TIMING AND CAUSES OF NEONATAL DALL SHEEP MORTALITY IN THE

CENTRAL ALASKA RANGE

by

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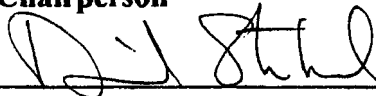for the degree of

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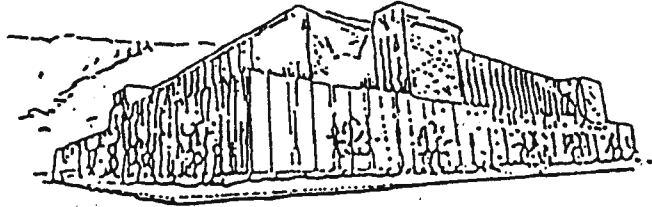The University of Montana

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Scotton, Bradley D., M. S. April 1998   Wildlife Biology

Timing and Causes of Neonatal Mortality in the Central Alaska Range (44 pp.)

Chairperson: Daniel H. Pletscher Ⅾᕼᖇ

   I captured and radiocollared 62 neonatal Dall sheep (*Ovis dalli*) in the central Alaska Range during the spring of 1995 (n = 25) and 1996 (n = 37). Three different techniques for capturing Dall sheep lambs were developed using two different types of helicopters. Three lambs were captured using a skid-mounted net-gun on a Hughes 500 (turbine engine) helicopter. Six lambs were captured by hand from the Hughes 500. Fifty-one lambs were captured by hand after jumping from a Robinson R-22 (piston engine) helicopter. Maternal behavior during the capture events varied between techniques. Use of the small (Robinson R-22) helicopter during this study was less disturbing to ewe/lamb pairs than the larger turbine helicopter. Duration of the capture event was shorter when using the R-22, and ewes fled further from the Hughes 500 turbine helicopter during capture events. Disturbance caused by researchers is often not quantified or critically considered, and should be minimized, especially for studies designed to measure survival or reproductive rates.

   Neonatal survival limits population growth and size in some ungulate populations. I investigated the timing and causes of mortality among radiocollared lambs for one year following initial capture. Twenty-three of the 56 lambs included in analysis died before one year of age. I attributed most lamb mortality (96%) to predation. Sixty-five percent of lamb deaths occurred within 60 days of birth; the remainder occurred primarily during winter. Coyotes (*Canis latrans*) accounted for 43% of all deaths, eagles (*Aquila chrysaetos*) 22%, wolves (*Canis lupus*) 4%, other large predators 9%, and unknown canids 17% (i.e., either wolves or coyotes). One lamb (4%) died in a rockslide. Heavier lambs exhibited higher survival ($P = 0.047$) than lighter lambs. Despite the 3-fold increase of the wolf population during my study, I detected no increase in wolf predation on lambs. Predation on young sheep by coyotes and eagles may slow the growth rate of sheep populations following weather-induced declines.

Table of Contents

List of Tables

List of Figures

INTRODUCTION

Neonatal survival is one of the most variable demographic traits among ungulates. Lamb:ewe ratios were lower in the central Alaska Range during 1991 - 1993 than all but one of the previously recorded during 25 years of Dall sheep research. Recent studies of caribou herds in interior Alaska concluded caribou populations were limited by high neonate mortality caused by grizzly bears and wolves. The wolf population within this study area had been reduced during the winters of 1993-94 and 1994-95 by the State of Alaska to benefit moose and caribou populations. Effects of previous wolf reduction programs on Dall sheep had been ambiguous. No cause-specific mortality study of neonatal Dall sheep has ever been conducted. The timing seemed appropriate in the spring of 1995 to begin an investigation which would assess the impacts of the recovering wolf population on lamb mortality, as well as identify specific causes and timing of mortality for lambs up to one year of age. Variables such as sex and mass of individual lambs were evaluated to see what their affects on survival might be. This project necessitated the development of capture techniques for newborn lambs, so capture methods using two different types of helicopter were developed and evaluated.

