *Rangifer* feeding on rhizomes has been documented elsewhere. For example, Bergerud *et al.* (2008), in Canada, observed caribou cows digging up green rhizomes of graminoids in June.

If the surface to volume ratio were used to adjust the fecal results, *Angelica lucida* could account for up to 74.4% of the total diet with an assumption that the non-epidermal and epidermal layers are equivalent in digestibility. Based on the adjusted values, *Angelica lucida* would form over half of the diet in May and June of 2008 (61.7% and 52% respectively). Because relative digestibility of non-epidermal and epidermal layers is not known, these estimates cannot be validated. However, given the very small surface to volume ratio, it is plausible that a microhistological analysis of a fecal sample underestimates *Angelica lucida* in the diet and further investigation is suggested.

Angelica lucida minerals and energy

In general, nutritional values of *Angelica lucida* taproot were higher than lichens in minerals, expect for Mn. Phosphorus, K, Mg, Na, and Fe were more than five times higher in the taproot than in lichens (Table 2.7). Minerals provided by puchki may help support maintenance requirements throughout the winter.

Crude protein, P, and Ca, are the major nutrients that aid in the growth of the animal (Robbins, 1993). For an average reindeer weighing 100 kg and gaining 100 g/d (based on monthly weights of reindeer at the UAF Experimental Reindeer Research Farm, unpublished) *Angelica lucida* exceeds the published CP values (8%) for maintenance and growth of a young and growing reindeer (NRC, 2007). Although higher CP is recommended for reindeer grown in an intensive production setting (12-18%, RRP, unpublished) free-ranging reindeer probably subsist on a lower CP diet. Although puchki has, on average, lower CP than these recommendations it is higher than some other available forage such as *Empetrum* spp. (4.6%), *Bryophyta* spp. (6.7%), and lichens (2.5%) (Person *et al.*, 1980; Staaland *et al*., 1983; Ahman & Ahman, 1984). However, more commonly used forage species have higher CP values, such as *Salix* spp. and *Poa* spp. (26% and 30%, respectively) (Finstad, 2008), suggesting that puchki may not enhance protein nutrition in reindeer.

Phosphorus and calcium are major minerals used in bone, teeth, lacation, and antler production. Puchki, in the spring, contained 0.49% P which is similar in content to other forbs found in Alaska (Klein, 1990). Puchki has a higher P content than grass, *Arctagrostis latifolic* (0.40%), *Carex spp*. (0.23%), and forb, *Hippuris vulgaris* (0.35%) (Finstad, 2008). Higher concentrations of P can be found in shrubs, including *Salix pulchra* (0.72%) and a forb, *Equisetum arvense* (0.70%). However, these species are not abundant on St. George Island. The Ca content of puchki was not significantly different in the spring and fall (0.45%, 0.44%, respectively), but it is greater than concentrations in other reindeer forages (*Carex aquatilis* (0.15%) (LeResche & Davis, 1973), grasses

(0.01%), mosses (0.02%) (van der Wal & Lonnen, 1998), lichen, *Cladonia mitis* (0.11%) (Scotter, 1972), and shrubs (*Vaccinium* and *Empetrum*) 0.44% (Ahman *et al*., 1986)). Although Ca is not generally limiting, puchki meets the required Ca levels (0.16%) for adult beef cattle (NRC, 1970). Based on the P and Ca levels, puchki could be an important winter forage in the maintenance of the animal's mineral-balance.

The highest percentage of puchki found in the reindeer diets occurred during the spring months. Based on personal observations, this plant was one of the first plants to emerge. In general, CP and mineral concentrations were highest in puchki taproot during the spring months when consumption was highest. CP was significantly higher (12.12%) during this time when energy requirements are at their peak.

Although puchki may contribute favorably to overall mineral and protein balance in reindeer, it may be most valuable as an energy source during winter, when reindeer are likely to be energy limited (Boertje, 1981). If lichens become overgrazed on St. George Island, reindeer could shift to *Angelica lucida* as an alternate winter forage. Based on puchki's energy levels and the substantial biomass on the island, the reindeer population would not be limited by the winter forage. This represents a notable advantage over many other island and continental populations.

Angelica lucida biomass

A conservative estimate of 344,000 kg of dry taproot biomass is available as forage on St. George Island. This estimate is conservative because it only accounts for the presence of *Angelica lucida* in 12 of the 22 ecological sites. This species is known to occur on at least 4.11 km^2 of the remaining ecological sites based on the NRCS ecological site map. An estimated additional 21,800 kg of dry taproot could be available, based on average number of plants per transect on all ecological sites, representing a valuable forage resource on St. George Island.

Island management implications

Based on 2007/2008 lichen biomass on St. George Island, and the amount of lichen being consumed throughout the year, the recommended total number of reindeer for the island was estimated at 161 (see chapter 3). According to the NRCS, lichen stands on parts of the island are overgrazed and the herd is expanding its range to the western side of the island where lichen is more abundant (Sonnen, 2004). Much of the western tip is owned by the U.S. Fish and Wildlife Service (USFWS), which wants to preserve the habitat and its diversity. According to Chris Merculief (St. George Traditional Council President) a 9.65 km, 2.44 m high permanent fence is under construction as of fall 2010 around areas identified by the NRCS as "extremely overgrazed" (Sonnen, 2005), and planning is underway for a fence around USFWS land on the western end. This will greatly reduce the amount of lichen available to the reindeer on the island. The current reindeer diet includes high proportions of lichens year-round. However, we believe once the lichens become overgrazed on the island, the reindeer may shift their winter diet to an alternate winter forage, specifically *Angelica lucida*, because it is available and appears to be highly nutritious. There have been numerous studies conducted on islands that indicate that lichens are not necessary for a productive, healthy herd. Examples of this can be seen on South Georgia, Greenland, Svalbard, Western Queen Elizabeth's Islands, and St. Paul Island (Scheffer, 1951; Thomas & Edmonds, 1983; Thing, 1984; Leader-Williams, 1988;

Staaland *et al.*, 1993; USDA-NRCS 2007, unpublished report). We propose that the availability of other forage rather than just lichen during the winter should be included in reindeer management plans.

St. George Island reindeer consume a unique diversity of forage throughout the year. In order to match the nutritional requirements of the reindeer to their forage, management should move the animals to the highest quality pastures available. Large antler production can be attributed in part to the high concentrations of CP and minerals (P and Ca) found in the grasses and forbs they are selecting in the spring and summer months. Puchki may also be providing nutrients to support early antler growth in spring before green-up. Ecological sites that contain high production of these species include Forb Tundra, Grassy Tundra, and Coastal Tundra along with Crowberry Forb, Crowberry Forb/Forb Tundra, Crowberry Forb/Grassy Tundra, Crowberry Lowland, Forb Tundra/Crowberry Forb, Moss Willow, and Rocky Crowberry Upland. Major areas of the island that contain high amounts of forbs and grasses include the southern end, areas around the airstrip and Maynard Hill, and scattered patches on the southeastern end of the island. Therefore, locating reindeer on these sites or ensuring access to these areas may help support the production of large antlered animals.

There was a significant increase in the percentage of sedges found in the fall diets. This is likely due to the high energy content in the sedges (Larter & Nagy, 2001) which aid in continued fat deposition. There are a few small ecological sites scattered along the southern coast that contain predominately sedges (Upland West Sedge and Wet Sedge

Lichen). Movement of reindeer to these areas will provide access to forages that support fat deposition.

Reindeer should be restricted from winter lichen ranges during the summer months. Movement of reindeer to areas of high lichen availability should occur in the fall and winter months. Ecological sites that contain lichens include Rocky Crowberry Upland, Rocky Crowberry Upland Steep, Boulder Mixed Tundra, and Crowberry Lowland, which are located primarily along the middle of the island. Therefore movement of animals to these areas would allow them access to the preferred winter forage.

