Alaska Department of Fish and Game
Division of Wildlife Conservation
October 1997

Estimating Rates and Causes of Neonatal Lamb Mortality of Dall Sheep in the Central Alaska Range

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Federal Aid in Wildlife Restoration
Research Final Report
1 May 1995–30 June 1997

Grants W-24-4, W-24-5
Study 6.12

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RESEARCH FINAL REPORT

STATE: Alaska **STUDY NO.:** 6.12

COOPERATOR: University of Montana

GRANT NO.: W-24-4 and W-24-5

STUDY TITLE: Estimating Rates and Causes of Neonatal Lamb Mortality of Dall Sheep in the Central Alaska Range

AUTHOR: Bradley D Scotton

PERIOD: 1 May 1995-30 June 1997

SUMMARY

I used a Hughes 500 turbine helicopter and a Robinson R-22 piston helicopter to capture and radiocollar 25 newborn Dall sheep (*Ovis dalli*) lambs in May 1995 and 37 in May 1996. I evaluated 3 techniques for capturing lambs and submitted a research paper entitled "Evaluation of Capture Techniques for Neonatal Dall Sheep Lambs" to *Wildlife Society Bulletin* in March 1997. Lambs were radiotracked daily for about 25 days and then at least monthly in both 1995 and 1996. Cause of death for lambs was determined when possible. Predation was the cause of death in 22 of 23 cases. Coyotes (*Canis latrans*) were the most common cause of mortality (43%) of radiocollared Dall sheep lambs. Golden eagles (*Aquila chrysaetos*) accounted for an additional 22% of collared lambs' deaths. Wolves accounted for only 1 of the 22 deaths. Mortality was highest during the neonatal period (<30 days old; 57% of all mortalities). Despite a 3-fold increase in the number of wolves (*Canis lupus*) in the study area from March 1995 to March 1997, predation of lambs by wolves did not increase. Peak lambing date was near 20 May both years. Postlambing surveys were flown in the study area both years to assess population productivity and estimate population size. Productivity improved since the early 1990s but remains below the long-term average. Numbers of sheep have stabilized and possibly increased slightly since 1994.

Key words: capture, coyote, Dall sheep, eagle, helicopter, lamb, mortality, surveys.

CONTENTS

BACKGROUND

Dall sheep (*Ovis dalli*) inhabit most major mountain ranges in Alaska. They are one of many big game species that thousands of visitors come to view, photograph, or hunt every year. Approximately 3000 hunters venture afield in Alaska every fall in pursuit of Dall rams.

Since the late 1960s, 150 to 450 sheep hunters have gone afield every year in the Central Alaska Range (CAR). Nonresident hunters are required to have a guide to hunt sheep, thus contributing greatly to Alaska's economy (Watson 1986). Residents frequently charter aircraft to hunt sheep which also contributes to the state's economy. Viewing and photography of wildlife increased during the past several years. Each summer one fly-in resort located in the middle of the CAR accommodated 5000 person/nights for wildlife viewing and recreation. Flight-seeing operations based at Denali National Park are increasingly extending eastward into the CAR to view spectacular scenery, sheep, and other wildlife. Other outdoor recreationists use the area primarily for trapping, skiing, dog mushing, and snowmachining during winter.

Biologists estimated the CAR contained between 4000 and 5000 Dall sheep from 1968 until 1989. No comprehensive surveys were flown during this time, but some trend areas were counted and mineral lick usage was monitored. Summer surveys conducted in 1991, 1992, and 1993 indicated that productivity of the population was low. Only 18 lambs:100 "ewes" (i.e., includes some yearlings and young rams) were seen in 1991, 5:100 in 1992, and 12:100 in 1993. All 3 years were well below the long-term average of 46:100 (primarily from lick counts which do not contain many yearlings or young rams) in the CAR. A comprehensive survey of the CAR in 1994 yielded an estimate of 1942 ± 17% (90% CI) sheep, indicating the population declined by approximately 60% (Whitten and Eagan 1995). Sheep numbers, hunter numbers, and harvests were all far below historical levels in 1994. Only 150 sheep hunters ventured into the CAR in 1994, harvesting 49 rams. These low numbers initiated interest in investigating factors influencing Dall sheep productivity and lamb survival in the CAR.

Predation, weather, disease, range condition, maternal investment, inbreeding depression, and human disturbance all impact survival of wild sheep lambs (Buechner 1960; Woodard et al. 1974; Nichols 1978; DeForge and Scott 1982; Burles and Hoefs 1984; Hoefs 1984; Douglas and Leslie 1986; Foreyt 1988; Hass 1989; Bleich et al. 1994; Rachlow and Bowyer 1994). Winter die-offs of adult sheep due to nutritional stress and increased predation have also been recorded periodically (Murie 1944; Burles and Hoefs 1984). Hunting of mature rams has had little or no effect on the sizes or productivity of Dall sheep populations in Alaska (Murphy et al. 1990).

Ratios of 5 to 67 lambs:100 "ewes" have been recorded in the CAR during late June/early July since 1968. Variability in lamb:ewe ratios has been loosely correlated with weather indices in some studies (Nichols 1978; Heimer and Watson 1986). Such high variability in calf:cow ratios of caribou (*Rangifer tarandus*) and moose (*Alces alces*) populations in the same general range has not been recorded (Gasaway et al. 1983), and causes of variability in sheep lamb:ewe ratios remain unclear. Summer lamb:ewe ratios have never been compared with known ratios of pregnant ewes, and lambs have not been collared to determine causes and timing of mortality. Survival of lambs through their first winter has been estimated by comparing lamb:ewe ratio to yearling:ewe ratios the following spring, but yearlings can be difficult to classify and estimations can easily be complicated by ingress or egress of yearlings or ewes from the count area. Causes of death are rarely known without marked individuals.