The results of my research are presented here in two papers. The first, entitled "Evaluation of a Capture Technique for Neonatal Dall Sheep", was submitted to Wildlife Society Bulletin in April 1997. It addresses the objective of developing and evaluating capture techniques used to capture lambs for the mortality investigation portion of the study.

The second paper is entitled, "Causes and Timing of Neonatal Dall Sheep Mortality in the Central Alaska Range." My three primary objectives were to: 1) assess

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Mortality in the Central Alaska Range." My three primary objectives were to: 1) assess possible changes in predation rates on lambs as the wolf population rebounded from a 2-year control program; 2) identify causes and timing of mortality for lambs from birth to 1 yr of age; and 3) identify factors such as sex or neonatal mass which may influence chances of survival for individual lambs. It is written in a format appropriate for submission to the Journal of Wildlife Management.

Evaluation of a Capture Technique for Neonatal Dall Sheep ˙

Abstract: Three different techniques for capturing Dall sheep (Ovis dalli) lambs were developed using two different types of helicopters. Three lambs were captured using a skid-mounted net-gun on a Hughes 500 (turbine engine) helicopter. Six lambs were captured by hand from the Hughes 500. Fifty-one lambs were captured by hand after jumping from a Robinson R-22 (piston engine) helicopter. Maternal behavior during the capture event varied between techniques. Use of a small (Robinson R-22) helicopter during this study was less disturbing to ewe/lamb pairs than the larger turbine helicopter. Duration of the capture event was shorter when using the R-22, and ewes fled further from the Hughes 500 turbine helicopter during capture events. Disturbance caused by researchers is often not quantified or critically considered, and should be minimized, especially for studies designed to measure survival or reproductive rates.

Introduction

Neonatal survival is one the most variable demographic traits among ungulates (Buechner 1960, Geist 1971, Clutton-Brock et al. 1987, Haas 1989, Adams et al. 1995). While considerable attention has been given to demographic parameters in adult Dall sheep (Ovis dalli) (Murphy and Whitten 1976, Hoefs and Bayer 1983, Simmons et al. 1984, Murphy et al. 1990) attention to neonatal wild sheep (Ovis spp.) and their recruitment into the breeding population has been lacking (DeForge and Scott 1982,

Festa-Bianchet 1988, Haas 1989). Predation, weather, disease, range condition, maternal

investment, inbreeding depression, and human disturbance all impact survival of wild

sheep lambs (Beuchner 1960, Woodard et al. 1974, , Nichols 1978, Burles and Hoefs

1982, Deforge and Scott 1982, Hoefs 1984, Douglas and Leslie 1986, Foreyt 1988, Haas

1989 , Rachlow and Bowyer 1994, Bleich et al. 1994). Capturing and marking lambs is

essential to collecting data on timing and causes of lamb mortality.

Hand-held net guns, drop nets, cannon nets, and remote drug delivery systems

have all been used to capture adult North American ungulates, including Dall sheep and

Bighorn sheep (Ovis canadensis) (Kock et al. 1987, Firchow et al. 1986, MacArthur et al.

1986, Bates et al. 1985, Krausman et al. 1985, Singer et al. 1984, Andryk et al. 1983,

Valkenburg et al. 1983, Barrett et al. 1982, Heimer et al. 1980). Evaluation of capture

and handling techniques for newborn ungulates is rare and often involves animals

habituated to humans (Haas 1989, Franklin and Johnson 1994). Alternate capture

techniques must be employed for species or populations that are not habituated to humans,

or occupy terrain not conducive to approach on foot.

Dall sheep are distributed among the rugged mountains of Alaska and the Yukon

and Northwest Territories of Canada. They inhabit dry, mountainous terrain and select

sub-alpine low shrub plant communities (Murie 1944, Geist 1971, Hoefs 1984). Ewes

usually isolate themselves for birthing and then rejoin groups or "nursery bands" soon

after parturition (Pitzman 1970). Lambs are precocial and follow their mothers soon after

birth (Pitzman 1970).

