FEDERAL AID FINAL RESEARCH PERFORMANCE REPORT

ALASKA DEPARTMENT OF FISH AND GAME
DIVISION OF WILDLIFE CONSERVATION
PO BOX 115526
Juneau, AK 99811-5526

PROJECT TITLE: Distribution, movements, and survival of muskoxen in northeastern Alaska

PRINCIPAL INVESTIGATORS: Stephen M. Arthur and Patricia A. Del Vecchio

COOPERATORS: U.S. Fish and Wildlife Service, Arctic National Wildlife Refuge

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STATE: Alaska

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I. PROBLEM OR NEED THAT PROMPTED THIS RESEARCH

From 1999 to 2006, the population of muskoxen (*Ovibos moschatus*) in northeastern Alaska declined to approximately 216 animals from a peak of approximately 700. The decline was especially severe in Unit 26C (arctic coastal plain between the Canning River and the Canadian border), where muskoxen had virtually disappeared by 2006. In GMU 26B (between the Colville and Canning Rivers) the population declined by 35%, and by 2006 these animals were effectively isolated from muskoxen that had spread eastward into Canada. During this period, increasing trends were documented for muskox populations on the Seward Peninsula and Nunivak Island, both in western Alaska (Brown 2005).

Understanding the causes of the decline of the northeastern Alaska muskoxen population is needed so as to determine appropriate management actions and to assess the likelihood that similar declines might occur in other parts of the state. The severity of the recent decline of the northeastern Alaska population and the speed with which it has occurred (60% reduction between 1999 and 2006) indicate the critical nature of the situation and suggest that an immediate response is needed to prevent the population from once again becoming extirpated.

This study was designed to assess calf production, age-specific survival rates, causes of mortality, nutritional status, and forage quality in muskoxen from northeast Alaska.

II. REVIEW OF PRIOR RESEARCH AND STUDIES IN PROGRESS ON THE PROBLEM OR NEED

Muskoxen occupy a limited range of habitat types, have a low rate of reproduction compared to many other ungulates, and are vulnerable to excessive mortality due to harvest, predation, or environmental influences. Thus, the species is susceptible to extreme fluctuations in abundance and was once extirpated from much of its range (Klein 2000). Furthermore, muskoxen are the only remaining species of a diverse assortment of large grazing mammals that inhabited arctic regions of North America during glacial and immediate post-glacial periods (Lent 1999). Considerable effort and funds were expended during the 1960s and 1970s to reestablish muskoxen in northeastern Alaska (Lent 1998). This population increased to a peak of approximately 700 muskoxen in 1995, including approximately 100 muskoxen that dispersed eastward into northern Yukon, Canada (Lenart 2011). Limited harvests were established in GMU 26C beginning in 1982 and in GMU 26B in 1990. From 1996 to 2006 total annual harvests from these units ranged from 3 to 20 and consisted predominantly of adult bulls. In response to the population decline, harvests were prohibited in GMU 26C from 2003 to 2007, and in GMU 26B beginning in 2006 (Lenart 2011). Causes for the decline in the northeastern Alaska population are unknown, although predation by grizzly bears (*Ursus arctos*) was prevalent during periods of both increasing and decreasing muskox abundance (Reynolds et al. 2002). However, the relative importance of predation vs. other mortality causes is unknown. For example, muskox blood and tissue samples collected during 2006 and 2007 indicated a high prevalence of a variety of infectious pathogens, including *Chlamydiophila*, *Pasteurella trehalosi* (pneumonia), bovine viral diarrhea, contagious ecthyma, and polyarthritic joint problems (indicative of disease). In addition, all wild muskoxen currently in Alaska are descended from 34 individuals that were imported from Greenland during the 1930s (Lent 1998). Thus, there is significant potential that low genetic diversity in Alaskan muskoxen might have negative effects on population dynamics.

III. APPROACHES USED AND FINDINGS RELATED TO THE OBJECTIVES AND TO PROBLEM OR NEED

OBJECTIVE 1: Estimate annual birth rates for muskox cows in northeastern Alaska.

We estimated minimum numbers of births for each year based on the numbers of newborn calves we observed during frequent (3–5 days/week) monitoring flights during March, April, and May. It is likely that not all births were documented (calves may have died before we observed them); thus, these estimates probably underestimate total numbers of births for the population.