Wolves (*Canis lupus*), grizzly bears (*Ursus arctos*), coyotes (*Canis latrans*), and wolverines (*Gulo gulo*) inhabit the area and are potential predators of adults and lambs. Golden eagles (*Aquila chrysaetos*) also inhabit the CAR and have been observed killing Dall sheep lambs in Canada (Nette et al. 1984). Burles and Hoefs (1984) noted an increase in predation by wolves and coyotes during a period of deep snow in Kluane Park, Yukon.

Wolf removal experiments in the CAR during the 1970s improved fall (Sep and Oct) and late winter (Mar and Apr) calf:cow ratios for moose but had little effect on Dall sheep productivity according to Gasaway et al. (1983). Heimer and Stephenson (1982) provided some anecdotal evidence that Dall sheep numbers were declining prior to wolf removal and may have stabilized as a result of the removal program. However, lamb:ewe ratios in late June were the only indicator of sheep productivity measured at the time and did not differ from an adjacent area (Denali National Park) where wolves were not removed (Murphy and Whitten 1976; Gasaway et al. 1983).

The wolf population in the CAR was again experimentally decreased by approximately 50% during the winters of 1993-1994 and 1994-1995 to benefit a declining caribou population. Wolf removal ended in January 1995 when only 9 wolves in 3 packs continued to use the current sheep study area (Fig 1). By March 1997 wolf numbers increased to 26 in 3 packs (M McNay, Alaska Dep Fish and Game, pers commun).

OBJECTIVES

- Develop a technique for the capture and handling of neonatal Dall sheep lambs (this has never been done).
- Determine the rate and causes of lamb (> 24 hr old) mortality within the study area.
- Assess possible changes in predation rates on lambs as the CAR wolf population rebounds following a 2-year wolf removal program.
- Determine the peak lambing date and birth weights of lambs in this study area.

METHODS

STUDY AREA

We captured and radiocollared newborn lambs in the central Alaska Range Mountains (Unit 20A) in a 1320 km^2 area approximately 75 km east of Denali National Park. This roadless area is accessible by aircraft or by off-road vehicles during winter months. Most sheep habitat is 950 to 2200 m above sea level. Vegetation is typically < 1 m high. Terrain varies greatly and contains large open bowls, steep scree slopes, steep bouldered slopes, sharp ridges with offset pinnacles, steep cliff faces with terrace-like benches, and gentle grassy slopes. Mature rams are hunted in this area during a 40-day period each fall; ewes are not hunted. Sheep in this area were not habituated to humans and were not easily approachable from the ground. Sheep density was approximately 1.3/km^2 in a 530 km^2 portion of the study area which is surveyed annually.

Field operations took place from an airstrip/cabin complex in the study area at the confluence of Newman Creek and Dry Creek in the CAR. Capture and daily radiotracking operations took place from this field camp between 11 May and 11 June 1995 and 1996. Once these daily operations were completed, personnel and aircraft were moved to Fairbanks.

We used 2 types of helicopters in our attempt to develop a capture technique for lambs. A Hughes 500 turbine helicopter equipped with a skid-mounted net gun was used to fire a 3.5 m x 3.5 m net (40-cm mesh) over newborn lambs. A 300-gram weight was attached to each corner of the net, which was propelled by a blank 0.308 rifle cartridge. A Hughes 500 and a Robinson-22 helicopter also were used to position researchers near lambs for capture by hand.

Each lamb was weighed with a sling and spring scale, and radiocollared (Telonics, Mesa, Ariz) with an elastic-banded, expandable collar designed to last 15 months. Each collar contained a motion-sensing "mortality" switch. Sex was recorded and age estimated by categorizing the umbilicus as wet (1 to 24 h old), partially dried (24 to 48 h), or dried (>48 h). We recorded the lamb's ability to run, color of its pelage, and stature as qualitative indices of age. Time of handling ranged from 2 to 15 minutes. The helicopter hovered or landed >500 m from the capture site while the biologist collared and weighed the lamb and returned immediately upon being signaled. We attempted to expedite reunification (by hazing the mother in the direction of the lamb) of ewe-lamb pairs that became separated by >500 m during the capture process. We visually estimated distance of mother from lamb when the location of the mother was known. Handling time was recorded to the nearest minute. We returned 4 to 20 hours later to assess whether ewe/lamb pairs were reunited in cases where the reunification was not witnessed immediately after the capture event.

Lambs were radiotracked at least once daily for approximately 20 days after capture with either a fixed-wing aircraft (Bellanca Scout) or R-22 helicopter. Thereafter, lambs were tracked at least once per month until the end of April and approximately biweekly during the summer. Mortality signals were investigated as soon as possible. We thoroughly inspected mortalities and mortality sites from the ground. A bloody collar or other trauma indicated predation. Animal tracks, feces, hair, feathers and patterns of consumption provided clues about the agent of death (Ballard et al. 1979). Mortalities with evidence of more than 1 predator at the site were classified as "unknown" but some predators were ruled out during this process.

I flew postlambing surveys in 1994, 1995, 1996, and 1997 in association with this research project. The survey area included the west side of West Fork Little Delta River, all of Dry Creek, Sheep Creek, Rogers Creek and the northern side of Kansas Creek (Fig 1). All sheep habitat in this area was inspected at an intensity of approximately 0.8 min/km^2 each year. I surveyed from a Supercub in 1994 and from an R-22 helicopter thereafter.