We developed and evaluated three techniques for capturing Dall sheep lambs as

part of a neonatal mortality study in the central Alaska Range mountains: Hand capture by jumping from a Robinson R-22 piston engine helicopter; hand capture by stepping from a Hughes 500 turbine helicopter; and entanglement of lambs with a net fired from a skid mounted net gun on a Hughes 500 helicopter.

Study Area

We captured and collared newborn lambs in the central Alaska Range mountains in a 1320 km^2 area approximately 75 km east of Denali National Park (Fig. 1). This roadless area is accessible by aircraft or by off road vehicles during winter months. Most sheep habitat is 950 - 2200 m MSL where vegetation is typically < 1 m in height. 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. Overflight by fixed-wing single engine aircraft occurs year around, but is most common during summer and fall months.

Methods

The all white sheep were easily seen in treeless habitat. We preferred single ewe/lamb pairs for capture, but also captured lambs from small groups of 2-5 ewes with lambs. We typically searched mountainsides with the capture aircraft from a distance of $\geq$ 200 m and 80 kph. All sheep habitat was searched opportunistically, as "typical" lambing

terrain was never identified and lambs were captured in widely varying terrain. An assessment of the condition of the lamb was made by close observation (< 50 m). A lamb was considered "catchable" if it could not keep up with its mother, appeared wobbly, had a grayish coat, or did not run.

The first capture method employed a Robinson R-22 piston engine helicopter. This small, two person, 150 horse power helicopter weighs approximately 400 kg empty and is powered by a 4-cylinder Lycoming engine. Small size makes it extremely maneuverable, and its small piston engine makes it considerably quieter than large turbine helicopters. This helicopter was chartered for $245/h. Both doors were usually removed from the helicopter to enhance visibility and facilitate unfettered departure from the helicopter. Piston powered engines cannot develop as much power as turbine engines at increasing altitudes, so control of weight was important. Thus, to reduce weight, fuel tanks were only partially filled to allow for one to one and a half hours of working time before refueling. Gear needed for handling captured animals was stored in a small backpack to leave the catcher's hands free.

Capture operations took place daily between 13 May and 7 June 1995 and between 13 May and 9 June 1996. Sheep were gently hazed with the helicopter for ≤ 2 minutes if they were in terrain that was unapproachable due to steepness or the narrowness of a small canyon. Once clear of dangerous terrain, the pilot quickly hovered into position directly above the ewe/lamb pair, placing them in the downward rotor wash. The passenger/catcher turned sideways in his seat and stood on the skid while still leaning on the seat and holding both sides of the door frame as the pilot maneuvered for position.

The catcher disconnected a restraining harness/belt when within 1-3 m of the lamb and dropped from the skid to the slope and manually restrained the lamb. The catcher departed the helicopter when he/she felt they could land within arms reach of the lamb and not incur self injury. Jumps seldom exceeded one meter. The helicopter flew away 300-500 m to limit disturbance of the ewe.

Quickness of this maneuver was important to success. Lambs would temporarily become disoriented in the downwash from the helicopter and hesitate before running. Once running, pursuit was generally futile as lambs older than a few hours could easily outrun humans on steep slopes. Variations of this technique were common. Running lambs were sometimes captured using the same basic technique except the helicopter was not in hover, but rather flying sideways and slightly ahead of the lamb while it was running. The catcher would jump to the ground 2-3 m ahead of the lamb and intercept it as it tried to pass by. A lamb sometimes stood against a cliff with its mother and refused to move. The catcher jumped off 5-10 m in front of the cliff, after which the pilot maneuvered the helicopter away from the sheep. Direct rapid approach by the catcher coupled with confusion by the lamb over which direction to run also resulted in some captures.

Method two was essentially the same, except a Hughes 500 turbine helicopter was used and researchers were not allowed to exit the helicopter until some portion of the landing gear was in contact with the terrain. Considerations for weight reduction were not as critical and doors were not removed. This helicopter was chartered for $540/h. The catcher remained seated in the helicopter with seat belt attached and doors closed.