This grazing management plan matches reindeer nutritional needs with available forage resources. Although it requires active management, we believe it will be effective in optimizing production while maintaining forage resources and will benefit stakeholders.

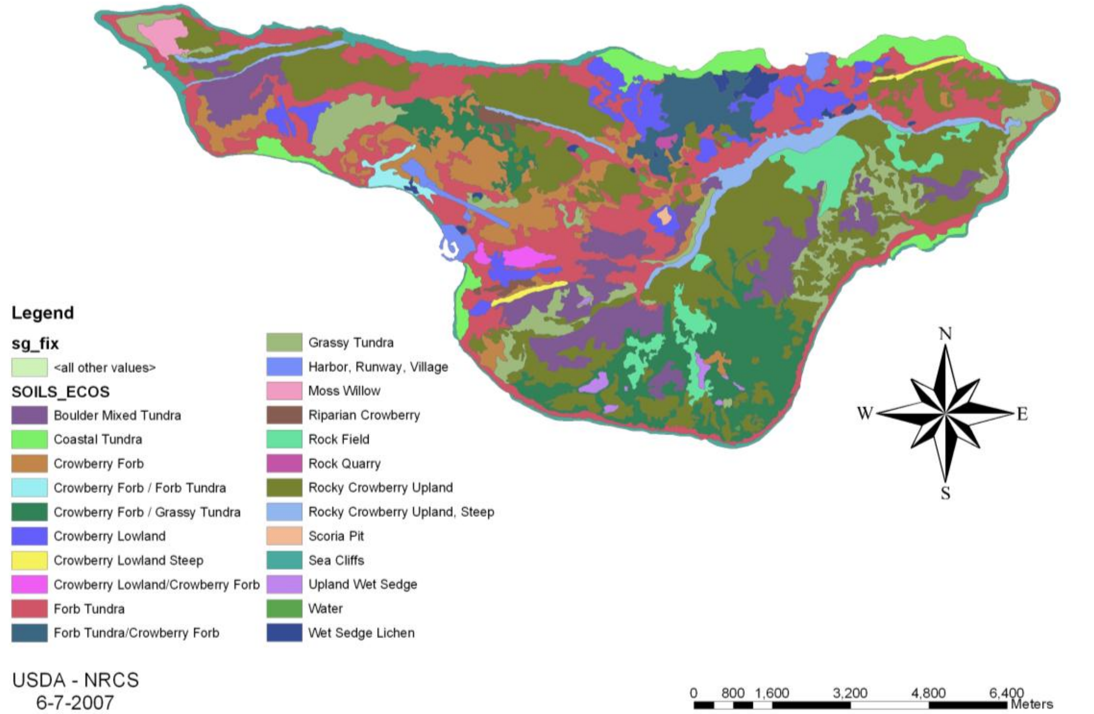

Figure 2.1 Location of ecological types on St. George Island, Alaska as described by the NRCS in 2007 (USDA-NRCS, 2007).

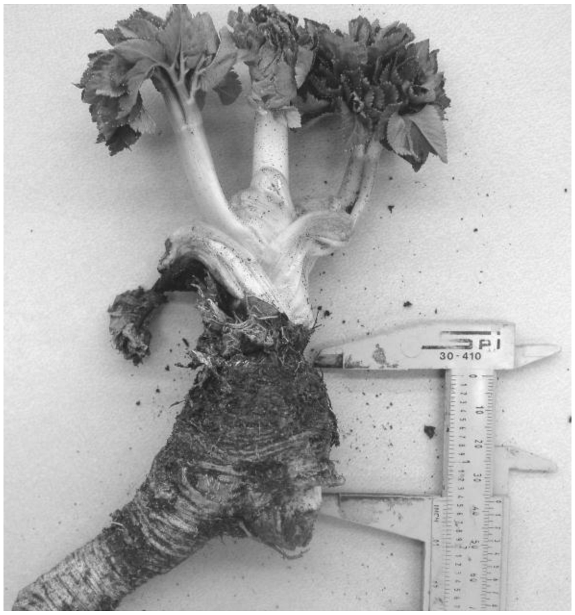

Figure 2.2 ***Angelica lucida*** **taproot demonstrating measurement to the natural breaking point.**

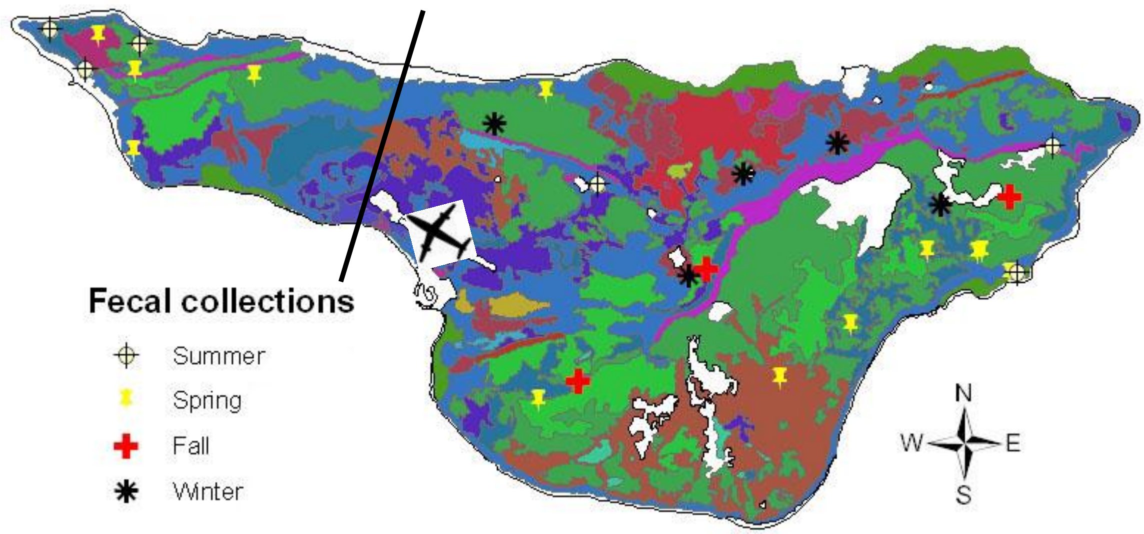

Figure 2.3 Seasonal fecal collection locations on St. George Island, Alaska. The line represents the division of the east and west regions of the island.

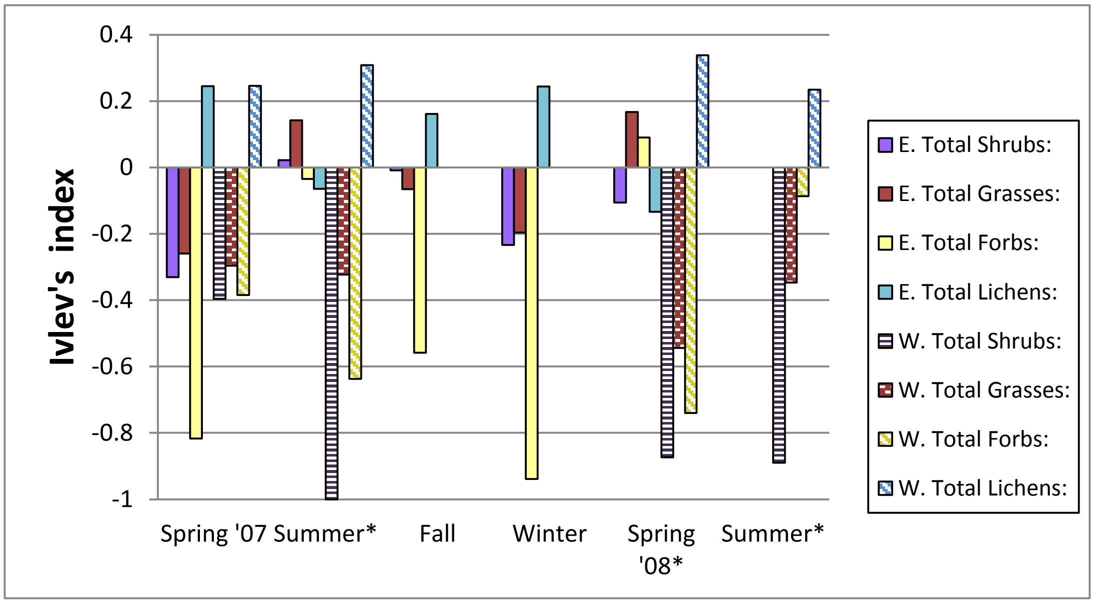

Figure 2.4 Seasonal forage preference of reindeer on St. George Island, AK from spring 2007-summer 2008, using forage availability estimates for the east or west side of the island as appropriate.
***Only one composite sample collected on the west side.**