RESULTS AND DISCUSSION

CAPTURE

Sixty-two lambs were captured and radiomarked during 1995 (n = 25) and 1996 (n = 37)

(Appendix A). We captured 53 lambs by hand from the R-22 (including 2 cases in which lambs, still wet and unable to run, were captured by landing more than 500 m away and approaching on foot) and 6 more lambs by hand from the Hughes 500. Three lambs were captured using the skid-mounted net gun on the Hughes 500. Two other attempts at the net-gun capture were aborted after long chases and 4 missed shots. We captured 30 males, 29 females, and 3 lambs of unknown sex. Thirty-seven lambs were estimated to be < 48 h old at capture and 25 were estimated to be 48 to 72 h old. Sixteen of 53 lambs immediately reunited with their mother when using the R-22, and 1 of 9 immediately reunited while using the Hughes 500. Two of 62 mothers attempted to defend their lamb by butting the biologist. Maternal distance from lamb at the time of release was greater for captures with the Hughes 500 ($\bar{x}$ = 300 m) than with the R-22 ($\bar{x}$ = 79 m; $t = 2.055$, df = 43, $P = 0.046$). Time of capture was greater when using the Hughes 500 ($\bar{x}$ = 11.0 min) compared to the R-22 ($\bar{x}$ = 2.8 min; $t = 2.29$, df = 27, $P = 0.03$).

MORTALITY

No lambs died immediately as a result of capture and handling. However, 2 lambs were probably killed before they reunited with their mothers. Both were captured simultaneously by hand from the Hughes 500. We excluded these lambs from analysis because of uncertainty whether these lambs had reunited with their mothers before an eagle attack. One additional lamb was killed by an eagle before it was seen with its mother. Pebbles in its stomach at the time of death indicated that it may have been abandoned. This was the second lamb captured and although capture/handling time was not recorded, the capture event was prolonged and included 8 to 12 minutes with the R-22 hovering nearby. This lamb was also excluded from analysis.

Predators killed 7 lambs (Table 1), and 12 lambs were still alive and on the air after 1 year. However, 2 lambs captured in 1995 shed their collars, and 1 radiocollar probably failed. Two lambs were killed by coyotes, 1 by an eagle, 1 by a wolf, 1 by a bear, and 2 others by either wolves or coyotes (Table 2). Five of the mortalities occurred May through October and 2 during the winter (Table 3). Thirty-two percent of lambs died before 1 year of age.

Three of 37 lambs captured in 1996 may have shed their collars and predators killed 16 lambs (Table 4). The shed collars were found only 5 days after capture with no blood on them or any sign of a mortality. Because ewes were not collared, there was no way to know if the lambs were alive. Three radiocollars failed midwinter and 15 animals were still alive and on the air after 1 year. Eight of the 16 mortalities were caused by coyotes, 4 by eagles, 1 by a wolverine, and 1 died in a rockslide (Table 5). Cause of death for the 2 other lambs could not be determined definitively, but they were killed by either a wolf or a coyote. Eleven mortalities occurred from May through October and 5 during winter months (Table 6). Mortality rate to 1 year of age was 47%.

Twenty-two of 23 mortalities that occurred during this 2-year study were attributed to predation. Forty-two percent of lamb deaths occurred during the neonatal period (1 to 30 days) in 1995 and 63% in 1996. Coyotes were the most common predators, causing 43% of mortality. Eagles caused 5 of 23 mortalities (22%), and wolves killed 1 of 23 (4%).

Cause of death could not positively be determined for 4 more lambs; however, they were killed either by wolves or coyotes (17%) (Tables 2 and 5). We observed coyotes in sheep habitat frequently during the study, while wolves were observed only once.

Birth Weight

A significant difference ($P = 0.032$) occurred between the weight of lambs born in 1995 ($\bar{x} = 8.9$) and those born in 1996 ($\bar{x} = 9.8$) (Table 8). Some of this difference may be attributed to age of the lambs at time of capture. Eighty-three percent of lambs captured in 1995 were <48 h old and 42% were <48 h old in 1996 (Table 9). Weights of lambs < 48 h old and > 48 h old did not differ significantly within years (1995:$P = 0.27$; 1996:$P = 0.24$); however, lambs estimated to be older tended to be heavier both years (Table 9). Birth weights of male and female lambs did not differ significantly, unlike those reported for caribou calves (Adams et al. 1995). However, when a model selection operation was performed on these data (Appendix B), an interaction between age at capture and sex became significant. Differences between years were essentially nullified by differences in age at capture. When year effects were removed, sex did become a significant indicator of weight.

Lambing Date

We estimated median lambing date to be on or near 20 May in both years. Because no adult ewes were collared, I recorded ewe:lamb ratios from daily observations of sheep. Sample size varied daily as different portions of the study area were surveyed. These data were viewed qualitatively to estimate median lambing date. Lambing seemed to be highly synchronous. Lambs were first seen on 15 May 1995 and 12 May 1996. We rarely found newborn lambs after 28 May either year, although I collared 1 newborn on 9 June 1996. Bunnell (1980) also documented predictable lambing periods for Dall sheep. Other researchers, however, have documented variation in timing and synchrony of parturition of Dall sheep (Nichols 1978; Rachlow and Bowyer 1994). Condition of ewes during the rut, or winter conditions during gestation, may influence birth date and, subsequently, survival through 1 year of age.

Population

Only 567 sheep were found in June 1997 where 1089 were found in 1984 (Table 7). A population productivity index of lambs:100 "ewes" (34:100 in 1994, 35:100 in 1995, 37:100 in 1996, and 28:100 in 1997) was higher than surveys indicated in 1991 (18:100), 1992 (5:100), and 1993(12:100). This indicates the sheep in the CAR are beginning to recover from the decline of 60% between 1984 and 1994. The total number of ewes (212) and lambs (85) counted in 1997 was down from 1996 (267 ewes, 137 lambs). The decreased number of adult ewes sighted during the June 1997 survey may indicate higher mortality during the winter of 1996-1997 or may indicate some emigration from the survey units. The relatively low ratios of lambs:100 ewes may be indicative of an age structure lacking in 4- to 7-year-old sheep. If young sheep are not yet reproducing and middle-aged sheep are not present, then older sheep are the only cohorts reproducing.

