Species Management Report and Plan ADF&G/DWC/SMR&P–2021–11

Muskox Management Report and Plan, Game Management Unit 26B and 26C Eastern North Slope:

Report Period 1 July 2014–30 June 2019, and

Plan Period 1 July 2019–30 June 2024

Elizabeth A. Lenart

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Alaska Department of Fish and Game Division of Wildlife Conservation

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Species management reports and plans provide information about species that are hunted or trapped and management actions, goals, recommendations for those species, and plans for data collection. Detailed information is prepared for each species every 5 years by the area management biologist for game management units in their areas, who also develops a plan for data collection and species management for the next 5 years. This type of report is not produced for species that are not managed for hunting or trapping or for areas where there is no current or anticipated activity. Unit reports are reviewed and approved for publication by regional management coordinators and are available to the public via the Alaska Department of Fish and Game's public website.

This species management report and plan was reviewed and approved for publication by Doreen Parker McNeill, Management Coordinator for the Division of Wildlife Conservation.

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Purpose of this Report

This report provides a record of survey and inventory management activities for muskox in Units 26B and 26C, Eastern North Slope, for the 5 regulatory years 2014–2018 and plans for survey and inventory management activities in the following 5 regulatory years, 2019–2023. A regulatory year (RY) begins 1 July and ends 30 June (e.g., RY14 = 1 July 2014–30 June 2015). This report is produced primarily to provide agency staff with data and analysis to help guide and record its own efforts but is also provided to the public to inform it of wildlife management activities. In 2016 the Alaska Department of Fish and Game's (ADF&G, the department) Division of Wildlife Conservation (DWC) launched this 5-year report to more efficiently report on trends and describe potential changes in data collection activities over the next 5 years. It replaces the muskox management report of survey and inventory activities that was previously produced every 2 years.

I. RY14–RY18 Management Report

Management Area

The management area includes all of Unit 26B, portions of eastern Unit 26A when muskoxen move outside of Unit 26B, and along the Canning River drainage boundary of Units 26B and 26C (Fig. 1). This population is referred to as the Eastern North Slope muskox population.

Summary of Status, Trend, Management Activities, and History of Muskox in Unit 26B and 26C Eastern North Slope

Muskox populations in Alaska disappeared in the late 1800s or early 1900s (Lent 1998). The Territorial Legislature of Alaska urged Congress to appropriate money to reintroduce muskoxen from Greenland to Nunivak Island during 1935–1936 for the purposes of domestication or husbandry experiments (Paul 2009). During 1969 and 1970, 51 animals from Nunivak Island were released on Barter Island, and 13 were released at the Kavik River on the eastern North Slope. The number of muskoxen in this area (Unit 26C) increased steadily during the 1970s and 1980s and expanded eastward into Yukon, Canada; during the late 1980s and early 1990s they expanded westward into Unit 26B, and into eastern Unit 26A in the mid-2000s. The population was considered stable during the mid-1990s at around 500–650 muskoxen in Units 26B and 26C, with perhaps an additional 100 animals in Yukon, Canada.

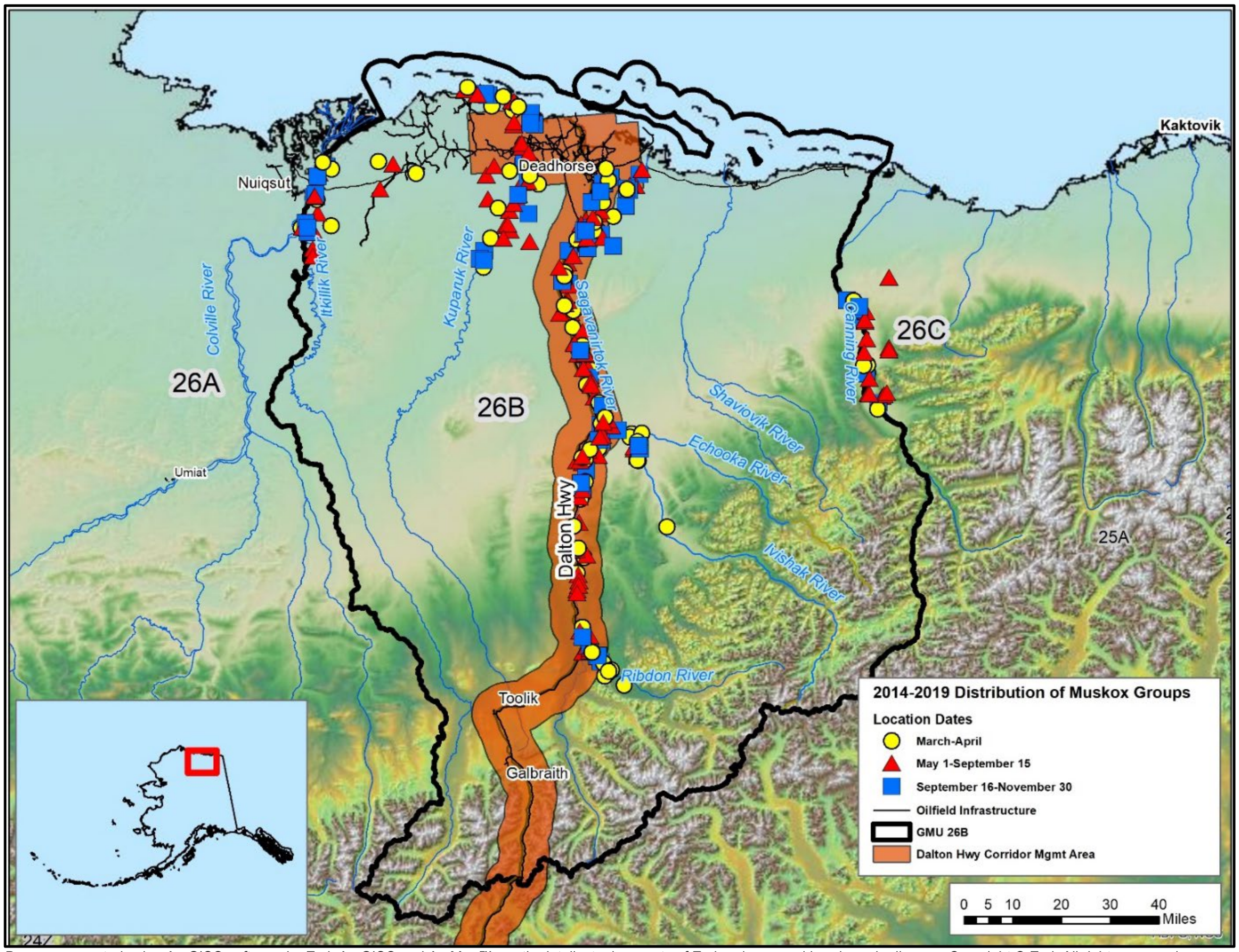
Beginning in 1999, calf production, yearling recruitment, and number of adults declined substantially in Unit 26C, and by 2003, only 29 muskoxen were observed in this unit (Reynolds 2008). Muskox numbers in Unit 26B appeared stable to slightly increasing from the mid-1990s through 2003 at approximately 300 muskoxen. The population declined to 216 by 2006, including a group of muskoxen that had moved into eastern Unit 26A. During 2007–2013, the population in Unit 26B stabilized at a reduced population size of approximately 200 muskoxen (Lenart 2015a). By 2013, the group of muskoxen in eastern Unit 26A had fallen through thin ice on a lake in fall 2012 and drowned. Since then, the Unit 26B muskox population has remained in Unit 26B and along the Canning River boundary of Units 26B and 26C. Note that the muskox population inhabiting eastern Unit 26A, Unit 26B, and Unit 26C is referred to as the Eastern North Slope (ENS) muskox population in this document.

ADF&G first opened a hunting season in Unit 26C in 1982 and in Unit 26B in 1990 (Lenart 2015a). Several regulatory scenarios were in effect since those openings. In regulatory year 1992, U.S. Fish and Wildlife Service (USFWS) took over management of subsistence hunting of muskoxen in Unit 26C and the state hunting season in Unit 26C was closed to prevent overharvest (Lenart 2003). State hunting seasons remained open in Unit 26B until 2006, when all hunting seasons were closed due to the population decline (Lenart 2015a). See Lenart (2015a) for a description of regulatory changes, and hunt and harvest history for 1996–2005.

Brown bear predation on muskoxen was documented in the 1980s (Reynolds et al. 2002) with an apparent increase in predation by bears noted during the early 2000s (Reynolds et al. 2002). During 2007–2011, ADF&G research staff determined that brown bear predation on adult and calf muskoxen was the most common cause of mortality, where a cause could be identified. Bear predation accounted for 62% of deaths of adults (n = 73), predominantly adult cows, and 58% (n = 43) of documented calf mortality (Arthur and Del Vecchio 2017).

To reduce brown bear predation on muskoxen, in RY10 the Alaska Board of Game (the board) liberalized the brown bear hunting seasons and permit requirements by Emergency Order for RY10 and RY11 (Lenart 2015b). In January 2012, the board approved the Unit 26B Muskox Recovery Plan (5 AAC 92.126). This plan included the use of department-authorized personnel to lethally remove brown bears that had been identified as threatening or as having killed muskoxen in Unit 26B (ADF&G 2012). The board expedited 5 AAC 92.126, which went into effect in spring 2012 (RY11) when lethal brown bear removal was implemented. In addition, brown bear hunting regulations were modified in spring 2012 to align with the Unit 26B Muskox Recovery Plan (Lenart 2015b).

Results of the first 2 calendar years (2012 and 2013) of predation control on brown bears in Unit 26B were summarized in E. Lenart and J. Caikoski (Area Wildlife Biologist, Assistant Area Wildlife Biologist, ADF&G, memorandum; Unit 26B Muskox Recovery Program–Field Activities Summary 2012, 16 November 2012, Fairbanks, unpublished report; and Unit 26B Muskox Recovery Program–Field Activities Summary 2013, 19 December 2013, Fairbanks, unpublished report).



Source: ©ADF&G 2020.

Figure 1. Location of muskox groups during radiotracking flights in Unit 26B and 26C, Alaska, 2014–2019. Orange polygon depicts the Dalton Highway Corridor Management Area (archery-only hunting) and the Prudhoe Bay Closed Area (closed to big game hunting).

Management Direction

Current management objectives were implemented January 2012 and are listed below. These objectives were developed in response to a decline in the muskox population from research conducted during 2007–2011 (Arthur and Del Vecchio 2017), from the Operational Plan for Unit 26B Muskox Recovery, 2012–2018 (ADF&G 2012) which was developed to provide guidance to staff to implement a muskox recovery program, and from the Non-Intensive Management Predator Control Plans for Unit 26B muskoxen recovery (5 AAC 92.126(b)) which authorized predation control on brown bears to reduce the effects of brown bear (also referred to as grizzly bear in Interior Alaska) predation on muskoxen.

The North Slope Muskox Harvest Plan (NSMHP; 1999, ADF&G files Fairbanks, unpublished report) is the template for managing muskoxen harvest in Unit 26B. Consistent with that plan, in March 1998 the Alaska Board of Game (board) determined that 20 muskoxen west of the Dalton Highway Corridor and 4 muskoxen east of the Dalton Highway Corridor were necessary to provide reasonable opportunity for subsistence use in Unit 26B. During 1999–2005, hunt and harvest strategies were based on this plan and these hunt structures currently remain in codified regulation (5AAC 85.050) even though all hunting seasons have been closed since 2006.

Existing Wildlife Management Plans

The plan section of this document outlines the current plan for Eastern North Slope Muskox in Units 26B and 26C. Previous management direction has been documented in the Central and Eastern Arctic Slope, Units 26B and 26C management reports of survey and inventory activities (Lenart 2015a), and the North Slope Muskox Harvest Plan (NSMHP, 1999, ADF&G files Fairbanks, unpublished report).

Goals

G1. Allow for growth and expansion of Northeast Alaska muskoxen into historic ranges.

G2. Provide opportunities to harvest Northeast Alaska muskoxen on a sustained yield basis.

G3. Provide opportunities to view and photograph muskoxen.

G4. Minimize any detrimental effects that muskoxen may have on caribou and caribou hunting.

Codified Objectives

Amounts Reasonably Necessary for Subsistence Uses

C1. Central and eastern Arctic Slope muskoxen have a positive finding as a population that has been customarily and traditionally taken or used for subsistence with the amounts reasonably necessary for subsistence uses (5 AAC 99.025) set at 20 muskoxen for Units 26A and 26B, west of the Dalton Highway Corridor Management Area (DHCMA); 4 muskoxen in Unit 26B, east of the DHCMA; and 15 muskoxen in Unit 26C.

Intensive Management

This population did not provide high levels of human consumptive use; therefore, no intensive management objectives were established.

Management Objectives

M1. Maintain a population of at least 300 muskoxen in the eastern Units 26A, Unit 26B, and Unit 26C contiguous muskoxen population (G1, G2, G3).

M2. Maintain a harvest rate of 1–3% per year of the spring precalving population in eastern Unit 26A and Unit 26B, when the population is at least 300 muskoxen and is growing (G1, G2, G3).

Management Activities

1. Population Status and Trend

Activity 1.1. Reduce brown bear predation on muskoxen in Unit 26B (M1, M2).

Data Needs

Brown bear predation was identified as the largest cause of mortality on adult and calf muskoxen in Unit 26B in a research study conducted during 2007–2011 (Arthur and Del Vecchio 2017). The Unit 26B muskox population had declined to approximately 200 muskoxen in 2004 and remained near 200 muskoxen for the following 13 years. The Board of Game authorized reducing brown bear predation on muskoxen during the January 2012 meeting based on the information provided in the Operational Plan for Unit 26B Muskox Recovery, 2012–2018.

Methods

Brown bears identified as threatening or killing muskoxen were lethally removed by shooting the bear from an R44 helicopter using a 12-gauge shotgun. Bear carcasses were then transported to a vehicle so that the hides and skulls could be salvaged for educational purposes (ADF&G 2012).