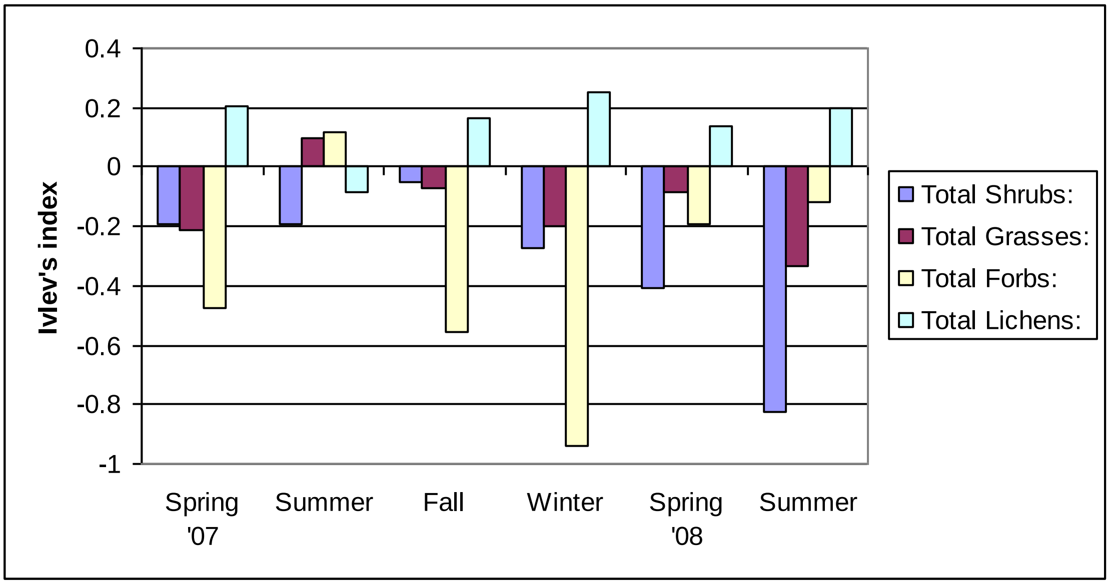

Figure 2.5 Seasonal forage preference of reindeer on St. George Island, AK from spring 2007-summer 2008, using forage availability estimates for the entire island.

Table 2.1 Area and percentage of the island classified as each NRCS's ecological type for St. George Island, Alaska.

Ecological type	km^2	percentage of island
Rocky Crowb.Upland	21.97	24.4%
Forb Tundra	17.19	19.1%
Crowb. Forb/ Grassy Tundra	8.33	9.3%
Boulder Mixed Tundra	7.85	8.7%
Crowb. Forb	5.99	6.7%
Grassy Tundra	5.72	6.4%
Crowberry Lowland	3.70	4.1%
Coastal Tundra	3.11	3.5%
Sea Cliffs	2.73	3.0%
Forb Tundra/ Crowb. Forb	2.92	3.2%
Rocky Crowb.Upland Steep	2.41	2.7%
Wet Sedge Lichen	0.64	0.7%
Riparian Crowb.	0.52	0.6%
Moss Willow	0.51	0.6%
Crowb. Lowland/ Crowb. Forb	0.40	0.4%
Upland Wet Sedge	0.35	0.4%
Crowb. Lowland Steep	0.34	0.4%

Table 2.2 Seasonal diet composition (%) for reindeer on St. George Island, AK (means ± S.E.). Comparisons of forage categories across seasons *p< .05.

	Shrubs	Grasses	Sedge/Rush	Forbs	Lichens	Mosses
#Spring 2007	4.9 ± 1.5	8.8 ± 1.7	5.6 ± 1.2	6.8 ± 1.9	64.9 ± 4.0	8.9 ± 1.5
n	12	12	12	12	12	12
Summer	4.8 ± 0.3	14.1 ± 6.4	6.7 ± 2.3	16.2 ± 3.4	51.3 ± 4.1	6.9 ± 3.1
n	12	12*	12	12*	12	12
Fall	5.9 ± 1.4	3.5 ± 1.1	12.9 ± 4.0	5.2 ± 2.9	58.2 ± 9.4	14.1 ± 2.6
n	9	9	9*	9	9	9
Winter	3.9 ± 2.3	5.8 ± 3.3	3.1 ± 1.8	0.6 ± 0.3	66.2 ± 5.2	20.4 ± 11.8
n	13	13	13	13	13	13*
Spring 2008	2.6 ± 1.8	13.5 ± 7.1	2.8 ± 2.7	11.7 ± 8.8	57.3 ± 27.4	12.0 ± 6.9
n	10	10*	10	10*	10	10
#Summer	0.7 ± 0.7	8.7 ± 2.0	1.9 ± 0.6	15.5 ± 4.8	66.8 ± 47.3	6.5 ± 1.3
n	3	3	3	3	3	3

contains data for only one month: spring is May; summer is June

Table 2.3 *Angelica lucida* taproot dry weight for 12 ecological types on St. George Island, Alaska.

Ecological type	Total area km^2	Total taproot biomass (kg)* (S.E.)
Boulder Mixed Tundra	7.85	2.05 (.00)
Crowberry Forb	5.99	28.83 (.02)
Crowberry Forb/ Forb Tundra	0.43	1.54 (.05)
Crowberry Forb/ Grassy Tundra	8.33	35.85 (.01)
Crowberry Lowland	3.70	19.73 (.03)
Rocky Crowberry Upland	21.97	67.35 (.01)
Rocky Crowberry Upland Steep	2.41	9.11 (.02)
Forb Tundra	17.19	100.91 (.02)
Wet Sedge Lichen	0.64	2.22 (.06)
Grassy Tundra	5.72	39.28 (.01)
Moss Willow	0.51	6.38 (.06)
Coastal Tundra	3.11	30.90 (.02)
	Total	**344.14**

* total taproot expressed in thousands

Table 2.4 *Angelica lucida* taproot fiber and lignin content by season (means ± S.E.). * indicates seasons are significantly different p<.01 A indicates no significant differences between two seasons.

	Mean %NDF	Mean %ADF	Mean % lignin
Summer	19.3 ± 1.7	14.1 ± 1.5	3.7 ± .4
n	15*	15*	15*
Fall	36.8 ± 2.5	29.8 ± 2.2	8.1 ± .6
n	19*	19*	19_A
Spring	29.4 ± .9	22.8 ± .83	7.2 ± .5
n	22*	22*	22_A

Table 2.5 Percentage of nutrient values found in *Angelica lucida* by season (means ± S.E.). Different subscripts indicate significant difference between seasons (p< .01).