CONCLUSIONS AND RECOMMENDATIONS

HELICOPTER COMPARISON

The Robinson R-22 proved to be a reliable and effective aircraft for capturing Dall sheep lambs. Ewes did not run as far from the R-22 as from the Hughes 500 and capture events were shorter. The result was a less disturbing capture event and probably a quicker reunification of ewe and lamb, and thus a decreased likelihood of researcher-induced mortality. It was difficult to separate lamb-ewe pairs adequately to obtain shots with the skid-mounted net-gun. A shoulder net-gun may be more effective because positioning of the helicopter is not as critical to the shot placement. The expense of using the R-22 was about half the cost of a Hughes 500 helicopter ($245/hr versus $550/hr). The R-22 is also a good platform for sheep surveys, has better visibility than a Supercub, and can be flown slower. Classification of sheep age/sex classes is also easier in the R-22 as lower, slower passes are possible. Supercubs are still less expensive and should be used for surveying large areas at low intensities where composition data are not required. Bleich et al. (1994) cautioned against the use of turbine helicopters for bighorn sheep surveys due to their disturbance level to sheep. Because the R-22 disturbed sheep less than the Hughes 500, I recommend use of the R-22 for future research projects involving Dall sheep when a helicopter is required and a choice of helicopter type is available.

PREDATION

Although mortality rates in 1995 and 1996 do not seem to be excessively high, predation of lambs was common during this study. Despite the 3-fold increase of the wolf population ranging within the sheep study area (9 in March 1995 to 26 in March 1997), we noted no increase in lamb mortality due to wolves. Wolves accounted for only 1 radiocollared lamb death but may have been involved in 2 other deaths each year. Hunting lambs may not be energetically efficient for wolves in this area where alternate prey are abundant. Wolves are known to prey on Dall sheep (Murie 1944; Sumanik 1987; Dale et al. 1993), but the effect of that predation on Dall sheep populations is not known. Sumanik (1987) believed that wolf packs could not prosper by hunting only sheep. Heimer and Stephenson (1982) reported that only 2% of wolf stomachs collected during wolf control in Unit 20A in the 1970s contained sheep remains. Sheep populations where alternate prey is scarce may be more strongly influenced by wolf predation. For instance, some parts of the Brooks Range have very low moose populations and seasonal caribou populations, leaving sheep as the only year-round prey for wolves. Wolves can hold moose populations at low densities (Gasaway et al. 1983) and can prevent growth of some Interior Alaska caribou herds (Adams et al. 1995; Boertje et al. 1996); others (Heimer and Stephenson 1982; Sumanik 1987) discussed wolf influences over Dall sheep populations.

Coyotes and eagles are currently the most important predators of Dall sheep lambs in this portion of the CAR. Coyotes were responsible for the death of at least 10 (43% of total deaths) of the radiocollared lambs and may have been involved in 4 other deaths. Anecdotal evidence indicates that coyotes are present throughout much of the sheep habitat in Interior and Southcentral Alaska; however, no studies have ever been conducted to determine the specific niches coyotes may occupy. We frequently observed coyotes while capturing and radiotracking lambs. In 3 of the 10 coyote kills, the head of the lamb was severed from its body and buried in the dirt or moss on a hillside. Burles and Hoefs (1984) found increased predation by coyotes on adult sheep during winters with high snowfall in Kluane Park, Canada. Guides and sheep hunters recently reported seeing more coyotes in the CAR and other parts of the state than they have in the past. The lack of knowledge about coyotes, coyote-wolf interactions, and coyote-prey interactions in Alaska invites further research.

Although no spatial analysis of mortality locations was performed, 1 pattern emerged from the data. Several mortalities that occurred during the winter were in the Sheep Creek drainage. At least 4 radiocollared lambs were killed at the bottom of steep bluffs in Sheep Creek at the base of the mountains to the north. While investigating radiocollared lamb mortalities, we found the remains of other sheep as well. Coyotes and wolves may use these bluffs to their advantage when hunting sheep. Murie (1944) described wolves running sheep to marginal escape terrain and using it to their advantage. Deeper snow in the valley bottom may provide further advantage to predators in this situation.

Eagles were common in the study area and killed 5 radiocollared lambs during the lambs' first 30 days of life. I recorded the number of eagles seen during the 1-day survey of the study area in each of 4 years. Four golden eagles were counted during the 1994 survey, 5 in 1995, 13 in 1996, and 24 in 1997. We have no estimate of the number of nesting eagles in the area. Eagles were seen daily during lamb capture operations and were observed hunting lambs. A study of golden eagle food habits and prey selection would help identify their relative importance to the dynamics of Dall sheep populations. Golden eagles may rely more heavily on sheep lambs in years when arctic ground squirrel (*Spermophilus parryii*) abundance is low.

A bear and wolverine each killed a radiocollared lamb, but these predators are probably not important in the long-term population dynamics of Dall sheep. Rugged terrain probably prevents bears from catching many sheep.

This study indicates that predation of lambs may be influencing the recovery rate of the CAR sheep population. Recruitment is a function of both productivity and survival of young. If adult survival and lamb birth rates remain high, the population should grow. If adult survival or lamb productivity is low, the low lamb survival may prevent growth of the population or lead to a decline. Information about adult survival and productivity is necessary to understand the dynamics of this sheep population. Collaring adult sheep in the CAR and in other populations would benefit our survey-and-inventory activities. By radiocollaring adults, we could monitor effects of predation and weather on adult survival. Variation in annual productivity could be monitored at the individual level by radiocollaring adult ewes.