Results and Discussion

No funding was provided during fiscal years (e.g., fiscal year 2014 = 1 July 2014–30 June 2015) 2014–2018 (FY14–FY18) to intensively monitor muskox groups to identify brown bears as threatening or killing muskoxen. However, lethal removal of brown bears was still authorized during this time period (5AAC 92.126(b)) and ADF&G staff was prepared to lethally remove brown bears that were threatening or killing muskoxen while conducting routine survey and inventory field activities for muskox, caribou, and moose in Unit 26B.

On 25 April 2015, we lethally removed an adult male brown bear (approximately 25-years old) that had entered a group of muskoxen near the Ribdon River and was bedded down near the group. The hide and skull were salvaged, a tooth was removed for aging, and hair was archived for future isotope work. The hide and skull were sealed.

Recommendations for Activity 1.1

Discontinue. Authorization to conduct predator control on brown bears in Unit 26B terminated on 30 June 2018.

Activity 1.2. Maintain 20–30 radio collars on adult female muskoxen (M1, M2). Opportunistically collect blood, nares, vagina swabs, and fecal samples when capturing muskoxen; and analyze samples when funding is available.

Data Needs

Radio collaring

Deploying radio collars on Unit 26B muskoxen is necessary to radiotrack groups of muskoxen; lethally remove brown bear to prevent it from killing, pursuing, or stalking muskoxen; conduct precalving surveys in early April to determine population size; conduct ground-based composition counts in April to determine herd composition; radiotrack in early June and late June to obtain an index to calf production and early calf recruitment; and to radiotrack in late fall to obtain an index of fall calf recruitment and to determine population size going into the winter.

SAMPLE COLLECTION

Acquire baseline data on trace mineral levels, gastrointestinal parasites, and exposure to pathogens to develop a monitoring program to investigate the health status of the ENS muskox population. Currently, monitoring potential exposure to viruses by measuring antibodies are only validated for cattle. In addition, it is unknown what range of trace mineral levels are adequate for good health in muskoxen and the impact of gastrointestinal parasites on muskoxen condition. Therefore, it is important when assessing wildlife disease or pathogen exposure to domestic animals or wildlife pathogens that we acquire baseline data. These data may provide guidance in the future to develop a disease and health status monitoring program for the ENS muskox population.

Methods

RADIO COLLARING

Adult female muskoxen ≥3-years old were captured and immobilized by darting a muskox from an R44 using a Pneu-dart Model 389 cartridge-fired projector rifle aiming for the rear rump or front shoulder. In 2014, we used 2 cc size darts with 1¼-inch needles. In 2015, 2016, and 2019, we used 2 cc size darts with 1½-inch needles. The drug combination used was 1.8 ml (5.4 mg) carfentanil citrate (Wildnil®, ZooPharm, Laramie, Wyoming; concentration = 3 mg/ml), 0.2 ml (20 mg) xylazine hydrochloride (Anased®, Lloyd Laboratories, Shenandoah, Iowa; concentration = 100 mg/ml) in 2014 and 2016, and 0.15 cc in 2015 and 2019. After determining that the immobilizing dart had stricken the muskox, the helicopter pilot moved the aircraft away, and we waited approximately 10 minutes before approaching the animal to determine if it was immobilized or if more immobilization agent was needed. Once we approached the animal, we placed a blindfold on the muskox. We applied oxygen (3 liters/min) to the muskox, removed the dart, and cleaned the dart wound according to protocol outlined in the September 2014 DWC Introduction to Wildlife Chemical and Immobilization and Safety Course manual.

In 2019, 1 muskox was immobilized from the ground using the method and drug combination described in the previous paragraph, except for use of R44 helicopter. This muskox was in an oilfield near infrastructure, making it safer to immobilize from the ground.

Temperature, respiration, and capillary refill was monitored for some animals. We collected conjunctival, nasal, and vaginal swabs. Blood was collected for the following tube types: 1 red-banded blue, 1 blue-banded blue, 2 tiger-top (serum separator) tubes in 2014 and 2016, 1 lavender-banded blue, 2 red-banded blue, and 2 serum-separating tubes in 2019. Blood was collected using an 18-gauge butterfly catheter from either the cephalic or the lateral saphenous vein. A small amount of feces was collected from some animals. We administered 15 cc oxytetracycline in 2014, none in 2015, 20 cc in 2016, and 29 cc oxytetracycline in 2019.

Muskox were fitted with a Telonics MOD 600 very high frequency (VHF) radio collar and an ear tag was attached after making a hole in the ear with an ear punch. Hair around the neck was pulled away to obtain a good collar fit. Beginning in 2019, we maintained a collar circumference of 28–35 inches which resulted in a better fit.

When handling was completed, we reversed the effects of carfentanil citrate by administering 11 ml of naltrexone hydrochloride (Trexonil®, ZooPharm; concentration = 50 mg/ml) and we reversed the effects of the xylazine with 3 ml of tolazoline hydrochloride (ZooPharm; concentration = 200 mg/30 ml) in 2014 and 2016, and in 2019 with 0.3 ml (1.5 mg) atipamezole (Orion Pharma; concentration = 5.0 mg/ml). The reversal was hand injected in 2 locations on the animal via either intramuscular or intravenous delivery.

The IACUC Protocol numbers were 2015-07, 2016-08, 0026-2017-26, 0026-2018-19, and 0026-2019-45.

Sample collection

We collected conjunctival, nasal, and vaginal swabs. Blood was collected for 1 red-banded blue, 1 blue-banded blue, and 2 tiger-top tubes in 2014 and 2016, and 1 lavender-banded blue, 2 red-banded blue, and 2 serum-separating tubes in 2019. Blood was collected using an 18-gauge butterfly catheter from the cephalic or lateral saphenous vein. A small amount of feces was collected from some animals.

Results and Discussion for 1.2.

<u>2014</u>—On 28 September 2014, we deployed 3 VHF radio collars on adult female muskoxen. For 2 muskoxen, we used an additional 5.4 mg of carfentanil resulting in a total of 13.8 mg of carfentanil and an additional 20 mg of xylazine resulting in a total of 40 mg of xylazine. On 1 muskox, we used an additional 3.0 mg of carfentanil for a total of 8.4 mg of carfentanil. Time from dart injection to reversal injection ranged 20–31 minutes for all 3 animals. Body temperature ranged 103.0–105.8ºF (immediately reversed when temperature reached 105.8ºF). One muskox had a respiration rate of 20 respirations/minute and a capillary refill of <2 seconds. Some fecal samples were collected from 2 animals. Conjunctival, nasal, and vaginal swabs; and blood samples were collected from all 3 animals. No capture mortalities occurred.

Results from vaginal swab testing for *Chlamydophila* indicated that all 3 muskoxen were negative. Likewise, results from conjunctival swab testing for *Chlamydophila* indicated that all 3 muskoxen were negative. Results from nasal swab testing for *Mycoplasma ovipneumoniae* indicated that all 3 muskoxen were negative. Serology from 5 muskoxen were tested for *Brucella abortus* and all were negative. Serology from 2 muskoxen were tested for *Erysipelothrix rhusiopathiae* and 1 was positive. The remaining samples were archived in the ADF&G Region III headquarters, ultralow freezer in Fairbanks, AK, pending funding to send samples out to laboratories for analyses.

<u>2015</u>—On 1 October 2015 we deployed VHF radio collars on 2 muskoxen, and accidentally recaptured a muskox that already had a radio collar on it. On 2 muskoxen, we used an additional 3.0 mg of carfentanil for a total of 8.4 mg of carfentanil. On 1 muskox, we used an additional 6 mg of carfentanil for a total of 11.4 mg of carfentanil. No additional xylazine was administered. Time from dart injection to reversal injection ranged 12–40 minutes. Body

temperature was recorded for 2 muskoxen: 102.4ºF and 104.8ºF. No swab or blood samples were collected. No capture mortalities occurred.

2016—During 28–29 March 2016, we deployed 12 VHF radio collars on adult female muskoxen in 8 groups (1 collar each in 6 groups, 2 collars in 1 group, and 4 collars in 1 group). Four muskoxen required additional carfentanil. On 2 muskoxen, we used an additional 3.0 mg of carfentanil for a total of 8.4 mg carfentanil. On 2 muskoxen, we used an additional 5.4 mg of carfentanil for a total of 10.8 mg of carfentanil. No additional xylazine was administered. Time from dart injection to reversal injection ranged approximately 22–47 minutes. We collected blood on only 5 of the 12 muskoxen because the blood was freezing in the needle due to extreme cold air temperatures (approximately -40ºF). Nasal and vaginal swabs were collected on 10 muskoxen, conjunctival swabs on 9 muskoxen, and fecal samples from 6 muskoxen. For the most part, body temperature was not recorded due to extreme cold. No mortalities occurred during captures. One muskox collar from a muskox that was captured in March was found lying on the tundra approximately 1½ months later near the capture location. We do not know if this was a capture-related mortality or a bear predation event.

Results from vaginal swabs testing for *Chlamydophila* indicated that all 10 muskoxen were negative, suggesting these muskoxen did not have Chlamydia. Similarly, results from conjunctival swabs for *Chlamydophila* indicated that all 9 muskoxen were negative. Results from nasal swab testing for *Mycoplasma ovipneumoniae* indicated that all 10 muskoxen were negative. Serology from 5 muskoxen tested for *Brucella abortus* indicated all were negative. The remaining samples are archived in the Region III headquarters, ADF&G ultralow freezer in Fairbanks, AK, pending funding to send samples to the laboratories for analysis.

2019—We immobilized one muskox on 26 May 2019 to remove a loose collar that was over its horn. The collar was removed, but not replaced as there was some discoloration over the eye.

On 18 June 2019, we deployed 6 VHF radio collars on adult female muskoxen in 5 groups, including 3 random adult females and 3 recaptures on adult females whose collars were loose, hanging over their horn. The recaptured animals were fitted with a new VHF radio collar. On 1 muskox, we used an additional 2.7mg carfentanil (injected by hand) for a total of 8.1 mg of carfentanil. Time from dart injection to reversal injection ranged 22–38 minutes. Body temperatures ranged 100.1–104.9 ºF. Respiration ranged 10–20 respirations per minute. Capillary refill time was 1 second. Conjunctival, nasal, vaginal, and blood samples were collected on 5 muskoxen. No mortalities occurred during captures.

Results from nasal swab testing for *Mycoplasma ovipneumoniae* indicated that all 5 muskoxen were negative. Results from serum testing for *Chlamydia*, *Contagious ecthyma*, *Coxiella burnetti* (Q fever), and *Brucella abortus/suis* indicated that all 5 muskoxen were negative. Serum tested for Leptospira had values less than 1:100 indicating that Leptospira was not detected. Serum was also tested for bovine viral diarrhea type 1 serum neutralization test (BVD 1 SN), bovine diarrhea type 2 SN (BVD 2 SN), Infectious Bovine Rhinotracheitis (IBR) virus SN resulting in all values <1:4, except 1 muskox (1:8), indicating no detection. For parainfluenza 3 (PI3) virus SN, values range from <1:4 to 1:512. Serum was tested for ceruloplasmin 5+ levels, resulting in a range of 8.5–15.7 mg/dL. Haptoglobin levels were 0.04 and 0.21 mg/ml for 2 animals and at <0.10 mg/ml for 3 animals. Serum amyloid A levels were at <0.10 mg/L for 4 animals, and 4.17

mg/L for 1 animal. Total protein, albumin/globulin (A/G) ratio, pre-albumin, alpha-1 globulins, alpha-2 globulins, beta globulins, and gamma globulins were measured via electrophoresis (results pending). Hair was archived and may be sent to an outside lab for trace mineral analysis.

Serum from 5 adult females was analyzed for the following trace minerals: calcium, copper, iron, magnesium, phosphorus, zinc, and selenium.

- Calcium—ranged 94–105 ug/g and was within the normal reference range of 70–120 ug/g for muskoxen.
- Copper—ranged 0.66–0.94 ug/g, with 1 muskox below the reference range of 0.70–1.5 ug/g.
- Iron—ranged 0.89–1.5 ug/g and was within the normal reference range of 0.64–1.68 ug/g.
- Magnesium— ranged 24–27 ug/g, and was within the normal reference range of 19–35 ug/g.
- Phosphorous—ranged 44.8–79.8 ug/g, with 1 muskox above the normal reference range of 44–75 ug/g.
- Zinc— ranged 0.62–0.9 ug/g with 2 samples below the normal reference range of 0.7–1.4 ug/g.
- Selenium—ranged 0.22–0.34 ug/g, indicating all animals were within the normal reference range 0.12–0.30 ug/g.

Blood, nares and vaginal swabs summary

Chlamydophila —No chlamydia was detected via vaginal swabs in muskoxen in Unit 26B in 2014 and 2016, although sample sizes were small (*n* = 13). In addition, no chlamydia was detected from serum in 2019. Prevalence of *Chlamydophila* collected from vaginal swabs of adult female muskoxen captured from Eastern North Slope muskox population during 2006–2008 was 33.3% (*n* = 21, 95% confidence interval (CI) 17.2–54.6); sera during 2000, and 2006–2007 was 5.9% (*n* = 34, 95% CI 1.5–19.1; Afema et. al. 2017). However, chlamydia antibodies were present in muskoxen populations at Nunivak Island, Seward Peninsula, and Cape Thompson, (K. B. Beckmen, M.S., D.V.M., Ph.D., Wildlife health and Disease Veterinarian, ADF&G, DWC, ADF&G unpublished files Fairbanks, 2009). Occurrence rates in sera from these 3 populations averaged 22% (*n* = 41; range: 17–25%).

Mycoplasma ovipneumoniae—Results from nasal swab testing for Unit 26B muskoxen during 2014–2019 indicated that all 18 muskoxen were negative. Nasal swabs from 2007 (*n* = 10) and 2011 (*n* = 1) were also recently tested and were negative (K. Beckmen, M.S., D.V.M., Ph.D., ADF&G Disease Veterinarian, unpublished files 2020).