Downwash from rotor blades was greater in the Hughes and the period of confusion by the lamb was longer. This allowed the helicopter to place one skid on the hillside above the lamb, where terrain was conducive, while the catcher exited. Some lambs were actually blown from their feet or laid down to avoid the rotor wash.

The third method used the Hughes 500 equipped with a skid-mounted net gun. This gun functioned in the same manner as hand-held models (Barrett et al. 1982), but was mounted on the foreword part of the helicopter landing gear. Four 254 g cylindrical weights attached to the corners of the net were propelled by a blank .308 caliber cartridge discharged by the pilot. The net was fired forward and downward over the target. The gun was equipped with 2 net baskets so a miss could be quickly followed by another shot without stopping. This remote gun mounting was used to reduce the risk of the gunner accidentally discharging the net into the main rotor, landing gear or tail rotor, which could result in catastrophic aircraft failure. This gun fired a 4 m X 4 m nylon net with 10 cm mesh for the Dall sheep lamb capture operations.

Handling

Each lamb was weighed with a sling and spring scale, sexed and radiocollared (Telonics, Mesa, AZ) with an elastic-banded, expandable collar designed to last 15 months. Age of captured lambs was estimated by categorizing the umbilicus to be wet or partially dried (< 48 hours), or dried (> 48 hours). The lamb's ability to run, pelage color, and stature were also considered qualitatively as indices of age. Handling time was kept to an absolute minimum to prevent abandonment. The helicopter hovered or landed 300 - 500 m from the capture site while the catcher was collaring and weighing the lamb and

returned immediately upon being signaled. Only in two cases of extreme separation (>500 m) from its mother did we attempt to expedite reunification by hazing the mother in the direction of the lamb. Distance of mother from lamb at the time of release was visually estimated and recorded when the location of the mother was known. Time of capture and handling was recorded to the nearest minute. We returned 4-20 hours later to assess whether ewe/lamb pairs were reunited in cases where the reunification was not witnessed immediately after the capture event.

Results

Sixty-two lambs were captured and radiomarked during 1995 ($\underline{n}$ = 25) and 1996 ($\underline{n}$ = 37). Fifty-three lambs were captured 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 distant and approaching on foot) and six more lambs were captured by hand from the Hughes 500. Three lambs were captured using the skid-mounted net gun in five attempts. Thirty males and 29 females were captured. Sex was not recorded for 3 lambs. Thirty-seven lambs were estimated to be < 48 hours old at capture, and 25 were estimated to be > 48 hours old. Sixteen of 53 lambs immediately reunited with their mother when using the R-22, while only 1 of nine immediately reunited while using the Hughes. Two of 62 mothers attempted to defend their lamb by butting the catcher. Maternal distance from lamb at the time of release was greater for captures with the Hughes 500 ($\bar{x}$ = 300 m) than the R-22 ($\bar{x}$ = 79 m; Student's t-Test t = 2.055, d.f. = 43, P = 0.046). Time of capture and handling varied between helicopters as well ($\bar{x}$ = 11.0 min. for the Hughes 500 and $\bar{x}$ = 2.8 min. for the R-22; Student's t-Test t = 2.29, d.f. = 27, P = 0.03).

No lambs died immediately as a result of capture and handling. However two lambs were killed by a golden eagle (<u>Aquila</u> <u>chrysaetos</u>) less than 4 hours after capture, before their mothers returned to them. Both had been captured simultaneously by hand from the Hughes 500. One other lamb was also killed by an eagle less than 30 hours after capture, 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 8-12 minutes with the R-22 hovering nearby the entire time.

Discussion

Prior to this study, some researchers believed that newborn Dall sheep lambs could not be captured safely, effectively, or without undo harm. The precocial nature of lambs presented some challenges, but all 3 methods were effective and safe for researchers. In 1995, three lambs died as a result of being handled, but modifications to capture techniques resulted in no handling related deaths in 1996.