Body Condition

Body condition has been closely correlated with reproductive performance in caribou (Cameron and Ver Hoef 1994). Body condition, pregnancy rates, and forage quality studies may by useful in understanding population trend count information. Lenart (1997) recently found that summer weather in Interior Alaska influences the quality and quantity of caribou forage at high elevation sites. A relatively warm and dry summer decreased the quality of forage (Lenart 1997). Dall sheep occupy rugged terrain in areas of high elevation, high latitude, and high predator density. This combination may make Dall sheep more prone to declines. Pregnancy rate among caribou in Interior Alaska herds declined during the early 1990s. This implies a widespread climatic event may have resulted in loss of body condition among caribou. A similar trend may have occurred among sheep, causing at least some sheep not to gain the physiological condition necessary to become pregnant, sustain a pregnancy, or even survive the winter. Forage availability to sheep during gestation or ewe body condition during estrus may explain variation in parturition date and synchrony observed by Rachlow and Bowyer (1994). Unfortunately, weather data in sheep habitat are lacking. Weather conditions in the mountains often differ significantly from weather reporting stations only a few miles away. I recommend establishing remote weather stations in sheep habitat. Comparison of these data with concurrent weather data collected at adjacent established weather stations would help us interpret the value of those traditional weather reporting stations for mountainous areas.

At low population numbers and densities, a conservative harvest strategy of full-curl rams only is adequate to ensure that hunting does not exacerbate sheep population fluctuations. As Interior sheep populations recover, a better understanding of sheep population dynamics and physiology could allow us to adopt more liberal harvest strategies and increase opportunities for hunters. Numerous potential research projects on Dall sheep exist. For example, research on predator-sheep dynamics, adult survival, physiology related to reproduction, rutting behavior, and impacts of ewe harvests on high-density sheep populations should be considered. In light of current budget restrictions, I would first recommend reviewing survey-and-inventory priorities and setting a schedule for surveying trend areas, using standardized techniques. Research priorities should then be considered.

ACKNOWLEDGMENTS

I thank J Larrivee (Pollux Aviation Ltd.) for his outstanding piloting skills and interest in the success of this project; P Valkenburg for his cooperation and assistance; S Murley and J Mitchell for their field support; R Schikora, J Sewell, and M Potter for the use of field facilities and the airstrip; K Whitten for his advice and review of this manuscript; K Taylor, B Martin, B Dale, M McNay, M Webb, T Cambier, R Swisher, D Miller, C Solloy, and M Keech for their assistance and B Lenart for her inspiration. This project was funded by sportsmen and gun enthusiasts through the Fish and Wildlife Restoration Fund and the Alaska Department of Fish and Game.

LITERATURE CITED

ADAMS LG, FJ SINGER AND BW DALE. 1995. Caribou calf mortality in Denali National Park, Alaska. *J Wildl Manage.* 59:584-594.

BALLARD WB, AW FRANZMANN, KP TAYLOR, T SPRAKER, CC SCHWARTZ, AND RO PETERSON. 1979. Comparison of techniques utilized to determine moose calf mortality in Alaska. Proc North Amer moose conf. 15:362-385.

BLEICH VC, RT BOWYER, AM PAULI, MC NICHOLSON, AND RW ANTHES. 1994. Mountain Sheep (*Ovis canadensis*) and helicopter surveys: Ramifications for the conservation of large mammals. *Biol Conserv*. 70:1-7.

BOERTJE RD, P VALKENBURG, AND ME MCNAY. 1996. Increases in moose, caribou, and wolves following wolf control in Alaska. *J Wildl Manage* 60(3):474-489.

BUECHNER HK. 1960. The bighorn sheep in the United States, its past, present, and future. *Wildl Monogr* 4:1-174.

BUNNELL FL. 1980. Factors controlling lambing period of Dall's sheep. *Can J Zool* 58:1027-1031.

BURLES DW AND M HOEFS. 1984. Winter mortality of Dall sheep, *Ovis dalli dalli*, in Kluane National Park, Yukon. *Can Field-Nat* 98:479-484.

CAMERON RD AND JM VER HOEF. 1994. Predicting parturition rate of caribou from autumn body mass. *J Wildl Manage* 58:674-679.

DALE BW, LG ADAMS, AND RT BOWYER. 1993. Winter wolf predation in a multiple ungulate prey system, Gates of the Arctic National Park, Alaska.

DEFORGE JR AND JE SCOTT. 1982. Ecological investigations into high lamb mortality. Desert Bighorn counc trans. 65-76pp.

DOUGLAS CL AND DM LESLIE JR. 1986. Influence of weather and density on lamb survival of desert mountain sheep. *J Wildl Manage* 50:153-156.

FOREYT WJ. 1988. Reproduction of Rock Mountain Bighorn sheep (*Ovis c. canadensis*) in Washington: Birth dates, yearling ram reproduction and neonatal diseases. *Northwest Science* 62:161-164.

GASAWAY WC, RO STEPHENSON, JL DAVIS, PEK SHEPHERD, AND OE BURRIS. 1983. Interrelationships of wolves, prey, and man in interior Alaska. *Wildl Monogr* 84:1-50.

HASS CC. 1989. Bighorn lamb mortality: predation, inbreeding, and population effects. *Can J Zool* 67:699-705.

HEIMER WE AND RO STEPHENSON. 1982. Responses of Dall sheep populations to wolf control in interior Alaska. Proc sixth biennial symp North Am wild sheep and goat counc. 3:320-329

—— AND SM WATSON. 1986. Comparative dynamics of dissimilar Dall sheep populations. Fed Aid in Wildl Restor. Final Rep. Job No. 6.9R.