Numbers of neonatal calves observed during spring were lowest during 2007, when only 35 calves were recorded (0.45 births per adult cow). Counts of calves during the other years ranged from 52 to 64 (0.61–0.82 births per adult cow). Similarly, spring-summer calf survival during 2007 was only 0.37, and ranged from 0.53 to 0.80 during the following years. Annual survival of radiocollared adult cows was also lowest during 2007 (0.74, $n = 23$). Cow survival was also low during 2010 (0.76; $n = 21$), but was considerably higher during 2008 (0.85; $n = 27$), 2009, and 2011 (0.91 during both years;

n = 23 and 22, respectively). Based on our estimates of birth and survival rates, annual estimates of population growth rate (λ) ranged from 0.80 to 1.05, and averaged 0.96. The earliest newborn calf we observed in any year was on 14 April 2011. The mean date that calves were first observed was 22 April (Julian date 112). Most (58%) births occurred between 1–15 May, and 83% of documented births occurred by 1 June. However, we continued to detect neonatal calves occasionally through 10 July, when monitoring flights became less frequent, and we observed a calf that was approximately 1 week old on 1 October 2009 (T. Craig, U.S. Bureau of Land Management, personal communication). Thus, a small number of births evidently occurred throughout the summer. Neither the earliest or latest-born calves survived. However, our observations suggested that survival was high for calves born during June and July (see below).

OBJECTIVE 2: Estimate annual recruitment of muskox calves in northeastern Alaska.

We estimated numbers of calves alive in October based on counts from monitoring flights, and numbers of yearlings each April based on both monitoring flights and the ground-based estimates of age-sex composition. We estimated spring-summer survival as the ratio of calves alive in October:minimum number of births; winter survival as the ratio of yearlings in April:calves alive during the previous October; and annual survival of calves as the product of these rates.

Spring-summer calf survival was lowest during 2007 (0.37), and ranged from 0.53 to 0.80 during the following years. Overwinter survival of calves was generally high (0.83–1.0), except for the 2009 cohort. This group had the highest spring-summer survival (0.80), but the lowest winter survival (0.69), so annual survival (0.55) for that year was only slightly above the mean for all years (0.50).

OBJECTIVE 3: Determine rates and causes of mortality of muskox in northeastern Alaska.

Whenever possible, we visited locations of dead muskoxen (including both collared and unmarked animals) and attempted to determine the cause of death.

Predation by grizzly bears was the most common cause of death of calves, and accounted for 25 (57%) of the 44 deaths for which there was sufficient evidence to assign a cause. In addition, 74 calves disappeared and were presumed to have died (63% of the 118 calves observed). It is likely that bears, wolves (*Canis lupus*) or wolverines (*Gulo gulo*) consumed these calves, preventing us from finding the remains. However, we cannot assume that predators killed all of these, as some may have been scavenged following death from some other cause. Other causes of death that were observed included abandonment (11%; usually due to a bear attack causing the muskox group to flee); disease (7%); starvation, goring by another muskox, and vehicle collision (2% each); and unknown perinatal (18%; defined as deaths within the first week of life for which predators were not involved but a specific cause was not identified). The 3 calves that died of diseases that could be identified included cases of pneumonia, peritonitis (“navel ill”), and chlamydophila.

Predation by grizzly bears was also the most common cause of death for adults and yearlings, and was responsible for 45 (62%) of 73 deaths that were assigned to a specific cause. Other mortality causes for adults and yearlings included human actions (11%; includes vehicle collisions and illegal shooting); drowning due to falling through thin ice (5%); disease (3%; consisted of 1 case each of pericarditis and pneumonia); and unknown nonpredation (8%; no evidence of predation but cause was not definitively determined). Of the 4 cases of drowning, 2 may have been influenced by stress of capture prior to the drowning event and 1 case occurred during a bear attack on the muskox group (this adult female muskox was also suffering from an advanced case of pneumonia). An additional 8 (11%) adults or yearlings disappeared and likely died of unknown causes. One of the deaths assigned to predation was an adult cow that died of stress myopathy following an incident in which a bear attacked and killed 2 other adult cows from the same group. Although the bear did not directly injure this cow, the stress of running from the predator caused the animal to die within 2 days of the attack.

Bear predation of both calves and older muskoxen began soon after bears emerged from their winter dens and continued through the period when bears were active (March–October). However, predation was most prevalent during spring: 61% of predation on calves and 87% of predation on older muskoxen occurred before 1 June. An additional 18% of calf predation and 11% of predation on older muskoxen occurred during the month of June. Some additional mortality may have occurred during summer, when our monitoring flights were less frequent and muskoxen were more widely dispersed. However, total counts of muskoxen seen on tracking flights were similar between late June and October, suggesting that mortality during that period was much less than during spring.