Erysipelothrix rhusiopathiae—*E. rhusiopathiae* was tested in the Unit 26B population during 1984–1992 (mostly Unit 26C) and 2000–2014 (eastern Unit 26A and all Unit 26B). During the early years 1984–1992 (approximately 14 years following reintroduction, when the population was growing), 4 of 36 samples tested positive with a prevalence of 11.1% (95% CI = 3.6–27.0) and during 2000–2014 (when the population declined and remained stable at a reduced density) 15 of the 75 samples were positive with a prevalence of 20% (95% CI = 12.0–31.1; Mavrot et al. 2020). This overall seroprevalence rate of 17% was lower than observed in the Nunivak Island and Seward Peninsula muskoxen populations in Alaska (Mavrot et al. 2020). The results of this study indicated widespread exposure of muskoxen to *E. rhusiopathiae* in Alaska and western Canada.

Erysipelothrix rhusiopathiae is an opportunistic and zoonotic bacterium, and a single genotype of *E. rhusiopathiae* was implicated as the cause of death during multiple muskoxen die offs in the declining populations of Banks and Victoria Islands in the Northwest Territories and Nunavut, Canada during 2009–2013 (Mavrot et al. 2020).

<u>Other studies</u>—See Afema et al. (2017) for results of a study conducted on archived sera collected during 1984–1992, 2000, and during 2006, 2007, and 2008 to determine prevalence of anitbodies for *Brucella, Chlamydophila* (see above, this section), contagiouos ecthyma, infectious bovine rhinotracheitis, *Leptospira interrogans,* malignant catarrhal fever, *Neospora caninum,* parainfluenza virus type 3, *Coxiella burnetii,* respiratory synctial virus, *Toxoplasma gondii* in the Eastern North Slope (ENS) and Western Alaska muskoxen populations. In addition, trace mineral levels, hemograms, and gastrointestinal parasites (from fecal samples) were evaluated during 2006–2008. Pathological investigations of carcasses were conducted on the ENS population during 2005–2008. The pathogens investigated were those that were believed could cause lameness, poor reproduction, or adversely affect general health.

Recommendations for Activity 1.2.

Continue to deploy radio collars on muskoxen to maintain 20–30 radio collars in the population. Consider deploying more radio collars if both the population and the number of groups increase.

Continue to collect blood, nares, vagina swabs, and fecal samples to acquire baseline data for future investigation in developing a disease and health monitoring program for ENS muskoxen.

<u>Satellite radio collars</u>—Consider deploying GPS satellite radio collars to determine intergroup movement. Recommend scheduling the data download such that the batteries would last approximately 5+ years to limit the number of capture events on muskox groups being disturbed by the helicopter and darting because the population is small (approximately 300 in 2019), and if collaring occurred annually, it would likely make conducting composition surveys more difficult because animals may become skittish around the helicopter.

<u>Immobilizing agent</u>—Consult with ADF&G Region V, Division of Wildlife Conservation staff for future captures because carfentanil will not be available as an immobilizing agent. Region V staff has experience using thiafentanil to immobilize muskoxen.

<u>Time of year to conduct captures</u>—I do not recommend capturing in the fall (late September and October) because we had to use more immobilizing agent in the past during these months likely due to accumulated fat on the animal, although Region V staff has successfully conducted captures in the fall. Conducting captures in April or May might be the best time of year; however, muskox composition surveys are conducted in April, and it would be difficult to get adequate good weather to conduct composition surveys and captures at the same time. It is

important to conduct the composition surveys prior to captures because the groups will be skittish once captures have occurred. Conducting captures in mid-June can allow for better weather, and yet still be cool; but groups have newborn calves who can be separated from their mothers during a capture event which can also occur in May. Note that female muskoxen calve from early April through the end of June. Capturing in July and August can be challenging because of warmer air temperatures. If wind is adequate, then warmer air temperatures can be moderated. This can frequently be the case for muskoxen near the coast; but not for muskoxen inland. We conducted captures in late March, but air temperatures were -40ºF, making it difficult or impossible to collect blood and swab samples; and difficult to fit the radio collar.

<u>Blood, nares and vagina swab, and fecal analysis</u>—I recommend that area management biologists have sera analyzed that had been archived post 2008 for the presence of the same antibodies that were detected in the Afema et al. 2017 study; also, it would be beneficial to analyze trace mineral levels, hemograms, and gastrointestinal parasites to compare to the Afema et al. 2017 study; continue anlayzing sera for *Erysipelothrix rhusiopathiae.*

I recommend compiling all historical disease analysis data from ADF&G, DWC wildlife health and disease veterinarian, and organizing it in the Unit 26B muskox survey and inventory files.

ACTIVITY 1.3. Conduct precalving surveys annually to obtain a minimum population estimate (M1, M2).

Data Needs

Abundance estimates are the primary metric used for monitoring the status of the population and are also important in assessing whether ANS objectives have been met. Estimates of population size provide regulatory boards and advisory committees needed information to make informed decisions or recommendations regarding regulatory actions.

Methods

To obtain a minimum count of muskoxen, we conducted precalving surveys during late March or early to late April by radiotracking collared muskoxen using a Cessna 182, and flying some drainages at 85–100 mph at altitudes of 300–700 feet above ground level. Muskoxen were counted from the air and identified as adults and yearlings. Photos of groups were taken from a hand-held digital camera from the radiotracking plane to aid in counting.

Results and Discussion

<u>2014</u>—On 21 April, we observed 177 muskoxen ≥1-year old in 10 groups. We located 24 of 24 active radio collars in 9 groups and a yearling female was observed by ConocoPhillips environmental staff at drill site 3G.

Note that on 23 June, we observed more muskoxen: 181 muskoxen ≥1-year old in 13 groups. We used this number as the 2014 population estimate (Table 1, Fig. 2). It is unusual to observe more muskoxen during surveys in June compared to April because groups are beginning to break up in June, often resulting in more uncollared groups of muskoxen.

2015—On 23 April 2015, we observed 198 muskoxen ≥1-year old in 10 groups (Table 1, Fig. 2). We located 23 of 23 active radio collars in 9 groups and one lone bull.

2016— During 28–29 March 2016, we observed 228 muskoxen ≥1-year old in 15 groups (Table 1, Fig. 2). We located 21 of 21 active radio collars in 9 groups and we located 5 groups of muskoxen (1– 5 animals) along the Sagavanirktok River and one muskox in the upper Canning River that were not associated with radio collars.

2017—During 18–20 April 2017, we observed 218 muskoxen ≥1-year old in 13 groups (Table 1, Fig. 2). We located 27 of 27 active radio collars in 9 groups and we located 4 groups of muskoxen (2–6 animals) along the Sagavanirktok River that were not associated with radio collars.

2018— During 18–20 April 2018, we observed 285 muskoxen ≥1-year old in 20 groups (Table 1, Fig. 2). We located 23 of 23 active radio collars in 11 groups. In addition, we located 6 groups of muskoxen (1–5 animals per group) along the Sagavanirktok River that were not associated with radio collars, 2 muskoxen in the Canning River drainage, and 1 muskox observed by oilfield workers on I pad.

2019—During 20–21 April 2019 and on 25 April 2019, we observed 297 muskoxen ≥1-year old in 20 groups (Table 1, Fig. 2). We located 17 of 17 active radio collars in 11 groups. In addition, we located 8 groups of muskoxen (1–7 animals per group) along the Sagavanirktok River that were not associated with radio collars, and 1 muskox in the Ivishak River drainage.

Historical/combined years—The muskox population in Unit 26B declined to approximately 200 muskoxen in 2004 (Lenart 2015a) and remained at that reduced density until 2016 (Lenart 2015a, Fig. 2). It is likely that mortality (particularly adult females) closely tracked or exceeded recruitment during 2004–2015 because some yearlings were being recruited into the population (Lenart 2015a, Table 1). In 2016, the population increased slightly to 228 muskoxen, and by 2019 it had increased to 297 muskoxen, almost achieving our management objective of 300 muskoxen that would be needed before any consideration of reopening a hunt.

Recommendations for Activity 1.3.

Continue to conduct precalving surveys annually during late March through late April to obtain a population estimate. Continue radiotracking and searching the Sagavanirktok and Canning River drainages while conducting moose surveys. It is necessary to occasionally search along the coast from Nuiqsut to Beechey Point via north-south transects to locate muskoxen groups without radio collars.

Table 1. Unit 26B and 26C (and eastern 26A for years 2007–2012) Eastern North Slope muskox precalving population estimates and composition counts, Alaska, 2007–2019.

		April composition					
Year	Precalving population estimate[a] Muskoxen observed	Date	Muskoxen classified ≥1-year old	No. cows >2-year	Bulls >3-yr: 100 cows >2-yr (no. bulls >3-yr)	Yearling: 100 cows>2-yr (no. yearling)	No. calves[b]
2007	201[c]	13 Apr	153	73	41 (30)	16 (12)	35, 13, 13
2008	191	21 Apr	162	79	28 (22)	18 (14)	67, 41, 34
2009	196	14–15 Apr	174	82	52 (43)	39 (32)	63, 45, 45
2010	187	15–16 Apr	187	88	25 (22)	35 (31)	52, 35, 32
2011	190[c]	14–15 Apr	185	84	31 (26)	39 (33)	55, 29, 29
2012	191	18–22 Apr	175	74	42 (31)	32 (24)	61, 49, 40
2013	198	18–20 Apr	190	85	46 (39)	40 (34)	41, 30, 17
2014	181[d]	20–21 Apr	177	82	30 (25)	17 (14)	33, 31, 26
2015	198	23 Apr	159	74	43 (32)	22 (16)	36, 32, 27–29
2016[e]	228	28–29 Mar	–	–	– –	– –	26, *n/a*, 39–25
2017[e]	218	18–20 Apr	–	–	– –	– –	57–58, 63, 37–40
2018	285	18–20 Apr	268	103	61 (63)	55 (57)	*n/a*, 60, 34–54
2019	297	20–21 Apr	223	70	81 (57)	60 (42)	39, 57, 36–43

[a] Precalving estimates were determined in late March or April based on total muskoxen observed during radiotracking flights.
[b] During 2007–2013, the first number in the column is the maximum number of calves observed born during 1 April to mid-June; the second number in the column is the number of calves observed at the end of June. During 2014–2019, the first number is the number of calves observed during early June radiotracking and the second number is the number of calves observed during late June radiotracking. The third number in the column is the number of calves observed at the end of September, in October, or November. The notation "*n/a*" indicates data not available due to incomplete radiotracking.
[c] Previous management reports reported slightly lower values; but re-examination of raw data indicated numbers were higher.
[d] In 2014 we observed more muskoxen (excluding newborn calves) during June surveys compared to the precalving survey in April. We used the value derived in June as the precalving population estimate.
[e] In 2016 and 2017, no composition surveys were conducted due to helicopter mechanical issues and weather.

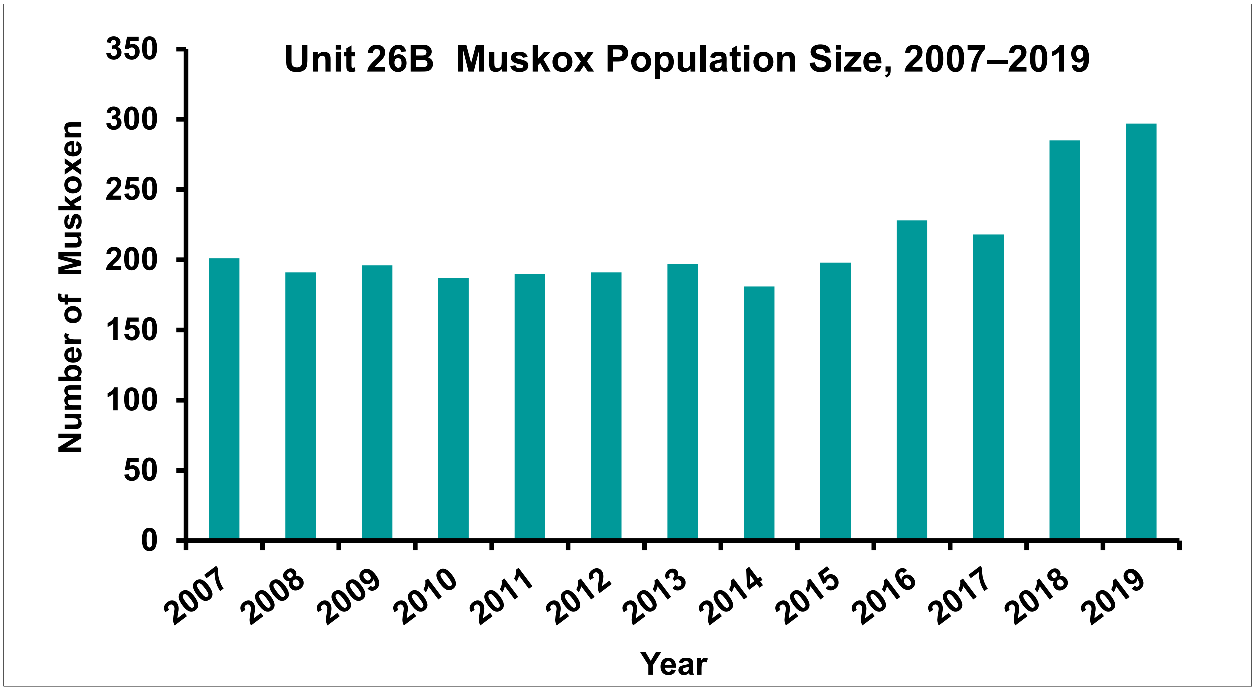


Figure 2. Unit 26B and 26C (and eastern Unit 26A in years 2007–2012) Eastern North Slope muskox population size, Alaska, 2007–2019.

ACTIVITY 1.4. Conduct spring composition surveys annually (M1, M2).

Data Needs

Sex and age composition data provide demographic data used to determine population trend and reproductive potential. These data are also used to inform appropriate harvest rates when a hunting season is opened.