	% CP	%P	%K	%Ca	%Mg	%S
Spring	12.12 ± .65	.49 ± .05	1.40 ± .08	.45 ± .03	.36 ± .02	.14 ± .01
n	10_{A}	10_{A}	10_{AB}	10_{A}	10_{A}	10_{A}
Summer	7.48 ± .49	.21 ± .02	1.19 ± .05	.20 ± .02	.22 ± .01	.10 ± .01
n	16_{B}	16_{B}	16_{A}	16_{B}	16_{B}	16_{B}
Fall	6.91 ± .27	.26± .02	1.52 ± .10	.44 ± .03	.41 ± .03	.11 ± .00
n	18_{B}	18_{B}	18_{B}	18_{A}	18_{A}	18_{B}

Table 2.6 Nutrient concentration of *Angelica lucida* taproot by season (means ± S.E.). Different subscripts indicate significant difference between seasons ($p < .05$).

	Na ppm	Cu ppm	Zn ppm	Mn ppm	Fe ppm	Co ppm
Spring	1955.30 ±182.99	6.35 ± .40	50.00 ± 4.59	86.30 ± 13.49	707.30 ± 180.38	.53 ± .10
n	10_A	10_A	10_A	10_A	10_A	10_A
Summer	737.56 ± 108.07	3.99 ± .34	19.44 ± 2.53	61.56 ± 7.15	628.06 ± 178.44	.49 ± .09
n	16_B	16_B	16_B	16_A	16_A	16_A
Fall	2267.11 ± 268.83	6.46 ± .76	28.17 ± 2.32	60.67 ± 7.25	368.00 ±163.84	.52 ± .18
n	18_A	18_A	18_B	18_A	18_A	18_A

Table 2.7 Mean nutritional values of *Angelica lucida* taproot and preferred reindeer lichens (means ± S.E.).

	CP%	P%	K%	Ca%	Mg%	Na%	S%	Cu ppm	Zn ppm	Mn ppm	Fe ppm
A. lucida	**8.30 ± .40**	**0.30 ± .02**	**1.37± .05**	**0.36±.02**	**0.33 ±.02**	**1640.05±160.99**	**0.11±.00**	**5.54 ±.38**	**29.95±2.40**	**66.82 ± 5.12**	**539.68± 102.09**
n	44	44	44	44	44	44	44	44	44	44	44
Lichen	**~2.5 ***	**0.05 ±.00**	**0.13±.02**	**0.26 ±.18**	**0.04 ±.00**	**241.88 ±85.59**	**0.03 ±.01**	**1.16 ±.06**	**15.89 ± 1.72**	**83.38 ±19.56**	**104.38 ±18.03**
n		8	8	8	8	8	8	8	8	8	8

*Person *et al.*, 1980

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3 Recommended stocking density of reindeer (*Rangifer t. tarandus)* based on standing crop of lichen on St. George Island, Alaska

Abstract

In 1980, 15 reindeer (*Rangifer t. tarandus*) were re-introduced to St. George Island, in the Bering Sea. The population grew to approximately 100 animals by 1991 and peaked in 2004 at approximately 450-500 animals. Declining lichen stocks has led to concerns of overgrazing with stakeholders calling for a reduction in herd numbers. The objectives of this study were to estimate reindeer stocking density based on current reindeer demographics, lichen demand, and total lichen biomass available for grazing. In spring of 2007 the population was 290 reindeer and increased to 320 reindeer in 2008. Calf:cow ratio increased from 48:100 in 2007 to 57:100 in 2008. Diet composition estimated by analysis of feces was 51% and 66% lichen in summer and winter months, respectively. We estimated the total lichen biomass for the entire island at ~5.4 million kg of dry matter, and recommended that the population be reduced to 161 reindeer or a density of 1.8 reindeer/ km^2 to conserve winter lichen ranges.

Introduction

Stocking density directly affects ungulate productivity, including calf production and animal weight gain. In general, ungulate performance decreases as stocking density increases. Animal productivity is maximized at low stocking density, but productivity per acre is maximized at moderate stocking density (Holecheck *et al*., 2004; Figure 3.1). High stocking densities can have long-term negative impacts on the forage base, which can decrease forage production and increase the unfavorable forage species, further decreasing animal production (Holecheck, 2002). As a result, stocking density can be the most important management decision a manager can make (White & McGinty, 1992) and optimal stocking density is ultimately dependent on the production of total usable forage on the range and the total forage demand of specific herbivores (Holecheck *et al*., 2004). Therefore a manager's goal becomes to manipulate animal density that either maintains vegetation species composition of the range or increase quality and quantity of targeted range species.

Winter range is often thought to be the limiting factor in the production and growth of reindeer populations. During the winter months lichens are the preferred food source for reindeer and caribou, and the quantity available for grazing is largely thought to determine carrying capacity (Pegau, 1970; Gaare, 1986; Kumpula *et al*., 2000). Body weight, calf production, and mortality can all be influenced by available forage on the winter range (Skogland, 1983; Kumpula & Nieminen, 1992; Kojola *et al*., 1995; Kumpula *et al*., 1998; Weladji *et al*., 2002).

Currently, two U.S. agencies, the Natural Resources Conservation Service (NRCS) and the Bureau of Land Management (BLM) make stocking density recommendations for reindeer in Alaska based on quantity of winter lichen (BLM, 2007). Range assessments, in conjunction with information on population size and structure, are key tools in understanding grazing condition and capacity (Holecheck *et al.*, 2004). In Alaska, the NRCS conducts rangeland assessments for reindeer owners and managers to enhance rangeland management (NRPH, 1997). For example, in 2002, Tanaq Corporation approached the NRCS with concerns that reindeer were overgrazing lichens on St. George Island, Alaska. The NRCS conducted a lichen utilization survey that year to estimate current lichen stocks and off-take rates in order to assist in development of a reindeer range management plan.

St. George Island reindeer management

In 1911, the United States government placed 15 reindeer on St. George Island (56^o 36’ N, 169^o 32’ W), in the Bering Sea to provide the Native people with a sustainable food source. The reindeer population peaked at 222 animals in 1922 but then rapidly declined to 60 individuals by 1926, and was extirpated by over hunting by 1950 (Scheffer, 1951). In 1980, 15 reindeer were re-introduced from Umnak Island, forming the existing herd (Swanson & Barker, 1992).

Reindeer population numbers on St. George Island were recorded annually by the Alaska fur-seal industry from the introduction (1911) until the extermination (1950) (Scheffer, 1951). Since the re-introduction in 1980, population estimates have been conducted by several entities at varying times of the year. However, there has never been a complete census (age, sex, recruitment rates) conducted on the St. George Island reindeer herd since 1980.

Range assessment by the NRCS

The NRCS has classified the landscape on St. George Island according to ecological site classification system. These classifications are based on plant communities, physical, climatic, geomorphic and hydrologic features, plant community dynamics, annual production estimates of plants, and soil types (NRPH, 1997). Vegetation species composition and annual production is estimated for each ecological site. Each ecological type is unique and classifies the landscape for monitoring, assessment, and management of rangelands (NRPH, 1997).

Lichen ranges were assessed after the loss of the reindeer on St. George Island in 1950 and were concluded to be in good condition (Scheffer, 1951). Reassessment in 1991 found the lichen ranges to be in “excellent condition” (Swanson & Barker, 1992). However, in 2002, the NRCS repeated these assessments, prompted by concerns about range condition, and found that the lichen on the southeastern side of the island was heavily grazed. It was also noted that because of poor grazing conditions, reindeer were crossing to the ungrazed west side of the island where grazing conditions were estimated to be excellent (Sonnen, 2004). Two years later, when the reindeer population was approximately ~450-550 animals, a follow-up survey found areas of continued reduction in lichen stocks. Areas on the west side of the island that showed “no use” in 2002, showed “some” to “moderately heavy” use in 2004 (Hulvey, 2004).