The hand-capture technique from the R-22 was developed by trial and error. Several unsuccessful attempts to land and pursue lambs were made before modification of the technique resulted in repeatable success. Five different individuals, ranging in age from 24 to 47 years, all successfully caught lambs by hand from the R-22. The maneuverability of the helicopter was an asset, as was its relative quietness. We successfully captured lambs with the R-22 in all types of lambing habitats used by the population. Some captures were not attempted because of high winds, turbulence or altitude (piston powered engines develop less power with increasing altitude, thus

captures made above 2000 m MSL were rare).

Although all helicopters are loud, some are louder and may cause more disturbance than others. Strict attention should be given to the effects that aerial harassment might have on wildlife (Krausman and Hervert 1983, Thompson and Baker 1981). Bleich et al. (1994) provided evidence that Bighorn sheep respond "dramatically" to turbine helicopter disturbance during surveys and urged caution in the use of aircraft to study wildlife. We found that the larger, louder Hughes 500 helicopter affected Dall sheep ewe/lamb pairs more than the smaller, quieter Robinson R-22 helicopter. Ewes moved significantly further from the lamb when the Hughes 500 was used for the capture. This may have been due to its louder nature, larger profile, or the fact that duration of disturbance was longer. A ewe tended to focus on her lamb once she could not hear the helicopter. Because the R-22 was quieter, it usually could not be heard by humans when the pilot flew the aircraft > 400 m away during the handling portion of the capture event. The Hughes 500 however, could generally be heard by humans throughout the capture and handling event. On several occasions a ewe stood in cliffs 400 m away staring at the Hughes 500 during the entire handling period of her lamb. In a predator rich environment like this one, quick reunification is necessary to prevent researcher-induced predation mortality. Ewes may travel even further when confronted with intense harassment in less rugged terrain.

Only five attempts were made to catch lambs with the net-gun technique. Two were unsuccessful after pursuits of 10 minutes and 2 missed shots each. Lambs are able to run quickly when < 24 hours of age and do not readily separate from their mother. Lambs ran very near or actually under the belly of their mother when pursued with the Hughes

500 helicopter. Because we were unwilling to risk injury to the lamb from being captured with its mother in the same net, obtaining opportunities for shots was difficult. This resulted in long pursuits, prolonged separations of ewe/lamb pairs following capture, and undo stress. Although we captured lambs using this technique, and lambs were not physically injured at the time of capture, we felt the level of disturbance caused by this technique was unacceptable. A shoulder mounted net-gun may have been more effective as helicopter positioning in relation to the sheep would not have been as critical.

The hand-capture from the Hughes was also successful, but increased intensity of disturbance, duration of disturbance and cost led us to use the R-22 exclusively during the 1996 field season. The reduced cost of the smaller helicopter allowed us to more efficiently utilize our budget and capture many more lambs than would otherwise have been possible. No lambs ($\underline{n}$ = 37) were abandoned or killed before reunification in 1996.

Capture times with the Hughes would likely have gone down if; (1) it had been used more, giving the pilot more experience, (2) we had removed doors, (3) were had exited while hovering. However, the intensity of disturbance during handling would not have changed. Similarly, a pilot inexperienced in mountain flying of an R-22 may have required much longer to position the aircraft for captures, thus increasing the duration of disturbance.

Wildlife biologists should constantly re-evaluate techniques as new technology becomes available. Harassment caused by researchers is too often not quantified or critically considered (MacArthur et al. 1986) and should be minimized.

The use of aircraft for wildlife research and management is a necessity and safety

for the biologists and pilots should always be the foremost consideration. Aircraft, pilot, and biologists' limitations should carefully be considered before each individual project is undertaken.

Hand capture of Dall sheep lambs from a Robinson-22 helicopter proved effective where ruggedness of terrain and non-habituation to people precluded the possibility of capture on foot, and may prove useful for other species as well.