OBJECTIVE 4: Assess prevalence of major diseases and parasites in muskoxen in this population.

We collected tissue samples (heart, lung, liver, kidney, muscle, hair, hoof, and long bones) from dead animals, and blood, serum, and hair from captured muskoxen. These were analyzed to estimate the prevalence of major infectious diseases and parasites. Results of these analyses will be presented in future reports prepared by ADF&G Wildlife Veterinary Services.

OBJECTIVE 5: Assess nutritional status of muskoxen.

We assessed nutritional status of muskoxen using 3 approaches: 1) determining diet composition in late winter; 2) estimating the proportion of metabolized N that was obtained from the winter diet, versus mobilization of N from body tissues; and 3) assessing the availability of trace minerals in soil and forage samples. We collected samples of urine (frozen in snow) and feces from sites where muskoxen were found during April. We initially collected fecal and urine samples from 2 coastal sites and 1 inland site due to the presence of large groups of muskoxen at each site. During 2010 and 2011 we sampled 2 additional inland sites and 1 additional coastal site to increase sample sizes for comparison of diets between sites of differing geography and vegetation composition. Fecal samples were sent to the Washington State University Wildlife Habitat Nutrition Laboratory (Pullman, Washington) for microhistological identification of plant fragments. Results from that analysis were corrected for differential digestibility using techniques described by Gustine et al. (2011). Urine and fecal samples were also sent to the University of Alaska Fairbanks for analysis of nitrogen isotopes to indicate sources of metabolized nitrogen (Gustine et al. 2011). Results of the N isotope study will be described in a future report to be prepared in cooperation with D. Gustine, U.S. Geological Survey.

During July 2009 we visited 20 sites that were currently used by muskoxen and 14 sites that had been used by radiocollared muskoxen prior to 2006, but were not occupied during our study. Locations of these sites were determined by examining locations where muskoxen were observed during the current study and by examining data from previous years provided by Patricia Reynolds (FWS, personal communication). At each site, we used a tubular soil sampler (Forestry Suppliers, Jackson, Mississippi) to collect 10 samples of mineral soil from within a 50 m diameter circle, spaced at random distances and bearings from the center. These samples were homogenized by thorough mixing in a stainless steel bowl and approximately 10 cm^3 of the mixture was retained. Homogenized soil samples were placed in paper bags and air dried at 20°C for 2 weeks. At each site we also collected 5 replicate samples of each of 2 species of muskox forage plants (total: 10 samples per site). Vegetation collected at most sites included 1 species of willow (*Salix pulchra* or *S. alaxensis*), and 1 of either sedge (*Eriophorum* spp. or *Carex* spp.) or grass (*Arctagrostis latifolium*). We selected the species to sample based on a subjective identification of the most common species of woody shrub and graminoid or sedge at each site. However, 2 sites were dominated by only shrubs or only graminoids and sedges (1 site each); in those cases we selected 2 species of that plant type. At 6 other sites we collected samples of only a single species due to the sparse vegetation. Vegetation samples were placed in paper bags and oven-dried at 40°C for 48 hours, then ground and passed through a 20 mm screen. Soil and plant samples were sent to the University of Alaska's Palmer Center for Sustainable Living (Matanuska Experiment Farm, Palmer, Alaska), where they were analyzed to determine concentrations of Cu, Fe, Zn, N, S, Mo, and Se, and to determine pH of soil samples. For most minerals, we compared mean concentrations between areas (current or past use), and we performed separate comparisons for each mineral and plant species. However, concentrations of Mo in soil samples were often less than minimum detectable levels (<0.15 ppm), so we compared proportions of sites where Mo was detected in soils. Concentrations of Se were below detectable levels (<0.40 ppm) for all soil samples and 96% of vegetation samples, so no further analysis was possible.

Microhistological analysis of fecal samples indicated that grasses and sedges were the most common plant type in diets of both coastal and inland muskoxen groups, followed by shrubs and mosses. Our sample sizes were insufficient to allow meaningful statistical comparisons, especially considering the need to control experiment-wise error rates over multiple comparisons. However, there was some evidence that inland groups consumed higher proportions of lichens, forbs, and mosses and smaller proportions of grass and sedge, compared to coastal groups. These differences parallel differences in vegetation composition of the areas inhabited by these groups (Walker et al. 2005).