Following declines in range condition the NRCS recommended the herd size be reduced to 100-150 individuals (Sonnen, 2004). In August of 2005, the NRCS continued surveys and found an even more noticeable change in lichen biomass on the west side of the island. Areas that had not been grazed since the original herd died out 55 years prior showed signs of use (Sonnen, 2005). Areas estimated to contain 1,500 pounds of lichen biomass per acre (1680 kg/ha) in 2002, declined to roughly 700 pounds per acre (783 kg/ha) in 2005. The NRCS range specialists concluded that reindeer had expanded their range onto the U.S. Fish and Wildlife Service (USFWS) land on the western peninsula in response to heavy use and decreased lichen biomass elsewhere on the island (Sonnen, 2005). In 2007, another NRCS range assessment showed further increases in lichen utilization and the NRCS recommended the herd size be reduced to 80-100 individuals (Sonnen, 2007 pers. comm.).

Land ownership

St. George Island has three major land owners. Tanaq Corporation is a Native organization that owns the reindeer and the majority of the land. The National Oceanic and Atmospheric Administration (NOAA) owns the coastal areas that encompass the seal rookeries. The U.S. Fish and Wildlife Service (Alaska Maritime National Wildlife Refuge) owns the lands on the outer edges of the island, including the western tip (Figure 3.2).

Significance

Stakeholders on St. George Island are concerned that the reindeer are beginning to overgraze lichen on parts of the island. They would like to reduce the herd to a sustainable population so they can continue to harvest both for subsistence and commercial use. St. George Traditional Council approached the University of Alaska Fairbanks Reindeer Research Program (RRP) to consult on development of a husbandry and range management plan, including stocking density and culling regime. The U.S. Fish and Wildlife Service (USFWS) is also concerned about the expansion of reindeer onto USFWS managed lands on the western peninsula. The USFWS management goal on St. George Island is to preserve the wildlife and habitat (USFWS, 2008). The range expansion and use of the western peninsula by reindeer conflicts with this objective since reindeer are considered a non-indigenous species.

Objectives

The purpose of this study is to estimate a culling strategy and recommended stocking density for St. George Island based on current lichen availability and off-take rates to fulfill the request made by St. George Traditional Council. The objectives of this study are to: 1) determine the age class (calves, yearlings, adults), sex ratios and recruitment rates of the reindeer population in 2007 and 2008; 2) estimate annual lichen consumption; 3) estimate available lichen biomass; and 4) estimate stocking density based on useable winter forage.

Study Site

St. George Island (~91 km^2) is located in the Pribilof Islands in the Bering Sea (56^o 36’ N, 169^o 32’ W). Approximately 100 people currently inhabit the island (U.S. Census Bureau, 2010). The island has only one 9.6 km road connecting the village to the airport; the rest of the island is only accessible by foot. Elevation varies from sea level to 366 m. Vegetation consists of forbs and grasses in the lowlands to rocky lichen outcroppings at higher elevations. The NRCS has identified 22 ecological sites on the island that contain over 100 species of plants and include ten species of lichen (USDA-NRCS, 2007). Based on the species composition of the entire island, lichens dominate the island (48%), followed by graminoids (23%), forbs (21%), and shrubs (8%) (USDA-NRCS, 2007).

Methods

Herd demographics

During May and early June of 2007 and 2008, we determined sex and age composition of the reindeer population via visual observation aided with a spotting scope or binoculars. Sex and age were determined by presence/absence of a dark vulva patch and body and antler size. Age classes were recorded as calves, yearlings, or adults, and sex classes as bulls or cows. The recruitment rate was defined as the calf:cow ratio during the spring months. Island geography allowed most parts of the island to be viewed from a central ridge, which was traversed during each survey. Areas not visible from the ridge were checked to ensure a complete census. The herd counts were done as often as possible within a two week period, weather permitting and we used the maximum count as the final count for that period.

Seasonal lichen composition

Fecal samples were collected opportunistically at least once per month from May 2007 to May 2008. A composite sample was collected for every 10 reindeer within a group, up to a maximum of three composites per group. Each composite sample consisted of 6 pellets from 10 different fecal piles, for a total of 60 pellets per sample. To prevent repeated sampling from the same pile, each pile was marked by flattening the pellets after collection. Fecal pellets were frozen until they could be cleaned of all non-fecal contaminants and dried at 60ºC for 48 hours. Once dried, all fecal samples were sent to the Wildlife Habitat Laboratory, Washington State University, for a microhistological 50 view, level A diet composition analyses. This analysis estimated diet composition based on identification of plants at the genus and species level.

Estimate of lichen biomass

The NRCS classified the vegetation communities on St. George Island into 22 different ecological types (Sonnen, 2005; Figure 3.1). Of the 22 ecological types, 2 are lichen specific, 7 contain both lichen and *Angelica lucida* (puchki), and the remaining 13 contain neither lichen nor puchki. We estimated live lichen biomass on all ecological sites that contain lichen (Figure 3.1).

Each ecological site (an area composed of a single ecological type) was converted into a polygon in a geographic information system (GIS) by the NRCS. The polygons were stratified by ecosite type and strata containing *Angelica lucida* and/or lichen were randomly sampled. A coordinate method using pace counts was used to determine random transect locations within each ecological site. A random computer generated bearing was determined, and at least six 100 m transects were laid in each individual ecological site. Initial sampling (38% of total transects) included 10 transects per ecological site. However, after conducting a bootstrap statistical analysis, a randomization test, on the initial data, 6 transects were determined to be statistically sufficient, therefore subsequent sampling included only 6 transects per ecological site.

We randomly placed ten 50 cm x 50 cm sampling plots (0.25 m^2) along each 100 m transect at random locations (Moen *et al*., 2007). At each plot, we oriented a sampling frame parallel to the ground using adjustable legs on its corners. At each of the 25 equally spaced intersections in the sampling frame, we placed a ruler perpendicular to the ground at the base of any intersecting live lichen and recorded height to the nearest 0.5 cm. Only five species of fruticose lichens preferred by reindeer were measured: *Cladina stellaris, C. rangiferina, C. arbuscular, Cladonia uncialis,* and *Flavocetraria cucullata* (Pegau, 1968; Danell *et al*., 1994; Brodo *et al*., 2001; USDA-NRCS, 2007). We estimated total lichen biomass (in dry matter) for each plot following Moen *et al.* (2007):

$$y = x28.39, \qquad (1)$$

where

y = total average biomass per frame (dry matter, g/0.25 m^2)

x = average lichen height per frame;

28.39 = a constant based on lichen biomass per cm of height (Moen *et al*., 2007).

We defined the average lichen biomass per sampling plot (i.e. per 0.25 m^2) for each site as the average across the 10 sample plots per transect and across all transects in that site. We calculated a weighted mean lichen biomass per plot for each ecological type as the sum of the mean biomass per 0.25 m^2 per site times the area of that site as a proportion of the total area of the ecological type. We calculated total lichen biomass for an ecological type as the weighted mean lichen biomass per plot multiplied by the total area of that ecological type, divided by 0.25 m^2:

$$TB_i = z_i \times A / 0.25\ m^2, \qquad (2)$$

where

TB_i = total lichen biomass per ecological type (dw, g)

z_i = the overall weighted mean lichen biomass per 0.25 m^2 for ecological type $_i$

A = the sum of the area (m^2) of all ecological sites for ecological type $_i$

<u>Stocking density</u>

We defined the total useable lichen per year as the overall total lichen standing crop (kg) multiplied by an annual production rate. Production rate of lichen varies from 3-11.6% (Kumpula *et al*., 2000); we used a conservative estimate of 3%. We then multiplied annual standing crop production by 50% (lichen available to grazing without decreased production) to obtain the total kg of available lichen for reindeer grazing (Gaare, 1986; Ogle & Brazee, 2009).

Reindeer consume 3.3% of their body weight of dry matter in summer, and 1.5% in winter (Reindeer Research Program unpublished). Annual consumption rate of lichen for reindeer was estimated based on the percent of lichen in the reindeer's diet during summer and winter months, adjusted for length of season, average body weight, and intake.