HOEFS M. 1984. Productivity and carrying capacity of a subarctic sheep winter range. *Arctic* 2:141-147.

LENART EA. 1997. Effects of weather on caribou forages, productivity and nutrition within the range of the Chisana Herd. Master's Thesis, Univ Alaska Fairbanks.

MURIE A. 1944. The wolves of Mt McKinley. US Dep Interior, Natl Park Serv. Fauna Serv. 5. 283pp.

MURPHY EC AND KR WHITTEN. 1976. Dall Sheep demography in McKinley Park and a reevaluation of Murie's data. *J Wildl Manage* 40:597-609.

——, FJ SINGER, AND L NICHOLS. 1990. Effects of Hunting on survival and productivity of Dall Sheep. *J Wildl Manage* 54:284-290.

NETTE T, D BURLES, AND M HOEFS. 1984. Observations of golden eagle, *Aquila chrysaetos*, predation on Dall sheep, *Ovis dalli dalli*, lambs. *Can Field-Nat* 98:252-254.

NICHOLS L. 1978. Dall sheep reproduction. *J Wildl Manage* 43:570-580.

RACHLOW JL AND RT BOWYER. 1994. Variability in maternal behavior by Dall's sheep: Environmental tracking or adaptive strategy? *J Mammal* 75:328-337.

SUMANIK RS. 1987. Wolf ecology in the Kluane Region, Yukon Territory. Masters Thesis, Michigan Tech Univ.

WATSON SM. 1986. Dall sheep hunting in Alaska: What is it worth? Proc fifth bienn symp north wild sheep and goat counc. 129-148pp.

WHITTEN KR AND RM EAGAN. 1995. Estimating population size and composition of Dall sheep in Alaska: Assessment of previously used methods and experimental implementation of new techniques. Res Final Rep. Study 6.11.

WOODARD TN, RJ GUTIERREZ, AND WH RUTHERFORD. 1974. Bighorn lamb production, survival, and mortality in South-Central Colorado. *J Wildl Manage* 38:771-774.

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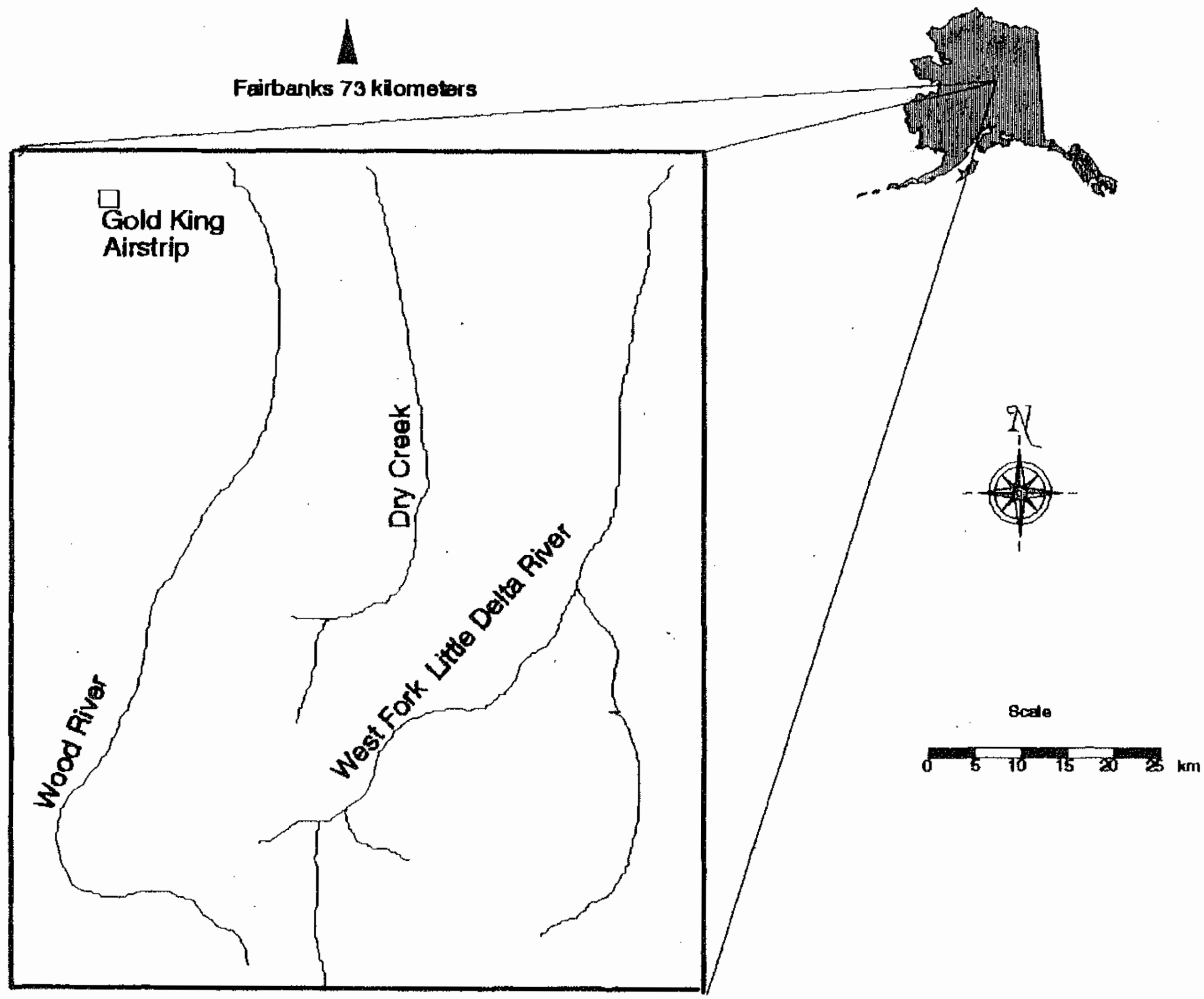

Figure 1 Dall sheep lamb mortality study area in the Central Alaska Range

Table 1 Summary of captures and mortalities May 1995 through April 1996

Number lambs captured/collared	Number excluded from mortality analysis	Total number of mortalities[a]	Number of shed collars
25	3[b]	7	2

[a] Does not include censored lambs.
[b] All due to eagles killing lambs before reunification with ewe.