Methods

To determine sex and age composition in the population, we conducted ground-based composition surveys. Groups of muskoxen were located during the precalving survey. A group is defined as ≥1 animal. Two ADF&G staff were transported to muskoxen groups via an R44 helicopter and dropped off. We used a spotting scope and binoculars to classify animals from the ground as ≥4-years old, 3-years old, 2-years old, yearlings, or calves of the current year. Ages of animals were ascertained by horn length (Fig. 3). Animals older than yearlings were also classified as male or female based on horn length and characteristics (Fig. 3). The ADF&G guide entitled Muskox: A guide to identification, hunting, and viewing (Nedwick 2010); and an ADF&G muskox hunter orientation guide found in Muskox Information on Identification and Hunting (Alaska Department of Fish and Game [n.d.]) were also used as references. When the group was small (≤4 animals), the animals were classified from a R44 helicopter or Cessna 182 airplane.

Results and Discussion

2014— During 21–22 April 2014, we classified 173 muskoxen ≥1-year old (Table 1). We observed 25 adult bulls >3-years old, 82 cows >2-years old, and 14 yearlings. The ratio of adult bulls >3-years old:100 adult cows >2-years old was 30:100 and the ratio of yearlings:100 adult cows >2-years old was 17:100 (Table 1).

Of the 173 muskoxen classified, 172 muskoxen were in 9 groups and a 2-year-old cow with no radio collar was observed at Drill Site 3G by ConocoPhillips. A total of 4 muskoxen (2%) of the 177 muskoxen ≥1-year old observed were not classified.

2015— During 24–25 April 2015, we classified 159 muskoxen ≥1-year old (Table 1) and observed 3 newborn calves, although all 3 calves appeared dead. We observed 32 adult bulls >3-years old, 74 cows >2-years old, and 16 yearlings. The ratio of adult bulls >3-years old:100 adult cows >2-years old was 43:100, and the ratio of yearlings:100 adult cows >2-years old was 22:100 (Table 1).

Of the 159 muskoxen classified, 158 muskoxen were in 9 groups and 1 lone bull with no radio collar was observed along the Sagavanirktok River. We were unable to survey a group (13 animals) near the Canning River due to weather and fuel constraints. A total of 39 muskoxen (20%) of the 198 muskoxen ≥1-year old observed were not classified.

2016 and 2017— No composition survey was conducted initially due to mechanical issues with the helicopter, and later due to weather.

2018— During 18–20 April 2018, we classified 268 muskoxen as ≥1-year old (Table 1) and observed 1 newborn calf. We observed 63 adult bulls >3-years old, 103 cows >2-years old, and 57 yearlings. The ratio of adult bulls >3-years old:100 adult cows >2-years old was 61:100 and the ratio of yearlings:100 adult cows >2-years old was 55:100 (Table 1).

Of the 268 muskoxen classified, 240 muskoxen were in 11 groups with radio collars. An additional 29 muskoxen were classified from 9 groups with no radio collars of which most were found on or along the Sagavanirktok River. A total of 17 (6%) of the 285 muskoxen ≥1-year old observed were not classified.

2019— During 20–21 April 2019, we classified 223 muskoxen ≥1-year-old (Table 1). We observed 57 adult bulls >3-years old, 70 cows >2-years old, and 42 yearlings. The ratio of adult bulls >3-years old:100 adult cows >2-years old was 81:100, and the ratio of yearling-to-adult cows >2-years old was 60:100 (Table 1).

Of the 223 muskoxen classified, 191 muskoxen were in 9 groups with radio collars. An additional 32 muskoxen were classified from 8 groups with no radio collars of which most were found on or along the Sagavanirktok River. We were unable to classify 2 larger groups of muskoxen (19 and 35 animals) due to weather. A total of 74 muskoxen (25%) of the 297 muskoxen ≥1-year-old observed were not classified; therefore, ratios could be different if all animals were classified.

Recommendations for Activity 1.4.

Continue to conduct April composition surveys to determine sex and age structure of the population because these data are used to determine population trend and reproductive potential. These data will also be used to inform appropriate harvest rates when a hunting season is opened. As the population increases, it may be difficult to logistically get to all the groups within one weather window. Consider making 2 trips; but this would result in a significant increase in cost. Consider working with a biometrician to explore if sampling the population would be an adequate alternative.

Recommend continuing conducting these surveys in April because that is the time of year when muskoxen are in fewer groups compared to June, July, or October, making it more likely to locate all muskoxen.

ACTIVITY 1.5. Conduct June radiotracking flights to obtain an index of calf productivity (M1, M2).

Data Needs

An estimate of calf production is one of the demographics used in determining trend in population size and may also serve as an index to adult female body condition. This metric provides information on the number of calves going into summer and can be compared to the number of calves observed in the October radiotracking flight to obtain an index to summer calf survival.

Methods

To determine an index to calf production, we radiotracked groups of muskoxen during early June and mid-late June, using a Piper PA-18 or a Cessna 182 airplane. We circled groups from the air and classified muskoxen as adult muskoxen ≥1-year old and as calves born that year (April–June). Beginning 2016, photos of groups were taken from a hand-held digital camera from the radiotracking plane to aid in counting. We used the largest number of calves observed from either radiotracking flight as an index to calf production.

Results and Discussion

2014— During 3–4 June 2014, we located 23 of 23 active radio collars, observed 165 adult muskoxen ≥1-year old, and 33 calves in 10 groups (Table 1).

On 23 June 2014, we located 23 of 23 active radio collars and observed 181 muskoxen ≥1-year old and 31 calves in 13 groups (Table 1).

2015— During 2–7 June 2015, we located 20 of 22 active radio collars, observed 184 adult muskoxen ≥1-year old, and 36 calves in 14 groups (Table 1), including 2 groups not associated with radio collars (3 and 5 animals). We heard the 2 missing radio collars during the subsequent June flight.

During 22–23 June 2015, we located 22 of 22 active radio collars and observed 147 muskoxen ≥1-year old and 32 calves in 11 groups (Table 1), including 2 radiocollared females that were each alone.

2016— On 26 May 2016, we located 28 of 28 active radio collars and observed 189–190 adult muskoxen ≥1-year old and 26–27 new calves in 12 groups. Part of the objective of this flight was to determine if any of the recently captured muskoxen in March 2016 had died, and that the VHF radio collars were still working. Two radio collared muskoxen that were captured in March 2016 were found dead (See Activity 1.7 for more details). Two of the radio collars that we did not hear were deployed in March. One of these radio collars was heard the day following deployment. We never did hear these 2 collars in subsequent radio tracking flights. The collars deployed in March had been sitting on the shelf since 2012.

During 3–4 June 2016, we located 28 of 28 active radio collars and observed 200 adult muskoxen ≥1-year old and 26 calves in 15 groups (Table 1), including 2 groups (2 and 5 animals) with no radio collars located on the Sagavanirktok and Kuparuk rivers.

On 28 June 2016, we located 10 of 28 active radio collars and observed 104 muskoxen ≥1-year old and 20 calves in 8 groups (Table 1), including an additional 12 muskoxen ≥1-year old and 4 calves in a group on the lower Sagavanirktok River (unknown if a radio collar was present). We were unable to complete radiotracking because we had caribou collars that had recently been removed from other caribou in the airplane, which caused interference.

2017— During 6–8 June 2017, we located 27 of 27 active radio collars and observed 193–194 muskoxen ≥1-year old and 57–58 calves (Table 1) in 13 groups, including 2 groups of muskoxen (3 animals in each group) along the Sagavanirktok River that were not associated with radio collars.

During 21–23 June 2017, we located 23 of 27 active radio collars and observed 201 muskoxen ≥1-year old and 63 calves in 15 groups (Table 1), including 2 groups of muskoxen (2 and 3 animals) along the Sagavanirktok and Kuparuk rivers that were not associated with radio collars .

On 30 June, we located the remaining 4 active radio collars and observed 21 muskoxen ≥1-year old. It was too brushy to observe calves. The late June survey resulted in 222 muskoxen ≥1-year old and 63 calves observed in 16 groups (Table 1).

Note that 1 radiocollared muskox was found dead by oil field workers after the 21–23 June flight and before 30 June. She was alone during the previous radiotracking flight in early June. This muskox was included in the total number of muskoxen observed for the late June survey (222 muskoxen ≥1-year old).

2018— During 31 May–3 June 2018, we located 8 of 23 active radio collars and observed 77 adult muskoxen ≥1-year old and 25 calves in 5 groups. We were unable to complete radiotracking due to fog on the coast.

During 21–22 June 2018, we located 20 of 21 active radio collars and observed 180 muskoxen ≥1-year old and 60 calves (Table 1) in 14 groups, including 3 groups of uncollared muskoxen (1– 4 animals per group). One radio collar deployed in 2010 was not heard, but she was heard in the November radiotracking flight.

2019— During 5–6 June 2019, we located 13 of 15 active radio collars and observed 175 adult muskoxen ≥1-year-old and 39 calves (Table 1) in 10 groups, including one lone bull muskox without a radio collar. We were unable to radiotrack 2 radio collars due to fog.

On 18–19 June 2019, we located 17 of 17 active radio collars (including 3 recaptures and 3 new radio collars deployed during survey) and observed 255 adult muskoxen ≥1-year-old and 57 calves (Table 1) in 18 groups, including 6 groups of uncollared muskoxen (1–11 animals per group, including 4 calves).

Recommendations for Activity 1.5.

Continue to estimate calf production because it is one of the demographics used in determining trend in population size and may also serve as an index to adult female body condition. This metric provides information on the number of calves going into summer and can be compared to the number of calves observed in the October radiotracking flight to obtain an index to summer calf survival.

These surveys are conducted in conjunction with caribou calving surveys; thereby reducing costs. If only 1 flight was to be conducted, it would be best to radiotrack during the second half of June because in some years it is not possible to fly groups of muskoxen on the coast in early June due to fog.

ACTIVITY 1.6. Conduct late fall/early winter radiotracking flights to obtain an index of calf survival through summer and population size going into the winter (M1, M2).

Data Needs

An estimate of summer calf survival is one of the demographics used in determining trend in population. This metric provides information on the number of calves going into winter and can be compared to the number of yearlings observed the following spring, providing some information on calf survival through the winter.

Methods

To determine muskox calf recruitment to fall (summer calf survival) and obtain a minimum count of muskoxen in October or early November, we radiotracked groups of muskoxen from a Cessna 182. We circled groups from the air and classified muskoxen as adult muskoxen ≥1-year old and calves that were born earlier that year. Photos of groups were taken from a handheld digital camera from the radiotracking plane to aid in counting. However, it was difficult to classify between long yearlings and calves in some photos. We were unable to search for groups not associated with radio collars because of the short daylight hours; therefore, we were likely missing some groups of muskoxen that did not have radio collars.

Results and Discussion

2014—On 26 and 28 September 2014, we located 21 of 23 active radio collars and observed 172 adult muskoxen ≥1-year old and 26 calves in 13 groups (Table 1). Although, we were unable to radiotrack the group near the Canning River (2 radio collars), a pilot reported observing 12 adults and 1 calf in this group on 26 September, which was included in the total. The number of calves observed in June was 33, indicating that summer calf survival was good. The number of yearlings observed the following spring in 2015 was 16, indicating that winter mortality may have been high. However, yearling values may have been higher than 16 because 39 muskoxen ≥1-year old (20%) were not classified during the composition survey.

<u>2015</u>— On 12 October 2015, we located 21 of 21 active radio collars and observed 181–183 adult muskoxen ≥1-year old and 27–29 calves (Table 1) in 13 groups, including one lone bull on the Sagavanirktok River. We observed a very small calf in the Ribdon group; due to its size we determined that this calf was probably born in late August or September. The number of calves observed in early June was 36, indicating that calf production was moderate. Yearling estimates were not obtained in spring 2016 because composition surveys were not conducted.

<u>2016</u>— On 24 October 2016, we located 28 of 28 active radio collars and we observed 183–189 adult muskoxen ≥1-year old and 19–25 calves (Table 1) in 10 groups. The number of calves observed in June was 26, indicating that summer calf survival was moderate to good. Yearling estimates were not obtained in spring 2017 because composition surveys were not conducted.

<u>2017</u>— On 15 November 2017, we located 25 of 25 active radio collars and observed 187–190 adult muskoxen ≥1-year old and 37–40 calves (Table 1) in 11 groups. The number of calves observed in June was 63, indicating that summer calf survival was moderate. The number of yearlings observed the following spring in 2018 was 57, indicating that we misidentified calves as adults in November. Note that only 17 muskoxen ≥1-year old (6%) were not classified during the composition survey in the spring.

<u>2018</u>— On 30 October and 2 November 2018, we located 18 of 18 active radio collars and observed 214–225 adult muskoxen ≥1-year old and 44–55 calves in 12 groups (Table 1), including 4 groups of uncollared muskoxen (range: 5–13 animals per group), and 10 muskoxen of unknown ages. The number of calves observed in June was 60, indicating that summer calf survival was moderate to good. The number of yearlings observed the following spring in 2019 was 42, indicating that winter mortality was likely low. The actual number of yearlings was likely higher because 74 muskoxen ≥1-year old (25%) were not classified during the composition survey.

<u>2019</u>— On 14 and 15 October 2019, we located 16 of 16 active radio collars and observed 239–246 adult muskoxen ≥1-year-old and 36–43 calves in 10 groups (Table 1). We were unable to locate one known group because the radiocollared muskox from that group was found dead. The number of calves observed in June was 57, indicating that summer calf survival was moderate.

Recommendations for Activity 1.6.

Continue to radiotrack muskoxen in late fall/early winter to obtain an index to summer calf survival. Acquiring a good photographer is essential on this radiotracking flight because it is difficult to identify calves from the air and from poor quality photos.

ACTIVITY 1.7. Determine annual adult female survival (M1, M2).

Data Needs

Estimates of annual survival/mortality provide an important demographic parameter to evaluate population trajectory particularly in years when abundance is not estimated and corroborate estimates in trends in abundance.

Methods

During 2014–2019, radiocollared (VHF-only radio collars) muskoxen were radiotracked from either a Cessna 182 or a Piper PA-18 Super Cub from 3 to 6 times per year to determine adult survival, population size, calf productivity in June, and summer calf survival through fall. In some years, new radio collars were deployed in the middle of a survival year (described below), and some radio collars went "missing" or "off the air".

A survival year begins in either March or April when the first radiotracking flight of the calendar year takes place and ends the following year when the first radiotracking flight of that year takes place (e.g., 1 April 2014–31 March 2015; Table 3).