Thus, we calculated summer and winter forage demand per reindeer per year as:

$$F_s = w \times bw_s \times c_s \times d_s \qquad (3)$$

where

F_s = forage demand (kg dry matter per reindeer) in season *s* (summer or winter)

w = average reindeer weight (82.82 kg) (Finstad & Prichard, 2000)

bw_s = daily dry matter intake in season *s* (3.3% summer; 1.5% in winter)

c_s = percent of lichen in the reindeer diet in season *s*

d_s = number of days in season *s* (165 days for summer; 200 for winter)

Next, we summed the summer and winter forage demands to obtain total forage demand/ reindeer/year, Tfd.

Finally, we estimated the recommended stocking density as:

$$D = Tl / Tfd \qquad (4)$$

where

D = Recommended stocking density

Tl = Total available lichen biomass based on production and use (kg)

Tfd = total forage demand/ reindeer/ year (kg)

Results

Demographics

In the spring of 2007 we observed a maximum count of 290 reindeer: 120 adult cows, 75 adult bulls, 17 yearling cows, 12 yearling bulls, and 66 calves. The calf:cow ratio was 48:100 and herd density was 3.2 animals per km^2 for the entire island. We observed an increase in the number of reindeer in the spring of 2008 with a maximum count of 320 reindeer: 120 adult cows, 47 adult bulls, 33 yearling cows, 32 yearling bulls, and 88 calves. The calf:cow ratio increased to 57:100 and the herd density was 3.5 animals per km^2 (Table 3.1).

Seasonal lichen composition

Based on microhistological analysis we found an average of 66% (± 5% S.E.) of the reindeer diet was composed of lichen during winter months (Dec., Jan., Feb., and March) and 51% (± 4% S.E.) during the summer months (June and July). For additional details of the seasonal diet analyses see chapter 2.

Total lichen biomass

We established a total of 219 transects throughout the island. The total estimated lichen biomass for the entire island, including USFWS land, was 5.698 million kg of dry matter (256 kg/acre) (Table 3.2). Excluding USFWS land, lichen biomass for the remainder of the island was 4.236 million kg (190 kg/acre) (Table 3.3), thereby reducing the available dry matter for grazing by roughly one quarter.

Stocking density

The recommended stocking density based on available lichen including USFWS land was 2.4 animals/km^2, or a total of 217 reindeer for the entire island. Excluding the available lichen on USFWS land the recommended stocking density was 1.8 animals/km^2, or 161 reindeer. We recommend the overall stocking density excludes USFWS land because reindeer grazing is not consistent with the USFWS's management objectives. Therefore, we would propose maintaining a herd size of 161 reindeer on St. George Island.

Discussion

Historically, management for reindeer has been based on the number of individuals the winter lichen range could support. Because lichens are fragile and slow-growing, they are considered the limiting factor when determining stocking density (Stern *et al*., 1980). Once grazing pressure exceeds lichen production, overgrazing occurs. The results of this study suggest the current reindeer population is consuming lichen at a rate higher than annual lichen production thus causing a decline in lichen productivity.

In 2008, the population was 320 animals. In general, the animals observed appeared to be in good body condition. However, based solely on lichen availability, we recommend the population to be reduced to a total population size of 161 animals. Initially, 160 animals will need to be culled to maintain the current lichen standing crop on St. George Island. If management objectives are to continue a harvest of roughly 30 animals per year (10 subsistence, 20 trophy animals), then at least 60 or more of the remaining population will need to be adult females to produce those 30 offspring per year (based on observed reproductive success rate). If however, less than 30 animals will be harvested per year, a higher proportion of the culled population should be adult females in order to reduce the reproductive potential of the herd. The optimal bull:cow ratio is 1:15-20 (RRP, unpublished data). However, if managers are interested in continued harvest of trophy bulls, fewer bulls should be culled. In all cases, harvest/ culling should occur annually to keep the population at the recommended density.

After a culling regime reduces the population so that lichen production meets or exceeds consumption, further management of lichen pastures is recommended. A rotational grazing system would prevent overuse of lichen patches by limiting seasonal use to specific patches while other patches are allowed to recover. While this approach requires active management, it would prevent overgrazing, which can lead to changes in vegetation composition as lichen mats are replaced with vascular plants (Klein, 1987) and would ensure that the lichen ranges on St. George Island remain healthy and available for grazing.

Studies have shown that reduced availability of lichens leads to an increase in alternate forage such as vascular plants and mosses in reindeer diets (Klein, 1968; Skogland, 1984; Klein, 1990). However, alternative forage consumption during the winter may have negative effects on reindeer. Skogland (1985; 1990) found that a smaller proportion of lichen in the diet of Norwegian reindeer was related to higher neonatal mortality rates, and led to smaller body size and reduced fat reserves in adult reindeer.

Kojola *et al*. (1998) found “lower-ranking, coarser foods” increased tooth wear and resulted in a smaller body size in adult females.

Although these studies suggest that consuming forage other than lichen during winter can have negative effects on reindeer, other populations consuming non-lichen forages show no effects (Skoog, 1968; Bergerud, 1974). For example, the winter diet of South Georgian reindeer consists almost exclusively of *Poa flabellate*, a native grass of this sub-Antarctic island (Leader-Williams, 1988). When lichens became overgrazed, Icelandic reindeer selected alternate forage, including vascular plants such as dicotyledons, and bryophytes such as mosses in winter (Leader-Williams, 1988- first cited by Egilsson, 1983). Currently St. George Island reindeer are consuming small amounts of *Angelica lucida* and grass (see chapter 2) during the winter months, which may be providing supplemental winter nutrition. Therefore, if lichens continue to decrease these forages could be used as alternate winter forage.

Basing stocking density on lichen production assumes reindeer numbers and forage production are balanced. However, some researchers question whether management practices, especially on islands, are even relevant when there seems to be a non-equilibrium relationship between the animals and their forage (Tyler, 1987; Behnke, 2000; Solberget *et al*., 2001; Gunn *et al*., 2003; Miller *et al*., 2005). Behnke (2000) first addressed arctic grazing systems as a non-equilibrium system between the consumer and forage resource. He suggested there are three abiotic factors that cannot be controlled which determine vegetation production: rainfall, snow cover, and temperature (Behnke, 2000). Solberg *et al.* (2001) suggests population density and growth rates are directly related to climatic variation. Tyler (1987) noted that harsh winter (i.e. deep snow and icing) caused large fluctuations in population size, independent of the population density. Miller *et al.* (2005) questioned Klein's (1968) conclusion that the crash on St. Matthew Island was caused by density-dependent limitation on winter lichen forage. They reanalyzed the data and found the population was still increasing in size (roughly 28% growth) despite the island being overgrazed. They also noted that the population was in good health based on the number of calves, yearling survival rates, and overall survival rates of both age and sex classes. Because the crash occurred in a short period, they believed it was not related to density or nutritional state of the animals (Miller *et al*., 2005). Other than St. Matthew Island, some of the biggest crashes (>30%) have occurred on St. Paul Island, and Bathurst Island, where population numbers were already low. Gunn *et al.* (2003) stated abiotic factors (i.e. snow and ice) caused reindeer populations to crash on five of the nine Alaskan islands. Based on the geographic locations of most of the islands, icing may have been the main factor causing the populations to crash (Miller *et al.*, 1982).

Global climate change models predict an increase of precipitation in the arctic, especially in the fall and winter, and particularly along the coastal regions (up to 30%). They also predict warmer winters, which could lead to an increase in icing events (Hassol, 2004). Aanes *et al.* (2000) found a negative correlation between the population growth rate of reindeer and the amount of precipitation in the winter. Helle & Kojola (2008) found icing could reduce the reproductive rate by as much as 49%. Increased winter precipitation could decouple the relationship between reindeer and the forage base, preventing equilibrium of animal and lichen production.

We believe that the St. George reindeer population may be susceptible to these climatic events, which would result in disequilibrium. Although our stocking density estimate is made under the assumption that this is an equilibrium grazing system (i.e. reindeer numbers and forage production are balanced), we believe the reindeer population is too large for the current lichen standing crop and needs to be reduced. Although small populations are not immune to crashes caused by icing events, population reduction will maintain lichen biomass and thus decrease likelihood of high mortality events.