Table 2 Causes of death May 1995 through April 1996

Cause of death						
Unknown (wolf/coyote)	Coyote	Eagle	Wolf	Bear	Wolverine	Rockslide
2	2	1	1	1	0	0

Table 3 Timing of mortality May 1995 through April 1996

Month											
May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
2	1	1	1 shed collar	0	1	0	1 shed collar	0	1	1	0

Table 4 Summary of captures and mortalities May 1996 through April 1997

Number lambs captured/collared	Number excluded from mortality analysis	Total number of mortalities	Number of shed collars
37	3	16	3

Table 5 Causes of death May 1996 through April 1997

Cause of death						
Unknown (wolf/coyote)	Coyote	Eagle	Wolf	Bear	Wolverine	Rockslide
2	8	4	0	0	1	1

Table 6 Timing of mortality May 1996 through April 1997

Month											
May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
6	4	1	0	0	0	2	1	2	0	0	0

Table 7 Results of surveys flown from 1984-1997

Year	Area 1	Area 2	Area 3	Total	No. adults (> 1 yr old)	No. lambs
1984[a]	350	393	246	1089	861	228
1991[a]	220	288	131	639	569	68
1993[a]	154	210	no data	364[b]	no data	incomplete data
1994[a]	167	169	106	442	370	72
1995[b]	200	216	170	586	477	109
1996[b]	260	226	171	657	520	137
1997[b]	272	189	106	567	482	85

[a] Surveys flow in Supercub PA-18.
[b] Not all subunits surveyed.
[c] Surveys flown in Robinson R-22 helicopter.

Table 8 Weights of lambs captured in 1995 and 1996

	1995 Weights (lb) (*n*)	1996 Weights (lb) (*n*)	*P*-value 95 versus 96
Males	8.8 (10)	9.9 (19)	0.015
Females	8.9 (13)	9.4 (16)	0.361
Combined	8.9 (23)	9.6 (35)	0.032

Table 9 Lamb weights by estimated age

Year	Average weight of lambs < 48 hr old	Average weight of lambs > 48 hr old	*P*-value
1995	8.7 pounds ($n = 20$)	9.8 pounds ($n = 4$)	0.27
1996	9.3 pounds ($n = 15$)	9.8 pounds ($n = 21$)	0.24

APPENDIX A List of all lambs captured, weight, sex, date of capture, date discovered dead or shed collar retrieved, and cause of death

Animal number	Date of capture	Helicopter type	Capture method	Weight (lb)	Sex	Date discovered dead/shed	Cause of death
3	5/18/95	Robinson	By hand	8.5	F	5/23/95	Coyote
1	5/18/95	Robinson	By hand	9.0	F	5/19/95	Eagle, before reuniting with ewe; excluded from analysis
2	5/18/95	Robinson	By hand	9.0	F	N/A	
6	5/19/95	Robinson	By hand	8.5	M	N/A	
9	5/19/95	Robinson	By hand	8.5	M	9/26/95	Wolf
5	5/19/95	Robinson	By hand	9.0	F	N/A	
8	5/19/95	Robinson	By hand	9.0	M	2/29/96	Coyote
7	5/19/95	Robinson	By hand	9.0	F	N/A	
4	5/19/95	Robinson	By hand	9.5	F	N/A	
10	5/20/95	Robinson	Walked to it			12/17/95	Censored (shed collar)
11	5/20/95	Robinson	By hand	8.0	M	N/A	
13	5/22/95	Hughes	By hand	8.0		N/A	
12	5/22/95	Hughes	Net gun	9.0	F	N/A	
14	5/22/95	Robinson	Walked to it	8.5	M	N/A	
15	5/23/95	Hughes	By hand	6.5	F	7/21/95	Unknown (wolf/coyote)
20	5/23/95	Hughes	By hand	7.0	F	5/24/95	Eagle
18	5/23/95	Hughes	By hand	7.5	F	5/23/95	Eagle, before reuniting with ewe; excluded from analysis
16	5/23/95	Hughes	Net gun	8.5	M	8/01/95	Censored (shed collar)
21	5/23/95	Hughes	Net gun	9.5	F	N/A	
19	5/23/95	Hughes	By hand	10.0	M	5/24/95	Eagle, before reuniting with ewe; excluded from analysis
17	5/23/95	Hughes	By hand	10.5	F	N/A	
22	5/24/95	Robinson	By hand	9.0	M	6/02/95	Bear
23	5/24/95	Robinson	By hand	9.5	M	N/A	
24	5/26/95	Robinson	By hand	9.5	M	2/01/96	Unknown (wolf/coyote)
25	5/26/95	Robinson	By hand	12.0	F	N/A	
26	5/12/96	Robinson	By hand	9.5	M	N/A	
30	5/13/96	Robinson	By hand	9.0	M	N/A	
31	5/13/96	Robinson	By hand	10.0	M	N/A	
33	5/13/96	Robinson	By hand	10.0	M	N/A	
32	5/13/96	Robinson	By hand	11.0	F	1/17/97	Coyote
27	5/13/96	Robinson	By hand	11.0	M	5/17/96	Censored (shed collar)
28	5/13/96	Robinson	By hand	11.0	F	5/23/96	Eagle