We found no differences in mean concentration of Cu, Fe, Zn, N, or S, or in pH of soil samples from areas used either currently or in past years. However, the proportions of sites where Mo was detected was greater for sites used in the past (71%) compared to sites used currently (30%; $\chi^2 = 5.67$; $P = 0.02$). Similarly, concentrations of most minerals did not differ between areas for mst forage plants. The only exceptions were for Cu in *Arctagrostis latifolium* (past > current; $t = 2.4$, $P = 0.04$); Fe in *Eriophorum vaginatum* (current > past; $t = 2.90$, $P = 0.03$); and S in *A. latifolium* (past > current, $t = 2.58$, $P = 0.03$).

OBJECTIVE 6: <u>Analyze and publish results</u>.

Progress reports were prepared annually. A final wildlife research report has been submitted for publication to DWC HQ.

IV. MANAGEMENT IMPLICATIONS

Considering the harsh environment occupied by muskoxen, their low reproductive potential, and the general tendency of arctic species to fluctuate in abundance over time, periodic declines and even local extinctions may be an inherent characteristic of muskoxen. Long-term survival may thus depend on the ability of local populations to recover from steep declines, or to be reestablished by animals dispersing from other areas. This suggests that significant management efforts, such as predator management, range improvement, or augmenting populations through translocations of additional muskoxen may be required to maintain small, isolated muskox populations. Additional research is needed to determine how best to manage harvest programs, and under what conditions harvesting from small populations should be permitted.

V. SUMMARY OF WORK COMPLETED ON JOBS IDENTIFIED IN ANNUAL PLAN FOR <u>LAST SEGMENT PERIOD ONLY</u>

OBJECTIVE 6: <u>Analyze and publish results</u>.

A final performance report and a final wildlife research report were completed and submitted to HQ for publishing.

VI. ADDITIONAL FEDERAL AID-FUNDED WORK NOT DESCRIBED ABOVE THAT WAS ACCOMPLISHED ON THIS PROJECT DURING THIS SEGMENT PERIOD

None.

VII. PUBLICATIONS

ARTHUR, S. M., AND P. A. DEL VECCHIO. 2013. Population dynamics of muskoxen in northeastern Alaska. Alaska Department of Fish and Game, Final Wildlife Research Report ADF&G/DWC/WRR-2013-1, Project 16.10, Juneau, Alaska. (*submitted to HQ for publishing 20 August 2013*).

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VIII. RESEARCH EVALUATION AND RECOMMENDATIONS

This study was intended to be a broad-based investigation into potential factors that might influence the status of the muskox population in northeastern Alaska. Thus, these results are best viewed as a guide for future, more definitive studies focused on specific hypotheses. With that caveat in mind, it seems clear that predation by grizzly bears was the single most influential force acting to limit muskox population growth. Although the results of our survey of diseases and parasites are not complete, we found no indication that any particular pathogen was widespread or especially virulent in the population (ADF&G, unpublished data). Our minimum counts of population size and our estimates of population growth rate were in good agreement, and both indicated a stable or slowly declining population. We found no other significant sources of mortality, and our estimates of calf production would be sufficient to allow for population growth if calf and adult survival were to increase. However, simply reducing the number of deaths due to predation might not result in an overall increase in survival, if this is accompanied by an increase in mortality from some other cause (e.g., disease or poor nutrition). In particular, there is some evidence to suggest that nutritional deficiencies might become important, if losses to predation were reduced. For example, concentrations of Cu in muskox forage plants were well below minimum levels recommended for domestic ruminants (>5 ppm; National Research Council 2007). Conversely, concentrations of Zn in willow species commonly consumed by muskoxen greatly exceeded the maximum concentrations recommended for livestock. Concentrations of Zn in excess of 100 ppm can reduce the ability of ruminants to absorb Cu (National Research Council 2007), and might exacerbate deficiencies caused by the already-low levels of Cu found in the plants we studied. Thus, muskox groups whose diets contain large amounts of willows may face dietary challenges resulting from insufficient availability of Cu. Low levels of Cu have been reported elsewhere in tissues of both wild (Barboza et al. 2003) and captive muskoxen (Blakley et al. 1998).