For each radiotracking event, we recorded:

- Date
- Number of radiocollared muskoxen alive
- Number or radio collars found dead since last radiotracking event.
- Number of new radio collars deployed since last radiotracking event (note that a new collared muskox found dead at a later radiotracking event near its capture location was censored and removed from the sample)
- Number of radio collars "missing" or "off the air" since last radiotracking event. These observations were censored. Censored observations were assumed to become censored halfway between radiotracking events.

Annual survival of radiocollared female muskoxen was estimated with an actuarial estimator using techniques described in Klein and Moeschberger (2003) and using the R package KMsurv (Charles University [n.d.]).

This method assumes that each year is an independent study such that the estimated survival is 100% in April of each year and is recalculated with each radiotracking event depending on deaths or missing collars with the final estimate of the year representing the annual survival. Because we did not collar new individuals on a regular basis, our sample may not be representative of the muskox population, particularly regarding age structure.

Results and Discussion

2014— One adult radiocollared female muskoxen was found dead during the 21 April radiotracking flight. This mortality was attributed to the previous year's survival rate for 1 April 2013–31 March 2014.

Beginning 21 April 2014, 24 radiocollared muskoxen that were located were found alive.

One adult radiocollared female muskoxen was found dead (likely killed by a brown bear) during the 03 June radiotracking flight, indicating it probably died prior to 03 June. No mortalities were found during the 23 June 2014 radiotracking flight. Therefore, 23 radiocollared muskoxen were alive on 03 and 23 June 2014.

Three new muskoxen were collared on 28 September 2014. One of these muskoxen was found dead the following April 2015. We could not rule out that the muskox had died short after capture; consequently, this animal was removed as if it were not collared. Therefore, 25 radiocollared muskoxen were alive on 28 Sept 2014.

Two adult radiocollared females were found dead during the following April 2015 radiotracking flight, indicating these animals died between 29 Sept 2014 and 23 April 2015.

Annual survival of radiocollared adult female muskoxen in 2014 was 0.87 (n = 24, Table 2, Fig. 4).

2015— Three adult radiocollared females were found dead during the 23 April 2015 radiotracking flight, indicating that these animals died during 29 September 2014–23 April. As mentioned previously, 1 of these muskoxen was collared in September 2014; therefore, we could not rule out that this was a capture related mortality. This animal was removed as if it were not collared. The mortality of 2 muskoxen was attributed to the previous year's survival rate for 21 April 2014–23 April 2015.

Beginning 23 April 2015, 23 radiocollared muskoxen were alive.

One adult radiocollared female muskoxen was found dead (likely killed by a brown bear) during the 2–3 June radiotracking flight, indicating it probably died prior to 2 June. No mortalities were found during the 22 June 2015 radiotracking flight. Therefore, 22 radiocollared muskoxen were alive on 2 and 22 June 2015.

One muskox was found dead on 03 September 2015. Two new muskoxen were collared on 01 October 2015 (no other radiotracking was conducted). During the 12 October 2015 radiotracking flight, 1 radiocollared muskox was found dead and 1 radio collar had gone off the air. Therefore, on 12 October 2015, 21 radiocollared muskoxen were alive.

No mortalities occurred during 13 October 2015–28 March 2016.

Annual survival of radiocollared adult female muskoxen in 2015 was 0.84 (n = 23, Table 2, Fig. 4).

2016— Beginning 28 March 2016, 30 radio collared muskoxen were alive. This included 9 collars deployed during 28–30 March 2016 (12 collars were deployed but 2 were never heard again and 1 was found dead during the 26 May 2016 radiotracking flight near its capture location which was attributed to capture mortality. These animals were removed from data as if they had not been collared.

Two adult radiocollared female muskoxen were found dead (likely killed by a brown bear) during the 26 May 2016 radiotracking flight. One of these muskoxen was captured in March but was found dead a long way from its capture location. During the 03 June radiotracking flight, no mortalities were heard and 28 radiocollared muskoxen were found alive. Only 10 radio collars were heard (no mortalities) during the 28 June 2016 radiotracking flight due to interference from caribou collars in the airplane; therefore, radiotracking was incomplete for this flight.

On 24 October 2016, 28 radiocollared muskoxen were alive. No mortalities were located during this radiotracking flight.

No mortalities occurred during 25 October 2016–18 April 2017.

Annual survival of radiocollared adult female muskoxen in 2016 was 0.93 (n = 30, Table 2, Fig. 4).

2017— Beginning 18 April 2017, 27 radio collared muskoxen were alive (1 radiocollared muskox was heard in October 2016, but not heard during 2017).

Beginning 06 June 2017, 27 radio collared muskoxen were alive. No mortalities occurred during the 21–23 June 2017 radiotracking flight. One muskox was found dead on 27 June 2017 by an oilfield worker.

During the 15 November 2017 radiotracking flight, one muskox was found dead. Therefore, 25 radio collared muskoxen were alive on 15 November 2017.

Two muskoxen were found dead during the following April 2018 radiotracking flight indicating that these animals died between 16 November 2017 and 18 April 2018.

Annual survival of radiocollared adult female muskoxen in 2017 was 0.85 (n = 27, Table 2, Fig. 4).

2018—Two adult radiocollared females were found dead during the 18 April 2018 radiotracking flight, indicating that these animals died between 16 November 2017 and 18 April 2018. The mortality of these 2 muskoxen were attributed to the previous year's survival rate (1 April 2017–31 March 2018).

Beginning 18 April 2018, 23 radiocollared muskoxen were alive.

Radiotracking was not completed in early June because of fog on the coast (8 radiocollared muskoxen were found alive). During the 21–22 June 2018 radiotracking flight, 2 muskoxen were found dead; we are uncertain if they were dead prior to early June. Therefore, 21 radiocollared muskoxen were alive on 21 June 2018.

Three muskoxen were found dead during the 30 October and 02 November radiotracking flights. Therefore, 18 radiocollared muskoxen were alive on 30 October 2018. Note that one dead muskox had the radio collar on for 13 years and the other 2 mortalities had their radio collars on for 11 years.

One adult radiocollared muskox was found dead during the following April 2019 radiotracking flight indicating that these animals died between 31 October 2018 and 31 March 2019.

Annual survival of radiocollared adult female muskoxen in 2018 was 0.74 (n = 23, Table 2, Fig. 4).

2019— One adult radiocollared muskox was found dead on 20 April 2019 indicating that this animal died between 31 October 2018 and 31 March 2019.

Beginning 20 April 2019, 17 radiocollared muskoxen were alive.

One radio collar was removed from a muskox on 26 May 2019 because the collar was over her horns. One radiocollared muskoxen was found dead during the 05–06 June 2019 radiotracking flight. Therefore, 15 radiocollared muskoxen were alive on 05 June 2019. Three new collars were deployed on 18 June 2019 and 1 radiocollared muskoxen was found dead during the 18–19 June 2019 radiotracking flight. Therefore, 17 radiocollared muskoxen were alive on 18 June 2019.

One muskox was found dead during the 14–15 October 2019 radiotracking flight. Therefore 16 radiocollared muskoxen were alive on 14 October 2019.

No radiocollared muskoxen were found dead during the following April 2020 radiotracking flight indicating that no animals died between 14 October 2019 and 24 April 2020.

Annual survival of radiocollared adult female muskoxen in 2019 was 0.81 (n = 17, Table 2, Fig. 4).

Survival 2007–2019— Survival rates for radiocollared adult female muskoxen in Unit 26B ranged 0.72–0.93 during 2007–2019 ($\bar{x}$ = 0.85; Table 2), indicating that in some years, mortality of adult females was high. No notable trends were detected, but sample sizes were small (range = 17–30; Table 2). These survival rates serve as a crude index to survival because sample sizes were small, and muskoxen were captured infrequently which may affect age structure.

Causes of mortality—Brown bears kill both calf and adult muskoxen and have been a more important predator than wolves in Unit 26B. Reynolds et al. (2002) concluded that brown bear predation on muskoxen began to increase during the late 1990s, and multiple mortalities of muskoxen were suspected to be caused by predation in Unit 26B which have been reported since 2000.

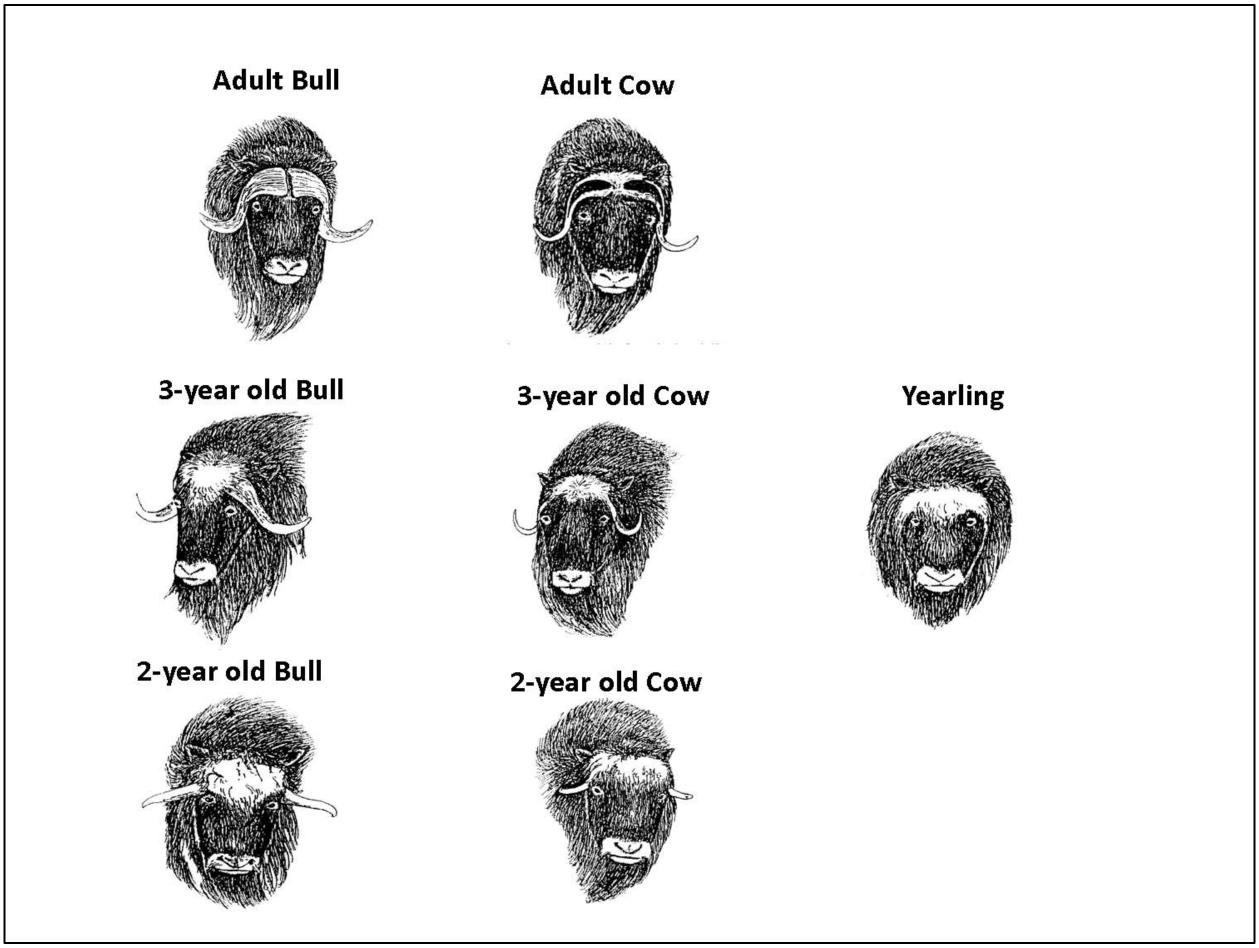
During 2007–2011, ADF&G research staff determined that brown bear predation on adult and calf muskoxen was the most common cause of mortality where a cause could be identified. Bear predation accounted for 62% of deaths of adults (n = 73), predominantly adult cows (Arthur and Del Vecchio 2017). The remaining documented causes of death for adults included unknown cause (11%), starvation/other nonpredation (8%), vehicle collision/illegal shooting (11%), disease (3%), and drowning (5.5%). Also, during 2007–2011, 58% (n = 45) of documented calf mortality was caused by brown-bear predation (Arthur and Del Vecchio 2017). The remaining documented causes of death for calves included having been perinatal (16.3%), abandoned (11.6%, often due to a brown bear scattering the group), diseased (7%), starved (2.3%), hit by a vehicle (2.3%), and gored (2.3%). Over the 5-year period (2007—2011), a total of 95 calves were classified as "missing"; their fates were unknown and not included in the above calculations. We suspect that all these calves died, and most deaths were likely related to brown bears either directly via predation or indirectly via abandonment because the bear was preying on the group of muskoxen. Most bear predation occurred during spring when little other food was available to bears with 87% of predation on adults and 61% of predation on calves occurring before 1 June (Arthur and Del Vecchio 2017).

Late winter storms contribute to mortality of calves, yearlings, and adults, but these losses are generally low. However, during breakup in May 2004, the Colville River flooded and killed at least 13 muskoxen in 2 groups (6 adults, 2 yearlings, and 5 calves). In early June 2006, 1 adult radiocollared female muskox, 1 yearling female muskox, and 1 calf were reported stranded on the sea ice off Northstar and Endicott islands and likely died of starvation. As noted previously, in spring 2013, we found 20 muskoxen frozen in a small lake southeast of Teshekpuk Lake. We determined that they were likely on thin ice in early winter 2012, broke through the ice, and drowned. Other observed causes of death include disease, winter malnutrition, and individuals falling through thin ice on lakes and rivers.

Some human-caused mortality occurs because of capture activities, and illegal take (Lenart 2015a); some muskoxen are killed by vehicles on the Dalton Highway. Causes of other mortalities are sometimes unknown.

Recommendations for Activity 1.7.

Continue to estimate annual survival/mortality because it is an important demographic parameter to evaluate population trajectory, particularly in years when abundance is not estimated, and to corroborate estimates in trends in abundance.