APPENDIX A Continued

Animal number	Date of capture	Helicopter type	Capture method	Weight (lb)	Sex	Date discovered dead/shed	Cause of death
29	5/13/96	Robinson	By hand	11.0	M	N/A	
35	5/14/96	Robinson	By hand	8.5	F	5/19/96	Censored (shed collar)
36	5/14/96	Robinson	By hand	8.5	M	5/20/96	Wolverine
34	5/14/96	Robinson	By hand	9.0	F	5/19/96	Censored (shed collar)
37	5/14/96	Robinson	By hand	10.5	M	N/A	
39	5/16/96	Robinson	By hand	8.0	F	N/A	
38	5/16/96	Robinson	By hand	10.0	F	N/A	
42	5/17/96	Robinson	By hand	9.0	M	6/02/96	Eagle
40	5/17/96	Robinson	By hand	9.0	M	6/10/96	Coyote
41	5/17/96	Robinson	By hand	11.5	M	N/A	
43	5/18/96	Robinson	By hand	7.5	F	5/30/96	Eagle
47	5/18/96	Robinson	By hand	10.0	F	N/A	
45	5/18/96	Robinson	By hand	10.0	M	11/18/96	Unknown (wolf/coyote)
46	5/18/96	Robinson	By hand	11.0	M	N/A	
44	5/18/96	Robinson	By hand	11.0	F	11/18/96	Unknown (wolf/coyote)
48	5/19/96	Robinson	By hand	8.5	M	6/17/96	Coyote
49	5/19/96	Robinson	By hand	9.0	F	6/26/96	Eagle
50	5/20/96	Robinson	By hand	7.0		5/25/96	Coyote
53	5/20/96	Robinson	By hand	8.5	F	N/A	
52	5/20/96	Robinson	By hand	8.5	M	N/A	
51	5/20/96	Robinson	By hand	9.0	M	N/A	
54	5/20/96	Robinson	By hand	9.5	F	5/28/96	Rockslide
55	5/21/96	Robinson	By hand	8.5	F	N/A	
56	5/22/96	Robinson	By hand	8.5	F	12/12/96	Coyote
57	5/24/96	Robinson	By hand	10.5	M	5/28/96	Coyote
58	5/28/96	Robinson	By Hand	13.7	M	N/A	
59	5/28/96	Robinson	By hand		M	N/A	
60	5/30/96	Robinson	By hand	10.5	F	N/A	
61	5/31/96	Robinson	By hand	9.5	F	06/17/96	Coyote
62	6/9/96	Robinson	By hand	7.5	M	12/23/97	Coyote

APPENDIX B Year, weight of lamb at time of capture, sex, and estimated age at time of capture

Animal number	Year	Weight	Sex	Estimated age at capture
3	1995	8.5	F	> 2 days
4	1995	9.5	F	> 2 days
5	1995	9.0	F	> 2 days
25	1995	12.0	F	> 2 days
1	1995	9.0	F	< 2 days
2	1995	9.0	F	< 2 days
12	1995	9.0	F	< 2 days
21	1995	9.5	F	< 2 days
7	1995	9.0	F	< 2 days
15	1995	6.5	F	< 2 days
17	1995	10.5	F	< 2 days
18	1995	7.5	F	< 2 days
20	1995	7.0	F	< 2 days
8	1995	9.0	M	< 2 days
14	1995	8.5	M	< 2 days
23	1995	9.5	M	< 2 days
6	1995	8.5	M	< 2 days
9	1995	8.5	M	< 2 days
11	1995	8.0	M	< 2 days
16	1995	8.5	M	< 2 days
19	1995	10.0	M	< 2 days
22	1995	9.0	M	< 2 days
24	1995	9.5	M	< 2 days
10	1995	-[a]	-[a]	< 2 days
13	1995	8.0	-[a]	< 2 days
56	1996	8.5	F	> 2 days
32	1996	11.0	F	> 2 days
34	1996	9.0	F	> 2 days
35	1996	8.5	F	> 2 days
38	1996	10.0	F	> 2 days
39	1996	8.0	F	> 2 days
44	1996	11.0	F	> 2 days
47	1996	10.0	F	> 2 days
49	1996	9.0	F	> 2 days
53	1996	8.5	F	> 2 days

APPENDIX B Continued

Animal number	Year	Weight	Sex	Estimated age at capture
54	1996	9.5	F	> 2 days
55	1996	8.5	F	> 2 days
60	1996	10.5	F	> 2 days
61	1996	9.5	F	> 2 days
43	1996	7.5	F	< 2 days
28	1996	11.0	F	< 2 days
27	1996	11.0	M	> 2 days
37	1996	10.5	M	> 2 days
41	1996	11.5	M	> 2 days
42	1996	9.0	M	> 2 days
46	1996	11.0	M	> 2 days
58	1996	13.7	M	> 2 days
59	1996	-[a]	M	> 2 days
26	1996	9.5	M	< 2 days
62	1996	7.5	M	< 2 days
29	1996	11.0	M	< 2 days
30	1996	9.0	M	< 2 days
31	1996	10.0	M	< 2 days
33	1996	10.0	M	< 2 days
36	1996	8.5	M	<2 days
40	1996	9.0	M	< 2 days
45	1996	10.0	M	< 2 days
48	1996	8.5	M	< 2 days
51	1996	9.0	M	< 2 days
52	1996	8.5	M	< 2 days
57	1996	10.5	M	< 2 days
50	1996	7.0	-[a]	< 2 days

[a] Missing data.

Alaska's Game Management Units