Another potential dietary issue is suggested by the prevalence of mosses in the diet of the inland muskox groups we studied. Ihl and Barboza (2007) suggested that consumption of mosses by muskoxen results in a net cost of dietary protein, because during digestion, mosses retain most of the protein they contain and adsorb particles of other forage plants, reducing availability of nitrogen from those foods. We noted that captured muskoxen from the inland groups were notably fatter than those from coastal areas, as were carcasses of muskoxen that we necropsied (this study, unpublished data). Thus, we believe that diets of the inland groups provided muskoxen with sufficient amounts of energy, but may have been deficient in nitrogen and perhaps Cu and Se.

Our data provide few clues as to possible causes of the decline of muskoxen in GMU 26C (Arctic National Wildlife Refuge) from 1998 to 2006. The change from a period of significant growth to a rapid decline suggests a major change in predator behavior or abundance, increased incidence of disease, reduced quality or abundance of food, or a change in some other limiting factor. Harvest of muskoxen in this area was thought to be well below the level that might influence the population, although the effects of selective removal of mature bulls might be more important than is currently supposed (Schmidt and Gorn 2013). There is no evidence that abundance of grizzly bears increased substantially during that period, and predation of muskoxen by bears was recorded throughout the period when the muskox population increased (Reynolds et al. 2002). However, most bear predation that we observed occurred during spring. The only other ungulate prey available to bears in northeastern Alaska at that time were moose (*Alces alces*) and caribou (*Rangifer tarandus*). The moose population throughout the area declined significantly beginning in 1988, and remained low through the early 2000s (Lenart 2010). Similarly, during the spring calving season the large Porcupine caribou herd migrated into the area occupied by muskoxen in northern GMU 26C for most of the 1980s and 1990s (Griffith et al. 2002), but the herd shifted its calving distribution eastward into northern Canada beginning in 2000 (Alaska Department of Fish and Game, unpublished data). Thus, availability of moose and caribou calves as prey for bears during spring was greatly reduced during the period when the muskox population declined, which may have caused some bears to increase predation on muskoxen.

Changes in climatic conditions may also have played a role in the muskox decline. Mean winter temperatures in northeastern Alaska reportedly increased by >2°C from 1980 to 2000 (Johannessen et al. 2004). However, since 2000, this warming trend has been accompanied by a reduction in number of growing degree days during summer, as reported by the U.S. National Weather Service station at Deadhorse airport, on the Arctic coast of northeastern Alaska. A possible explanation for this is an apparent increase in cloud cover and fog that we observed along the coast during our spring fieldwork. Other recent changes that are consistent with predicted effects of a warming climate include increased winter precipitation, more frequent occurrence of icing events, thawing of permafrost, increasing depth of the active layer of soil, and drying of the soil due to increased drainage during winter (Hinzman et al. 2005). Effects of these changes on the quality and quantity of forage available to muskoxen are unknown and difficult to predict, but will likely be significant in the future.

An additional effect that should be considered is the potential for interactions among forage quality and the incidence of diseases and parasites. Dietary concentrations of trace minerals, particularly Cu, are important factors affecting the ability of animals to resist disease and parasite infestation (Underwood 1977, National Research Council 2007). At the same time, an overabundance of intestinal parasites may reduce the ability of an animal to absorb nutrients from the diet, creating a feedback mechanism. For example: low dietary Cu may lead to an increased parasite load, which further reduces availability of Cu (Adogwa et al. 2005). Thus, muskoxen inhabiting an area where the concentration of Cu in forage plants is below optimum levels may gradually build up parasite populations, which might eventually reach levels sufficient to inhibit absorption of what little Cu is available in the forage. In this case, an area that initially appears capable of supporting muskoxen might prove unable to maintain a population over the long term. It probably is impossible to determine retrospectively if such a process played a role in the decline of muskoxen in GMU 26C, but this could be investigated in other areas currently showing signs of a population decline (e.g., the Seward Peninsula of western Alaska).

It should also be noted that the potential negative effects discussed above are neither a comprehensive list nor are they mutually exclusive; any or all of these could have contributed in some way to the muskox decline (i.e., the cause may have been “death by a thousand cuts” rather than a single negative influence).

IX. APPENDICES

See separate PDF submitted with this report:

ARTHUR, S. M., AND P. A. DEL VECCHIO. 2013. Population dynamics of muskoxen in northeastern Alaska. Alaska Department of Fish and Game, Final Wildlife Research Report ADF&G/DWC/WRR-2013-1, Project 16.10, Juneau, Alaska. (*submitted to HQ for publishing 20 August 2013*).

PREPARED BY: Scott M. Brainerd, ADF&G (*for Arthur and Del Vecchio*)

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