Source: ADF&G files.

Figure 3. Sex and age composition for muskoxen based on horn length and characteristics.

Table 2. Unit 26B and 26C (and eastern Unit 26A for years 2007–2012) Eastern North Slope annual survival rates of radiocollared female muskoxen, Alaska, 2007–2019.

Survival year	Start date	End date	No. collars alive at start	No. deaths	No. censored	No. collared	Survival
2007	11 Apr 2007	9 Mar 2008	21	5	3	11	0.72
2008	9 Mar 2008	31 Mar 2009	24	4	0	0	0.83
2009	31 Mar 2009	22 Apr 2010	20	2	0	0	0.90
2010	22 Apr 2010	3 Apr 2011	18	3	0	6	0.83
2011	3 Apr 2011	2 Apr 2012	21	2	0	2	0.90
2012	2 Apr 2012	29 Mar 2013	21	3	1	9	0.85
2013	29 Mar 2013	21 Apr 2014	26	2	0	0	0.92
2014	21 Apr 2014	23 Apr 2015	24	3	1	3	0.87
2015	23 Apr 2015	28 Mar 2016	23	3	4	14	0.84
2016	28 Mar 2016	18 Apr 2017	30	2	1	0	0.93
2017	18 Apr 2017	18 Apr 2018	27	4	0	0	0.85
2018	18 Apr 2018	20 Apr 2019	23	6	0	0	0.74
2019	20 Apr 2019	24 Apr 2020	17	3	1	3	0.81

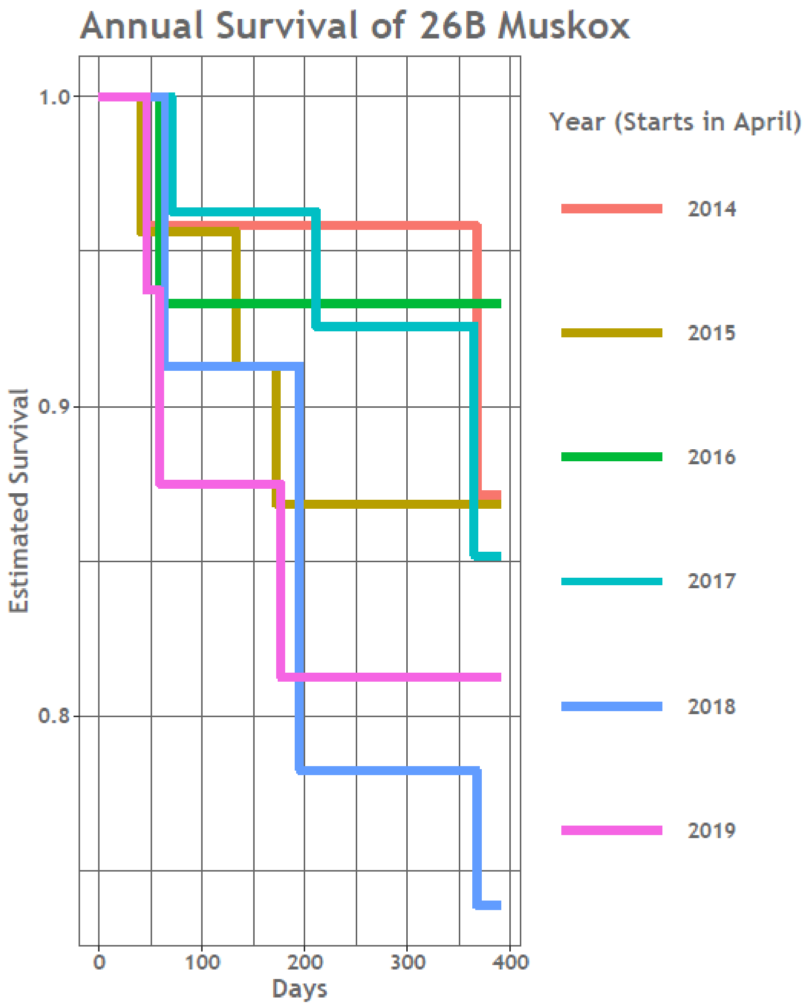


Figure 4. Annual survival rates by days of radiocollared female muskoxen in Unit 26B and 26C, Alaska, 2014–2019.

ACTIVITY 1.8. Determine distribution of Unit 26B muskoxen (M1, M2).

Data Needs

This activity is associated with the management objective to increase the eastern Unit 26A, Unit 26B, and Unit 26C contiguous muskoxen population to 300 muskoxen by reducing brown bear predation on muskoxen in Unit 26B. Determining the distribution of muskoxen was necessary in order to estimate the population size and determine the population trajectory.

Methods

Radiotrack muskoxen via VHF radio collars in April, June, October, and opportunistically when conducting field work on the North Slope. Compile anecdotal observations of muskox and muskox groups from wildlife biologists and the public.

Results and Discussion

During 2014–2019, in Unit 26B, muskoxen groups were found primarily near the mouth of the Itkillik River, along the coast from Beechey Point to the Kuparuk River Delta, along the lower Kuparuk River, on the Sagavanirktok River delta across from Deadhorse, along the Sagavanirktok River from the Ribdon River to the Sagavanirktok River delta, and on the lower Ribdon and Ivishak rivers (Fig. 1). Another small group (<25) was found along a small portion of the Canning River on the boundary between Units 26B and 26C (Fig. 1).

The distribution of muskoxen east and west of the Dalton Highway is important when contemplating opening a hunt because of how the hunt is structured (see Activity 2.1). During the 2014–2019 precalving surveys in April, 73–81% ($\bar{x}$ = 76%) of the muskoxen were east of the Dalton Highway with most of these muskoxen located within the DHCMA. Historically (1997–2013), distribution of muskoxen east of the Dalton Highway ranged 46–71% ($\bar{x}$ = 61%). Movement east to west or west to east can occur; but generally, movement is along the Sagavanirktok River. However, in October 2019, we noted that 2 muskoxen radio collars that had been west of the Dalton Highway in April 2019 near Beechey Point (group size = 17 adults ≥1-year old) were located on the Sagavanirktok River Delta (group size 12 adults ≥1-year old) east of the Dalton Highway.

Muskoxen tend to form larger groups of 6–65 during winter and remain in one location for most or all the winter. During summer, they form smaller groups of 5–30 and move more frequently.

Considerable shifts in distribution have occurred since 2003 (Lenart 2007, Reynolds 2007). Long range movements (≥50 miles) of groups and individual radiocollared animals have also been noted (Lenart 1999, 2003, 2005, 2007). No long-range movements or major shifts in distribution from the Unit 26B muskox population occurred during 2014–2019 except what was noted above for 2019.

Since 1980, lone bulls and small groups of muskoxen have also been reported south of the Brooks Range in Unit 25A (Lenart 2015a). During 2014–2019, between 1 and 2 bull muskoxen annually were observed along the Dalton Highway between Coldfoot and Chandalar shelf. One bull muskox was observed on the North Fork Chandalar River beginning at least in 2010 (this may be the same animal that was observed along the Dalton Highway). In addition, a group of approximately 12 muskoxen, both male and female, were observed along the upper Coleen River during 2015–2019. In recent years, calves of the year were observed in this group. This group likely came from the muskox population in Yukon Canada which had originated from the Unit 26C population.

Recommendations for Activity 1.8.

Continue to determine distribution of muskox. Consider deploying satellite radio collars (see Recommendations for Activity 1.2).

2. Mortality, Harvest Monitoring and Regulations

ACTIVITY 2.1. Monitor harvest through Tier I, Tier II, and drawing permit hunts, maintaining a harvest rate of 1–3% per year of the spring precalving population in eastern

Unit 26A and Unit 26B while the population in eastern Unit 26A, Unit 26B, and Unit 26C is less than 650 muskoxen (M1, M2).

Data Needs

Estimates of annual harvest are important to ensure that harvest is within sustainable limits and to evaluate ANS objectives (C1).

Methods

The hunting season was closed during the report period (RY14–RY19). Physical paper permits used to be available for Tier II and Tier I hunts; the Utqiaġvik (Barrow) ADF&G area wildlife biologist would assist applicants in Nuiqsut in completing their Tier II paper application in early November, while conducting other business. Tier I paper permits were also available in Nuiqsut and Kaktovik. The Tier I "season to be announced" was based on travel conditions on the eastern North Slope and weather forecast.

When muskoxen were harvested, the muzzle and horns were destroyed by ADF&G if removed from Unit 26 according to permit discretionary authority for Tier I and Tier II permits. The horns were cut in half and a piece of the muzzle was removed from the hide.

Season and Bag Limit

Area	Bag limit	Subsistence season	Open season
Units 26A and 26B, that portion west of the Dalton Highway	1 muskox by Tier II subsistence permit only; up to 20 muskoxen may be taken *(Permits were issued for east of longitude 153 and west of DHCMA)*	Aug. 1–Mar. 31 (Subsistence hunt only)	No open season
Unit 26B, that portion east of the Dalton Highway	1 muskox by Tier I permit only *(Permits were issued east of the DHCMA)* Or 1 bull by drawing permit only if the harvestable surplus is greater than 4 muskoxen; up to 5 muskoxen may be taken.	Season to be announced. *(Closed no later than 31 March)* (Subsistence hunt only) Sept. 20–Oct. 10 Mar 10–Mar. 30	No open season

Other relevant regulations include the following:

Unit 26B has a positive customary and traditional (C&T) finding by the board for muskoxen, an ANS of 20 muskoxen west of the DHCMA, and an ANS of 4 muskoxen east of the DHCMA.

The Dalton Highway Corridor Management Area (DHCMA) includes an area extending 5 miles on both sides of the Dalton Highway between the Yukon River and the Arctic Ocean (5AAC 92.530 (7)). The DHCMA (5 miles on either side of the Dalton Highway) and the Prudhoe Bay Closed Area (PBCA) are closed to hunting; however, big game, small game, and fur animals may be taken by bow and arrow only, and small game may also be taken by falconry. In addition, the PBCA (5 AAC 92.510(16)(A)) is closed to the taking of big game.

Results and Discussion

Unit 26B muskox hunting seasons were closed during RY14–RY19, although seasons and bag limit remained unchanged in codified regulation (5AAC 85.050(a)(3)). See Lenart (2015a) for a description of historical hunting seasons, permit availability, and harvest of muskoxen in Unit 26B.

Alaska Board of Game Actions and Emergency Orders

February 2014—The Board of Game was updated on the Unit 26B Muskox Recovery Plan with a PowerPoint presentation.

March 2017—No Unit 26B muskox proposals were submitted.

March 2020 —Proposal 77 requested reauthorization of Unit 26B muskox registration (Tier I) or drawing permits to Alaska residents. ADF&G has authority to open these hunts but sought the board's guidance because the muskox population had barely reached the management objective of 300 muskoxen. The board recommended that more time was needed to determine the trajectory of the muskox population before considering reopening hunts.

Recommendations for Activity 2.1.

Modify the harvest rate to ≤2% of the spring precalving population and maintain a harvest rate of 1% for 2–3 years after the population has reached ≥300 muskoxen. Only issue permits for bull muskoxen. More information regarding how to approach opening hunts can be found below in section "II. Project Review and the RY19–RY23 Plan" and also in the Activity 2.1 methods section within the plan section below.

The current hunt structure in codified regulation makes it extremely difficult to open the Tier I hunt because the ANS is 4 muskoxen east of the DHCMA and with a 1% harvest rate and a population of 300 muskoxen, allowable harvest is 3 bull muskoxen. For similar reasons, it makes it almost impossible to open the drawing hunt. Consider seeking guidance from the Board of Game on how to implement hunts with the current hunt structure. In addition, consider submitting a proposal to the board at the Region III spring BOG meeting in 2023 for the board to review the hunt structure and revisit ANS to determine if there is a better way to offer more opportunity.

3. Habitat Assessment and Enhancement

None.

NONREGULATORY MANAGEMENT PROBLEMS OR NEEDS

None.

Data Recording and Archiving

Original raw data field forms can be found in Room 110 file cabinet under 26B Muskox. Electronic copies of capture, composition, aerial surveys, and telemetry scanned raw data; excel files, results, maps, reports, and memoranda can be found on E. Lenart's hard drive (H:\Muskox) and will also be stored on ADF&G's Wildlife Information Network database, WinfoNet, under Data Archive and Unit 26B Eastern North Slope Muskox (https://winfonet.alaska.gov/index.cfm/Data Archive/Unit 26B Eastern North Slope Muskox Survey and Inventory Program).

Agreements

None.

Permitting

None.

Conclusions and Management Recommendations

Amounts Reasonably Necessary for Subsistence Uses

C1. Units 26A and 26B west of the Dalton Highway Corridor Management Area (DHCMA), 20 muskoxen, and Unit 26B, east of the DHCMA, 4 muskoxen, and Unit 26C, 15 muskoxen. The ANS (5 AAC 99.025) objective was not met because the population was below 300 muskoxen and all hunts remained closed.

Management Objectives

M1. Increase the eastern Unit 26A, Unit 26B, and Unit 26C contiguous muskoxen population to 300 muskoxen by reducing brown bear predation on muskoxen in Unit 26B. This objective was partially met because the population was 297 muskoxen in 2019. Predator control to reduce brown bear predation was not funded during 2014–2018; therefore, this portion of the objective was not met. It is inconclusive whether reducing brown bear predation contributed to population growth when it was funded in 2012 and 2013.

M2. When the population is at least 300 muskoxen and is considered growing, maintain a harvest rate of 1–3% per year of the spring precalving population in eastern Unit 26A and Unit 26B while the population in eastern Unit 26A, Unit 26B, and Unit 26C is less than 650 muskoxen.

This objective was not met because the population barely reached 300 muskoxen in 2019; thus, all hunts remained closed during RY14–RY19.

Priority of activities—If budgets do not allow all activities to be conducted, recommendation of priority of activities is as follows:

Estimating population size—Activities 1.3 (estimate population size) and 1.2 (deploy radio collars) are the 2 highest priorities to continue conducting. It is important to maintain radio collars on the population to be able to locate groups to estimate population size.