Including potential alternate forages (i.e. puchki) into the stocking density model may increase the total stocking density number. At this time puchki does not seem to be a major part of the winter diet, but flexibility in the stocking density equation to include this forage should be considered in future years.

In conclusion, data suggest the forage base cannot support the present reindeer density on St. George Island and the population will need to be culled to a level where off-take is less than annual production of lichen. Culling efforts will need to occur regularly to keep the population in check because of the high recruitment rate (up to 57%). Depending on the management goals (commercial hunting or subsistence harvest) the sex ratio of culled animals will vary. Regardless of whether the grazing system on St. George Island is in equilibrium or not, population reduction will help sustain lichen reserves and maintain sustainable reindeer production.

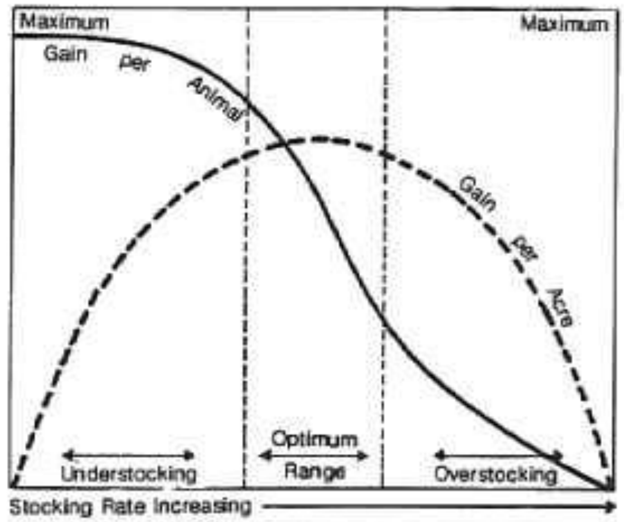

Figure 3.1 The relationship between stocking density and production (Saskatchewan Ministry of Agriculture, 2008).

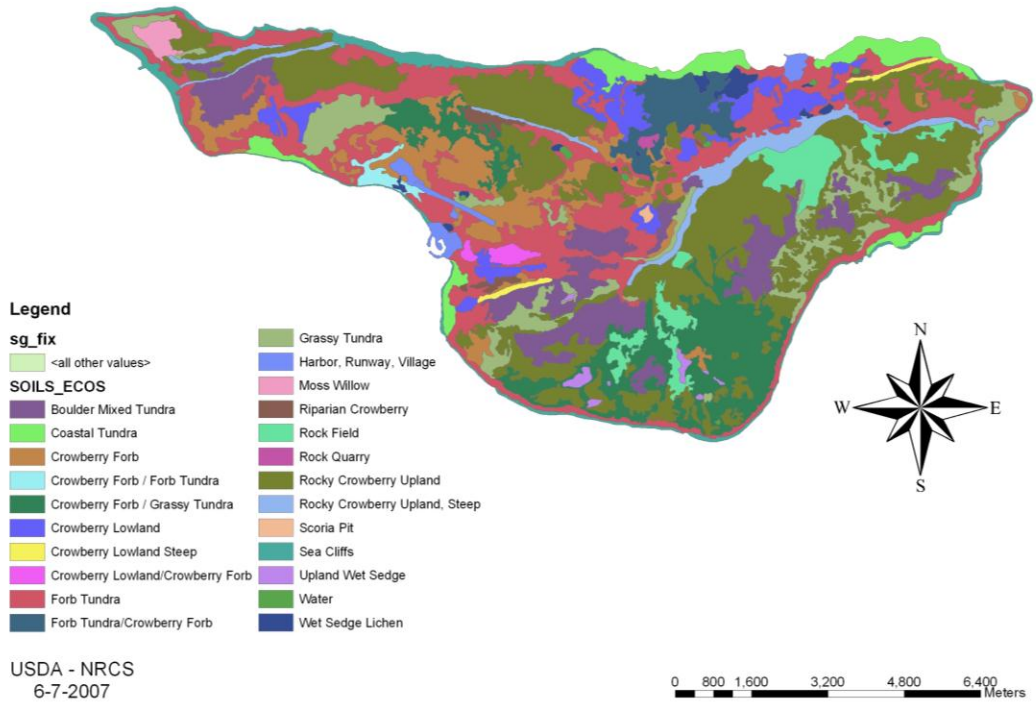

Figure 3.2 St. George Island ecological type map (USDA-NRCS, 2007).

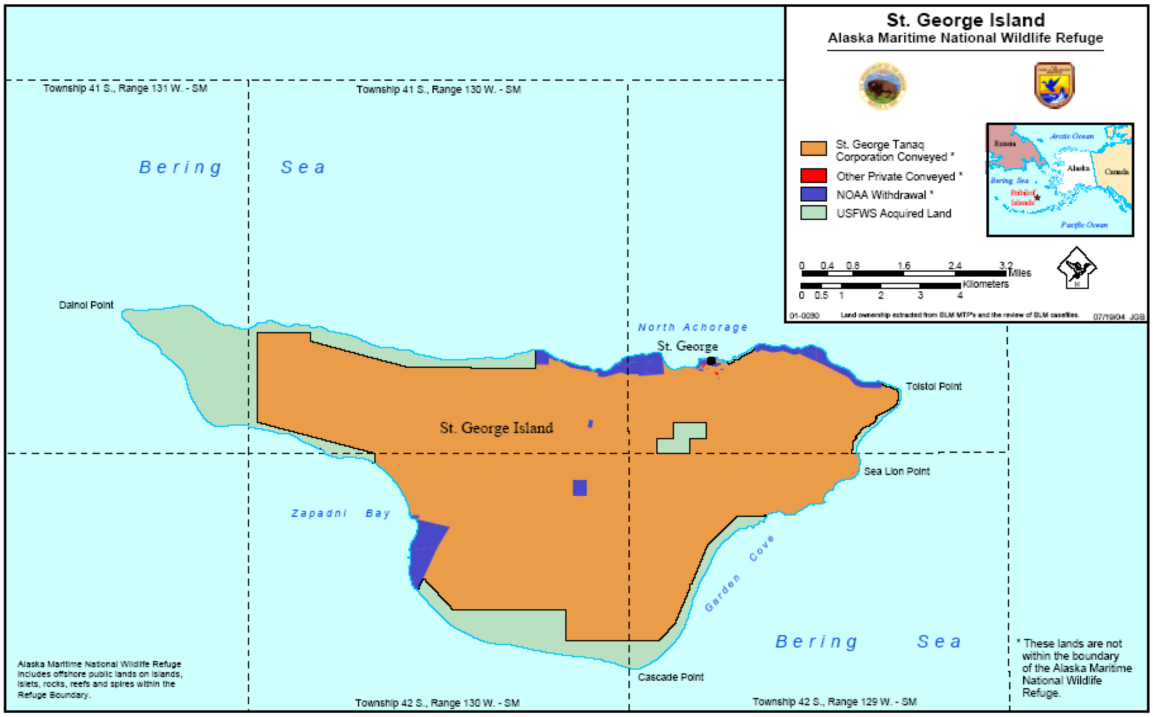

Figure 3.3 St. George Island land ownership map.

Table 3.1 Observed demographics of reindeer during the spring of 2007 and 2008 on St. George Island, Alaska.

	2007		2008	
	Male	**Female**	**Male**	**Female**
Adults	75	120	47	120
Yearlings	12	17	32	33
Calves	66		88	
Total	**290**		**320**	
Calf:cow ratio	48%		57%	
Male ratio	39%		34%	
Female ratio	61%		66%	

Table 3.2 Estimated live lichen dry matter in 8 ecological types on St. George Island, Alaska (2007) including U.S. Fish and Wildlife Service land.