Determining an index to calf production—Activity 1.5 would be the third priority because costs are minimized as this survey is conducted in conjunction with caribou calving surveys. It provides an index to potential recruitment and nutritional status of adult female cows.

Determining an index to summer calf survival—Activity 1.6 would be the fourth priority. Conducting this radiotracking flight provides an index to potential recruitment and annual survival, although this can also be obtained with 1 radiotracking flight per year.

Estimating annual adult female survival—Activity 1.7 is related to radiotracking flights. Fewer radiotracking flights result in less information regarding the time period a muskox died.

Estimating distribution of muskoxen in Unit 26B—Activity 1.8 is also related to the number radiotracking events. Fewer radiotracking flights result in less information regarding distribution of muskoxen. However, one annual flight (in April) would provide some information on expansion of distribution.

Conducting annual spring composition surveys—Activity 1.4 would be one of the lowest priorities because it is one of the most expensive activities (approximately $10,000), and while having information on sex and age classes can be used to inform population trajectory, the population estimate is the most important activity to conduct for the management of Unit 26B muskoxen.

Analyze blood samples, nasal swabs, vaginal swabs, and fecal samples—Activity 1.2., sample collection, would be the last priority because blood could be archived if funding is not available; however, fecal samples cannot be frozen and will need to be sent to the lab immediately.

Review recent annual memoranda regarding the cost of each activity to determine which activity to scale back on or eliminate if funding is not available (E. A. Lenart, Area Wildlife Biologist, ADF&G, unpublished memoranda, 07 April 2019, and 22 January 2020).

II. Project Review and RY19–RY23 Plan

Review of Management Direction

MANAGEMENT DIRECTION

Goals G1–G3 will remain the same for the plan period, RY19–RY23. Goal G4 was removed because there is no evidence that muskoxen had detrimental effects on caribou or on caribou hunting, and this goal conflicted with goal G1.

Management objective M1 will remain the same for RY19–RY23. Management objective M2 was changed slightly from maintaining a harvest rate of 1–3% per year to maintaining a harvest rate of ≤2% per year of the spring precalving population in eastern Unit 26A and Unit 26B, when the population is at least 300 muskoxen and is considered growing. This change was made to implement a more conservative harvest management approach because the population is growing slowly.

The North Slope Muskox Harvest Plan (NSMHP; unpublished document, ADF&G, 1999, Fairbanks) has been the guide for managing muskoxen harvest in Unit 26B. Consistent with that plan, in March 1998, the Alaska Board of Game (board) determined that 20 muskoxen west of the Dalton Highway Corridor and 4 muskoxen, east of the Dalton Highway Corridor was necessary to provide reasonable opportunity for subsistence use in Unit 26B. During 1999–2005, hunt and harvest strategies were based on this plan and these hunt structures currently remain in codified (5AAC 85.050), even though all hunting seasons have been closed since 2006.

A goal of the NSMHP was to change the management priority for muskoxen on the North Slope from one of population growth and expansion (following reintroduction of muskoxen in 1969 and 1970) to one of providing opportunities for local residents to harvest muskoxen while maintaining a stable population including initially harvesting at a rate of up to 10% per year of the spring precalving population in the hunt area (eastern Units 26A and 26B); this is partially to inhibit expansion and growth of the herd further west in Unit 26A. During 1996–1999 (period of planning), the muskox population in Unit 26B ranged from 207 to 279 animals (Lenart 2015a). The population on ENS peaked in 1995 at approximately 650 muskoxen (Lenart 2015a). A harvest rate of 10% is not sustainable, even when the population was 650 muskoxen; although, the intent was to prevent expansion of muskoxen. During 1996–2005, when managing under the NSMHP, the harvest rate ranged 1–5% (Lenart 2015a) and was not considered to be a factor in the decline.

Note that the NSMHP committee only consisted of representatives from North Slope communities and agencies (North Slope Borough Fish and Game Management Committee, North Slope Subsistence Regional Council, North Slope Borough, Alaska Department of Fish and Game, U.S. Bureau of Land Management, U.S. Fish and Wildlife Service-Arctic National Wildlife Refuge). Other stakeholders (e.g., Alaskan residents, various Fish and Game advisory committees) were not included in this planning effort. The Alaska Board of Game did instruct the NSMHP committee to involve other stakeholders in some of their meetings; however, these stakeholders were not well received, their concerns were dismissed, and at that point, the planning process was almost completed.

The department has expended significant funds and time on this muskox population including reintroduction of muskoxen in 1969 and 1970, maintaining a survey and inventory program since the mid-1990s, implementing a research program to determine causes of mortality during 2007–2011, and implementing a predator control program to reduce the effects of brown bear predation on muskoxen (FY12 and FY13) and not allow the population to continue to decline. Because the department has invested time and funds to maintain a muskox population on the eastern north slope, and this population had declined to approximately 200 muskoxen in 2004 and remained at this reduced density for 13 years (with concerns that the population would go extinct), the department goals and objectives should be adjusted to allow for growth in the population and maintain stable numbers of muskoxen to provide opportunities to harvest muskoxen. Alaskan residents throughout the state are interested in hunting opportunities on the ENS muskox population. In addition, because adult mortality of muskoxen exceeded recruitment for 13 years, harvest rates should be small when initiating reopening hunts.

The department should consider conducting a few meetings with all stakeholders to develop goals and objectives for the operational plan following this one because management of the ENS muskox population has digressed from the NSMHP. However, current budget constraints will likely prevent or inhibit progress in the immediate future. Therefore, based on the information discussed in this section, I recommend the following goals and management objectives listed below for this operational plan period.

Goals

G1. Allow for growth and expansion of the ENS muskox population.

G2. Provide opportunities to harvest muskoxen on a sustained yield basis.

G3. Provide opportunities to view and photograph muskoxen.

Codified Objectives

Amounts Reasonably Necessary for Subsistence Uses

C1. Central and eastern Arctic Slope muskoxen have a positive finding as a population that has been customarily and traditionally taken or used for subsistence with the amounts reasonably necessary for subsistence uses (5 AAC 99.025) set at 20 muskoxen for Units 26A and 26B, west of the Dalton Highway Corridor Management Area (DHCMA); 4 muskoxen for Unit 26B, east of the DHCMA; and 15 muskoxen for Unit 26C.

Intensive Management

This population did not provide high levels of human consumptive use; therefore, no intensive management objectives were established.

MANAGEMENT OBJECTIVES

M1. Maintain a population of at least 300 muskoxen in the eastern Unit 26A, Unit 26B, and Unit 26C contiguous muskoxen population (G1, G2, G3).

M2. Maintain a harvest rate of ≤2% per year of the spring precalving population in eastern Unit 26A and Unit 26B, when the population is at least 300 muskoxen and is considered growing (G1, G2, G3).

REVIEW OF MANAGEMENT ACTIVITIES

See section I. RY14–RY18 of the above report, Conclusions and Management Recommendations, for a list of priorities of activities if funding is insufficient to conduct all activities listed below.

1. Population Status and Trend

ACTIVITY 1.1. Maintain 20–30 radio collars on adult female muskoxen (M1, M2). Opportunistically collect blood, nares, vagina swabs, and fecal samples when capturing muskoxen and analyze samples when funding is available.

Data Needs

RADIO COLLARING

Deploying radio collars on muskoxen is necessary to radiotrack groups of muskoxen, to conduct precalving surveys in early April to determine population size, conduct ground-based composition counts in April to determine herd composition, to radiotrack in early and late June to obtain an index to calf production and early calf recruitment, to radiotrack in late fall to obtain an index of fall calf recruitment, and to determine population size going into the winter.

SAMPLE COLLECTION

Acquire baseline data on trace mineral levels, gastrointestinal parasites, and exposure to pathogens to develop a monitoring program to investigate the health status of the ENS muskox population. Currently, monitoring potential exposure to viruses by measuring antibodies are only validated for cattle. In addition, it is unknown what range of trace mineral levels are adequate for good health in muskoxen and the impact of gastrointestinal parasites on muskoxen condition. Therefore, it is important when assessing wildlife disease or pathogen exposure to domestic animals or wildlife pathogens that we acquire baseline data. These data may provide guidance in the future to develop a disease and health status monitoring program for the ENS muskox population.

Methods

RADIO COLLARING

Adult female muskoxen ≥3-years old will be captured and immobilized by darting muskox from an R44 using a Pneu-dart Model 389 cartridge-fired projector rifle aiming for the rear rump or front shoulder using a 2 cc dart with a 1½-inch barbed 14-gauge needle (a 1-inch barbed needle may be adequate for captures in June) and a drug combination of 1.3 ml (13 mg) thiafentanil (concentration = 10 mg/ml), 0.2 ml (20 mg) xylazine hydrochloride, and 0.5 ml (200 µg) hyaluronidase (concentration = 300 µg/ml) for female muskoxen >30 months of age (B. Parr, ADF&G personal communication on 24 April 2020; and B. Parr and B. Dunker (Wildlife Biologists, ADF&G, memorandum, 2018 Muskox Thiafentanil Drug Trial, 3 January 2019, Nome). The dart can be topped off with sterile water if captures occur in late spring or summer. Note that this drug combination has only been used on adult muskoxen darted from the ground. Therefore, the thiafentanil dose may need to be adjusted. Muskoxen are sensitive to xylazine, so do not increase the dosage for xylazine. It is also possible that hyaluronidase will not be necessary (used as an absorption agent for thiafentanil). Prior to a capture event, ADF&G wildlife biologists will consult with ADF&G Region V wildlife biologists (Brynn Parr, Bill Dunker, and Lincoln Parrett) who have experience immobilizing muskoxen using thiafentanil and ADF&G Capture Veterinarian Jack Mortenson, DVM, MS, and ADF&G Disease Veterinarian Kimberlee Beckmen, M.S., D.V.M., Ph.D. (has experience immobilizing muskoxen).

After determining that the immobilizing dart has stricken the muskox, the helicopter pilot will move the aircraft away, and wait approximately 10 minutes before approaching the animal to determine if it is immobilized or if more immobilization agent is needed. A blindfold will be placed on the animal once the animal is approached. Next oxygen (3 liters/min) will be applied to the muskox, the dart removed, and the dart wound will be cleaned according to protocol in the September 2014 DWC Introduction to Wildlife Chemical and Immobilization and Safety Course manual.

The animal's status will be monitored by taking temperature and respiration. Biologists will then collect swabs from conjunctiva, nares, and vagina. Blood samples will be collected in collaboration with ADF&G's wildlife disease veterinarian. Fecal and hair samples will be collected. If air temperature is amenable, 30 cc of oxytetracycline will be administered.

The muskox radio collar is fitted by pulling hair away from neck and using a collar circumference of 28–35 inches to obtain a good fit. A hole is made in the ear with an ear punch to then attach an ear tag; the ear punch is archived.

When handling is completed, the effects of thiafentanil are reversed by administering 20 mg of naltrexone per 1 mg thiafentanil resulting in 5.2 ml (260 mg naltrexone hydrochloride, concentration = 50 mg/ml), and the effects of the xylazine are reversed by administering 0.1 mg atipamezole per 1 kg xylazine (0.3 ml = 1.5 mg, concentration = 5.0 mg/ml). Reversal drugs will be hand injected via intramuscular or intravenous delivery. ADF&G Region V wildlife biologists (Brynn Parr, Bill Dunker, and Lincoln Parrett) who have experience immobilizing muskoxen using thiafentanil and ADF&G Capture Veterinarian Jack Mortenson, DVM, MS, and ADF&G Disease Veterinarian Kimberlee Beckmen, M.S., D.V.M., Ph.D. (has experience immobilizing muskoxen) will be consulted. Note that doses will be different if concentrations are different.

Sample Collection

In consultation with the ADF&G wildlife health and disease veterinarian, ADF&G biologists will collect conjunctival, nasal, and vaginal swabs. Blood for 1 lavender-banded blue, 2 red-banded blue, and 2 serum-separating tubes using an 18-gauge butterfly catheter from the cephalic or lateral saphenous vein will also be collected along with fecal and hair samples; fecal material cannot be frozen. Hair samples will be archived.

In consultation with the ADF&G wildlife health and disease veterinarian, sera will be analyzed for the presence of the same antibodies as were analyzed in muskoxen captured in 2019 and 2020, and if funding is available as in the Afema et al. 2017 study. Trace mineral levels, hemograms, and gastrointestinal parasites will be analyzed also to compare to 2019 and 2020 animals and the the Afema et al. 2017 study. Sera will be analyzed for *Erysipelothrix rhusiopathiae.* Archived 2010–2019 sera and samples will be analyzed according to protocols found in Afema et al. 2017, also consulting with the ADF&G wildlife health and disease veterinarian.

All historical disease data analyses from the ADF&G wildlife health and disease veterinarian will be obtained and organized in the area wildlife biologist's files.

ACTIVITY 1.2. Conduct precalving surveys annually to obtain a minimum population estimate (M1, M2).

Data Needs

Estimating abundance is the primary metric used for monitoring status of the population and is also important for meeting ANS objectives. Estimates of population size provide regulatory boards and advisory committees information to make informed decisions or recommendations regarding regulatory actions.

Methods

To estimate minimum population size, precalving surveys will be conducted during late March or by mid-April by radiotracking collared muskoxen using a Cessna 182 aircraft flying along the Sagavanirktok River drainage from Atigun Gorge to the coast at 85–100 mph at altitudes of 300–700 feet above ground level. If time allows, we will fly the lower Kuparuk River drainage. Count muskoxen from the air and identify adults and yearlings (if possible). Take photos of groups with a hand-held digital camera from the radiotracking plane to aid in counting.

ACTIVITY 1.3. Conduct spring composition surveys annually (M1, M2).

Data Needs

Sex and age composition data provide demographic data used to determine population trend and reproductive potential. These data are also used to inform appropriate harvest rates when a hunting season is opened.