Ecological type	Total area km^2	Total lichen (kg)* (S.E.)
Crowberry Lowland	3.70	0.64 (.01)
Crowb Forb_Grassy Tundra	1.60	0.02 (.00)
Crowb Forb_Forb Tundra	0.43	0.02 (.00)
Forb Tundra	17.19	0.49 (.01)
Boulder Mixed Tundra	7.85	0.55 (.01)
Rocky Crowberry Upland	21.97	2.99 (.01)
Rocky Crowberry Upland Steep	2.41	0.77 (.00)
Crowberry Forb	5.99	0.22 (.00)
	Total	**5.70**

* total lichen expressed in millions

Table 3.3 Estimated live lichen dry matter in 7 ecological types on St. George Island, Alaska (2007) excluding U.S. Fish and Wildlife Service land.

Ecological type	Total area km^2	Total lichen (kg)* (S.E.)
Crowberry Lowland	3.70	0.64 (.01)
Crowb Forb_Grassy Tundra	1.60	0.02 (.00)
Crowb Forb_Forb Tundra	0.43	0.02 (.00)
Forb Tundra	17.19	0.30 (.00)
Boulder Mixed Tundra	6.37	0.09 (.00)
Rocky Crowberry Upland	20.51	2.85 (.01)
Rocky Crowberry Upland Steep	1.99	0.09 (.00)
Crowberry Forb	5.35	0.23 (.01)
	Total	**4.24**

* total lichen expressed in millions

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4 General Summary

The St. George Traditional Council believed lichen stocks were being overgrazed and the reindeer population needed to be reduced before lichen range deteriorated and the reindeer population crashed. Consequently, they approached the Reindeer Research Program at UAF to help develop a comprehensive reindeer management plan for the island. Our goals were to collect baseline data through inventories of the reindeer and range resources to assist in development of a management plan for St. George Island.

Since 2002, the Natural Resources Conservation Service (NRCS) has conducted lichen utilization surveys on St. George Island every two to three years which suggested a downward trend in lichen stocks. In 2007, a population reduction of 80-100 animals was recommended by the NRCS to sustain and/or promote re-growth of lichens on St. George Island. Some entities contested this population reduction (from 320 animals) because they believed the population was not limited by lichen availability. In order to develop a management plan for the reindeer on St. George Island, an inventory of both the forage and the animals was conducted. Specifically, seasonal diet composition, nutritional analysis of a potential alternate winter forage (*Angelica lucida*), herd demographics, and lichen biomass were conducted.

Seasonal diet shifts of reindeer occurred on St. George Island, reflecting the nutritional values of the forages available. Significantly higher proportions of forbs and grasses were found in the spring and summer months. These grasses including, *Arctagrostis sp*., *Poa sp*., and *Phleum sp*., and forbs including *Angelica lucida* and *Lupinus sp*., have high levels of crude protein (CP) and P, which are essential in supporting gestation, lactation, and antler growth. We believe the unique species composition of forage on St. George Island, which provide high levels of energy, CP, and minerals are driving the high recruitment rate and antler growth of reindeer.

Sedges, specifically *Carex aquatilis*, were significantly higher in the diet in fall months. This forage has been found to contain higher levels of CP and digestible fiber later in the fall that support fat deposition. Lichens (66%) and mosses (20%) dominated the winter diet. Moss consumption on island populations tends to be high. It is unclear why reindeer and caribou consume mosses because they have low digestibly and nutrient levels. However mosses are a more nutrient-rich forage than lichens, which may help reindeer meet nutritional requirements in a way that has not yet been explained. St. George reindeer are also consuming grasses in the winter, which help meet energy requirements and thus maintain their body weight. Overall, forage quantity and quality is more than adequate to meet reindeer requirements indicated by the high reproductive rate and large antler size.

Based on seasonal diet composition, the reindeer on St. George Island are selecting forage to meet their nutritional demands. Management efforts should be made to keep the reindeer in areas that complement their nutritional strategy throughout the year. During the spring and summer months when nutritional demands to support growth are high, reindeer should be moved to areas high in grasses and forbs in the southern area of the island and areas around the airport (see figure 2.3 in Chapter 2). In the fall there was a significant shift in diet to sedges which likely support fat deposition. Ideally, managers should move the reindeer in the fall to areas along the southern coast where production of sedges is highest. Lichens were the dominant forage throughout the year, and consumption was highest in the winter (66%). Reindeer grazing should be restricted exclusively to ridges on St. George Island during the late fall and winter months, when nutritional demands are lower. Managers should keep the reindeer off these areas in the summer months to prevent the lichens from becoming overgrazed or trampled.

Local residents have reported St. George Island reindeer consuming *Angelica lucida* (puchki) taproots during the winter months. We estimated puchki taproot on the island at 344,140 kg of dry matter. This total represents a considerable potential winter forage resource on St. George Island. The average CP (8%) also met the basic requirements for maintenance and growth of a young and growing reindeer, although higher CP levels are recommended for reindeer grown in an intensive production setting. The fiber content (NDF, ADF, and lignin) were lowest in the summer months. The digestibility was 74.4%, which is similar to many reindeer forages. Puchki was found at significantly higher proportions in the spring and summer diet, but could be a valuable winter forage resource if lichens become depleted.

Although fecal microhistological analysis did not reveal large quantities of puchki in their winter diet it may be an underestimation. Further investigation of the surface to volume ratio of the puchki taproot indicated a small surface to volume ratio (1:9). Assuming digestibility is equal for epidermal cells (identified in the diet composition analysis) and non-epidermal (overlooked in the diet composition analysis) puchki could represent a much higher percentage of the St. George diet than what was actually found, suggesting this could be a major forage in the reindeer diet. We believe puchki contributes to the productivity of the herd as a result of its nutritional profile, digestibility, and abundance on the island.

The population was surveyed and demographics were established for the herd in the spring months of 2007 and 2008. The population grew from 290 to 320 from 2007 to 2008 and also showed an increased calf:cow ratio (48:100, 57:100 respectively). Anecdotal evidence suggests that the winter of 2007-2008 was one of the heaviest snow fall years in memory. However, despite heavy snowfall, there was no negative effect on the reproductive success of these animals. This may be an indicator of good nutritional status and suggests that the range resources on the island are providing sufficient nutrition to meet maintenance and reproductive thresholds.

We conducted a lichen biomass inventory across the entire island and found 5.698 million kg of dry lichen. Roughly 26% of all the lichen on the island is found on the western peninsula where the U.S. Fish and Wildlife Service (USFWS) own the land. Lichens dominate this area, creating a thick mat (up to 9 cm of live lichen) across the rocky ridges. In contrast, lichens are less abundant on the rest of the island, especially the southeast portion where crowberry and moss dominate.

Based on our lichen assessments, inclusive of the USFWS land, we recommend a stocking density of 2.4 animals/ km^2 or a total island population of 217 animals. However, excluding USFWS land we recommend a stocking density of 1.8 animals/ km^2 or 161 animals. Plans for the construction of a 2.44 m high fence extending across the western ridge are underway, and will effectively exclude reindeer from this portion of the island. Therefore, based on available lichen annual production, we recommend a stocking density of 1.8 animals/ km^2 or 161 animals. In order to maintain this reindeer population at recommended levels, continuous culling efforts will need to be made due to the high reindeer recruitment e rate (57%).

In general, the St. George Island reindeer herd is productive. Their seasonal diet composition matches their nutritional needs and lichen is the dominate forage in their diet. However, if the lichen stands decrease, a shift to grasses and forbs (particularity *Angelica lucida*) could occur, similar to the reindeer on the neighboring island of St. Paul. Managers of this population should continue to cull the population to the recommended stocking density if maintaining lichen ranges is the goal. Continued monitoring of the herd and their forage is recommended. If lichen stands become depleted reindeer could potentially shift winter diets to consume forages such as puchki and grasses.