Methods

Groups of muskoxen will be located during the precalving survey, and sex and age composition will be conducted from the ground. Two ADF&G staff will be transported to muskoxen groups via an R44 helicopter and dropped off. A spotting scope and binoculars will be used to classify animals from the ground as ≥4-years old, 3-years old, 2-years old, yearling, or calf of the current year. Ages of animals will be ascertained by horn length (Fig. 2). Animals older than yearlings will be also classified as male or female based on horn length and characteristics (Fig. 2). The

ADF&G guide titled Muskox: A guide to identification, hunting, and viewing (Nedwick 2010) and an ADF&G muskox hunter orientation guide (ADF&G 2010) will also be used as references. When the group is small (≤4 animals), the animals can be classified from a R44 helicopter or Cessna 182. A group is defined as ≥1 animal.

ACTIVITY 1.4. Conduct June radiotracking flights to obtain an index of calf productivity (M1, M2).

Data Needs

An estimate of calf production is one of the demographics used in determining trend in population size and may also serve as an index to adult female body condition. This metric provides information on the number of calves going into summer and can be compared to the number of calves observed in the October radiotracking flight to obtain an index to summer calf survival.

Methods

To determine an index to calf production, groups of muskoxen should be radiotracked during early June and mid-late June using a Piper PA-18 or a Cessna 182 airplane. Groups are circled from the air and classified as adult muskoxen ≥1-year old or as calves born that year (April–June). Photos will be taken from a handheld digital camera from the radiotracking plane to aid in counting. The largest number of calves will be used from either radiotracking flight as an index to calf production.

ACTIVITY 1.5. Conduct late fall/early winter radiotracking flights to obtain an index to calf survival through summer and population size going into the winter (M1, M2).

Data Needs

An estimate of summer calf survival is one of the demographics used in determining trend in muskox populations. This metric provides information on the number of calves going into winter and can be compared to the number of yearlings observed the following spring, providing information on calf survival through the winter.

Methods

To determine muskox calf recruitment to fall (summer calf survival) and obtain a minimum count of muskoxen in October or early November, we will radiotrack groups of muskoxen from a Cessna 182 or Piper Super Cub, circle groups from the air, and classify muskoxen as either adult muskoxen ≥1-year old or calves that were born earlier that year. Photos will be taken of groups from a handheld digital camera from the radiotracking plane to aid in counting. Note that even with photos it can be difficult to classify between long yearlings and calves. If time allows, we will search for uncollared groups along the Sagavanirktok and lower Kuparuk rivers.

ACTIVITY 1.6. Determine annual adult female survival (M1, M2).

Data Needs

Estimates of annual survival/mortality provide an important demographic parameter to evaluate the population trajectory particularly in years when abundance is not estimated and corroborate estimates in abundance trends.

Methods

Muskoxen are radiotracked from a Cessna 182 or a Piper Super Cub airplane 3 to 6 times per year to obtain the following population demographic data: 1) population size once in April, 2) calf productivity twice in June, 3) summer calf survival through fall once in October, and 4) other radiotracking flights when necessary.

In some years, new radio collars are deployed in the middle of a survival year (described below), and some radio collars go “missing” or “off the air”.

A survival year begins in either March or April when the first radiotracking flight of the calendar year takes place and ends the following year when the first radiotracking flight of that year takes place (e.g., 1 April 2014–31 March 2015; Table 3).

For each radiotracking event, the following will be recorded:

- Date.
- Number of radiocollared muskoxen alive.
- Number or radiocollared muskoxen found dead since last radiotracking event.
- Number of new radio collars deployed since last radiotracking event (note that a new collared muskox found dead at a later radiotracking event near its capture location should be censored and removed from the sample)
- Number of radio collars “missing” or “off the air” since last radiotracking event. These observations should be censored. Censored observations are assumed to become censored halfway between radiotracking events.

Annual survival of radiocollared female muskoxen is estimated with an actuarial estimator using techniques described in Klein and Moeschberger (2003) and using the R package KMsurv (Charles University [n.d.]). This method assumes that each year is an independent study such that the estimated survival is 100% in April of each year and is recalculated with each radiotracking event depending on deaths or missing collars, with the final estimate of the year representing annual survival. Because we do not collar new individuals on a regular basis, our sample may not be representative of the muskox population, particularly regarding age structure. Other methods to estimate annual survival will likely yield similar results and can be explored.

ACTIVITY 1.7. Determine distribution of Unit 26B muskoxen (M1, M2).

Data Needs

Determining distribution of muskoxen is necessary to estimate population size and determine trajectory of population. Distribution of muskoxen east and west of the Dalton Highway is important when considering opening a hunt because of the hunt structure.

Methods

Radiotrack muskoxen via VHF radio collars in April, June, and October and opportunistically when conducting field work on the North Slope. Compile anecdotal observations of muskox and muskox groups from wildlife biologists and the public.

2. Mortality-Harvest Monitoring

ACTIVITY 2.1. Administer permit hunts when the population is at least 300 muskoxen and considered growing while maintaining a harvest rate of ≤2% of the precalving population (M1, M2).

Data Needs

Estimates of annual harvest are important to ensure that harvest is within sustainable limits and to evaluate ANS objectives.

Methods

Once the spring precalving population estimate in eastern Unit 26A and Unit 26B has reached 300 muskoxen and is considered growing, we will implement a harvest rate of 1% (bulls only) for 2–3 years, maintain a harvest rate of 1–2%, and allow harvest of bulls only. See Recommendations for Activity 2.1 in the report section above for more information.

Opening Tier II hunt, west of the DHCMA—Using the 1% harvest rate, first consider opening the Tier II hunt west of the Dalton Highway for 1 bull muskox when the population has been ≥300 muskoxen (or close) for 2 years. Historically, most Tier II permit winners were residents from Unit 26A (Lenart 2015; ADF&G [n.d.] unpublished files), so there is often only 1 muskox group accessible to hunt. Therefore, evaluating that adult bulls are present in the group that is closest to Unit 26A is essential for ADF&G area management staff to determine annually, ideally during the April survey. If more than 1 Tier II permit can be issued, we will consider constructing hunt zones to distribute the harvest, although muskoxen groups west of the Dalton Highway are frequently within the PBCA and the oilfields within 26B (Fig. 1). It is unlikely in the next 5 years that more than 2 Tier II permits could be issued because of the distribution of muskoxen unless distribution changes or growth in the population occurs, including population expansion into western Unit 26B. Only 56 muskoxen were observed west of the Dalton Highway in April 2019, 12 of which moved to the Sagavanirktok River Delta in October 2019. During 2014–2019, a range of 49–62 muskoxen were observed west of the Dalton Highway during April surveys (ADF&G Fairbanks unpublished files). The small numbers of muskoxen observed west of the Dalton Highway in recent years is related to the mortality event in November 2012 when 22 muskoxen drowned in a lake in eastern Unit 26A (Lenart 2015a).

Opening Tier I hunt, east of the DHCMA—If using the 1% harvest rate, the Tier I hunt cannot be opened until the population has grown to 500 muskoxen because the ANS for muskox east of the DHCMA is 4 muskoxen and at least 1 muskox will already be assigned to the Tier II permit. If using the 2% harvest rate, Tier 1 permits could be issued for 1 bull sustainably; however, these permits are for muskoxen located east of the DHCMA, and most muskoxen are within the DHCMA or the PBCA (Fig. 1). It is possible that there is enough movement and mixing of muskoxen groups along the Sagavanirktok River drainage and DHCMA that harvesting 4 muskoxen east of the DHCMA would not be problematic for those specific groups of muskoxen.

Because Tier I permits are unlimited, and the restriction is a harvest quota of 4 muskoxen, devising a method to distribute these permits is challenging. Historically, permits were available in person in Nuiqsut and Kaktovik. Occasionally, Alaska residents from outside of Unit 26 would drive through the oilfields to Nuiqsut to obtain a permit; however, if they harvested a muskox and removed the animal from Unit 26, the horns and hide were destroyed (see Activity 2.1, Methods in report section above). The hunt was last opened in 2005, so it is difficult to predict how many hunters would be interested in the permit if the horns and hide must be destroyed. Residents of Unit 26 may also be more interested in utilizing the Tier I permit compared to the past because fewer Tier II permits will be issued. If more than 4 hunters are interested in pursuing the hunt, it will be challenging prevent overharvest.

Opening Drawing hunt, east of the Dalton Highway—A drawing hunt could only be considered if the harvest rate is 2% and the population is 350 muskoxen. Drawing permit holders could hunt within the DHCMA (bow and arrow only), where most muskoxen are located. See Recommendations for Activity 2.1 (this document, above report section) regarding guidance from the Board of Game on how to implement these hunts.

3. Habitat Assessment and Enhancement

None.

Nonregulatory Management Problems or Needs

None.

Data Recording and Archiving

All raw data sheets. Scanned raw data sheets, excel files, memoranda, and maps will be stored on an internal database housed in WinfoNet/Data Archive/Unit 26B Eastern North Slope Muskox (https://winfonet.alaska.gov/index.cfm: Data Archive/Unit 26B Eastern North Slope Muskox Survey and Inventory Program) and on E. Lenart's Home Drive (H:\Muskox). Original raw data field forms will be in Room 110 file cabinet under "26B".

Agreements

None.

Permitting

None.

References Cited

Alaska Department of Fish and Game. 2012. Operational plan for Unit 26B muskox recovery, 2012–2018. Division of Wildlife Conservation, Juneau.

Alaska Department of Fish and Game. 2010. Muskox: Information on identification and hunting [slideshow]. Division of Wildlife Conservation.

Alaska Department of Fish and Game. [n.d.]. Muskox hunting in Alaska [web page]. Division of Wildlife Conservation. http://www.adfg.alaska.gov/index.cfm?adfg=muskoxhunting.orientation (Accessed 17 April 2020).

Arthur S. M. and P. A. Del Vecchio. 2017. Effects of grizzly bear predation on muskoxen in northeastern Alaska. Ursus 28(1):81–91. https://doi.org/10.2192/URSU-D-16-00023.1.

Afema, J. A, and K. B. Beckmen, S. M. Arthur, K. Burek Huntington, and J. A. K. Mazet. 2017. Disease Complexity in a Declining Alaskan Muskox (*Ovibos Moschatus*) population. Journal of Wildlife Diseases, 53(2), 2017, pp. 311–329.

Charles University. [n.d.]. Lifetable or actuarial estimator. Faculty of Mathematics and Physics, School of Mathematics. Sokolovská, Prague. https://www.karlin.mff.cuni.cz/~pesta/NMFM404/survival.html#Lifetable_or_actuarial_estimat or (Accessed 16 April 2020).

Klein, J. P., and M. L. Moeschberger. 2003. Survival Analysis: Techniques for censored and truncated data. Springer, 2nd Edition (1 December 2010). 556 pp.

Lenart, E. A. 1999. Units 26B and 26C muskox. Pages 30–43 [*In*] M. V. Hicks, editor. Muskox management report of survey–inventory activities 1 July 1996–30 June 1998. Alaska Department of Fish and Game, Division of Wildlife Conservation, Federal Aid in Wildlife Restoration Study 16.0, Juneau.

Lenart, E. A. 2003. Units 26B and 26C muskox. Pages 54–71 [*In*] C. Healy, editor. Muskox management report of survey and inventory activities 1 July 2000–30 June 2002. Alaska Department of Fish and Game, Division of Wildlife Conservation, Federal Aid in Wildlife Restoration Project 16.0, Juneau.

Lenart, E. A. 2005. Units 26B and 26C muskox. Pages 49–68 [*In*] C. Brown, editor. Muskox management report of survey and inventory activities 1 July 2002–30 June 2004. Alaska Department of Fish and Game, Division of Wildlife Conservation, Federal Aid in Wildlife Restoration Project 16.0, Juneau.

Lenart, E. A. 2007. Units 26B and 26C muskox. Pages 49–69 [*In*] P. Harper, editor. Muskox management report of survey and inventory activities 1 July 2004–30 June 2006. Alaska Department of Fish and Game, Division of Wildlife Conservation, Federal Aid in Wildlife Restoration Project 16.0, Juneau.

Lenart, E. A. 2015a. Units 26B and 26C muskox. Chapter 4, pages 4-1 through 4-26 [*In*] P. Harper and L. A. McCarthy, editors. Muskox management report of survey and inventory activities 1 July 2012–30 June 2014. Alaska Department of Fish and Game, Species Management Report ADF&G/DWC/SMR-2015-4, Juneau.

Lenart, E. A. 2015b. Units 25A, 25B, 25D, 26B, and 26C brown bear. Chapter 25, pages 25-1 through 25-23 [*In*] P. Harper and L. A. McCarthy, editors. Brown bear management report of survey and inventory activities 1 July 2012–30 June 2014. Alaska Department of Fish and Game, Species Management Report ADF&G/DWC/SMR-2015-1, Juneau.

Lent, P. C. 1998. Alaska's indigenous muskoxen: A history. Rangifer 18(3-4):133–144.

Mavrot F., and K. Orsel, W. Hutchins, L. G. Adams, K. Beckmen, J. E. Blake, M. Branigan, S. Checkley, T. Davison, J. DiFrancesco, B. Elkin, L.-M. Leclerc, A. Schneider, M. Tomaselli, and S. Kutz. 2020. Novel insights into serodiagnosis and epidemiology of *Erysipelothrix rhusiopathiae*, a newly recognized pathogen in muskoxen (*Ovibos moschatus*). PLoS ONE 15(4):e0231724. https://doi.org/10.1371/journal.pone.0231724.

Nedwick, M. M., editor. 2010. Muskox: A guide to identification, hunting and viewing [revised booklet]. Alaska Department of Fish and Game, Division of Wildlife Conservation, Kotzebue.

Paul, T. W. 2009. Game transplants in Alaska. Second edition. Alaska Department of Fish and Game, Division of Wildlife Conservation, Technical Bulletin 4, Juneau.

Reynolds, P. E., H. V. Reynolds, and R. T. Shideler. 2002. Predation and multiple kills of muskoxen by grizzly bears. Ursus 13:79–84.

Reynolds, P. E. 2008. Muskoxen in the Arctic National Wildlife Refuge, Game Management Unit 26C, 2007–2008. Arctic National Wildlife Refuge, U.S. Fish and Wildlife Service, Fairbanks, Alaska.