Literature Cited

Adams, L. G., F. J. Singer, and B. W. Dale. 1995. Caribou calf mortality in Denali National Park, Alaska. Journal of Wildlife Management. 59:584-594.

Andryk, T. A., L. R. Irby, D. L. Hook, J. J. McCarthy, and G. Olson. 1983. Comparison of mountain sheep capture techniques: helicopter darting versus net-gunning.

Wildlife Society Bulletin 11:184-187.

Barrett, M. W. , J. W. Nolan, and L. D. Roy. 1982. Evaluation of a hand-held net-gun to capture large mammals. Wildlife Society Bulletin. 10:108-114.

Bates, J. W. Jr., J. W. Bates and J. G. Guymon. 1985. Comparison of drive nets and darting for capture of Desert Bighorn Sheep. Wildlife Society Bulletin. 13:73-76.

Bleich, V. C., R. T. Bowyer, A. M. Pauli, M. C. Nicholson, and R. W. Anthes. 1994. Mountain Sheep Ovis canadensis and helicopter surveys: Ramifications for the conservation of large mammals. Biological Conservation. 70:1-7.

Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present, and future. Wildlife Monographs. 4:1-174.

Burles, D. and M. Hoefs. 1982. The influence of winter severity on Dall sheep productivity in southwestern Yukon – a preliminary assessment. Biennial Symposium of Northern Wild Sheep and Goat Council. p. 67-84.

Clutton-Brock, T. H., M. Major, S. D. Albon, and F. E. Guinness. 1987. Early development and population dynamics in Red Deer. I. Density-dependent effects on juvenile survival. Journal of Animal Ecology. 56:53-67.

DeForge, J. R. and J. E. Scott. 1982. Ecological investigations into high lamb mortality. Desert Bighorn Council Transactions. p. 65-76.

Douglas, C. L. and D. M. Leslie Jr. 1986. Influence of weather and density on lamb survival of desert mountain sheep. Journal of Wildlife Management. 50:153-156.

Festa-Bianchet, M. 1988. Birthdate and survival in bighorn lambs (Ovis canadensis). Journal of Zoology., London. 214:653-661.

Firchow, K. M., M. R. Vaughan, and W. R. Mytton. 1986. Evaluation of the hand-held net gun for capturing pronghorns. Journal of Wildlife Management. 50:320-322.

Foreyt, W. J. 1988. Reproduction of Rocky Mountain Bighorn sheep (Ovis c. canadensis) in Washington: Birth dates, yearling ram reproduction and neonatal diseases. Northwest Science 62:161-164.

Franklin, W. L. and W. E. Johnson. 1994. Hand capture of newborn open-habitat ungulates: The South American Guanaco. Wildlife Society Bulletin. 22:253-259.

Geist, V. 1971. Mountain sheep, a study in behavior and evolution. University of

Chicago Press, Chicago, Illinois.

Hass, C. C. 1989. Bighorn lamb mortality: predation, inbreeding, and population effects.

Canadian Journal of Zoology. 67:699-705.

Heimer, W. E., S. P. Dubois, and D. G. Kellyhouse. 1980. A comparison of rocket-

netting with other methods of capturing Dall Sheep. Biennial Symposium of the

Northern Wild Sheep and Goat Council. 2:601-614.

Hoefs, M. 1984. Productivity and carrying capacity of a subarctic sheep winter range.

Arctic. 2:141-147.

Hoefs, M. and M. Bayer. 1983. Demographic characteristics of an unhunted Dall sheep,

Ovis dalli dalli, population in Southwest Yukon, Canada. Canadian Journal of

Zoology. 61:1346-1357.

Kock, M. D., D. A. Jessup, R. K. Clark, and C. E. Franti. 1987. Effects of capture on

biological parameters in free-ranging Bighorn sheep (Ovis canadensis): Evaluation

of drop-net, drive-net, chemical immobilization and the net-gun. Journal of

Wildlife Disease. 23:641-651.

Krausman, P. R. and J. Hevert. 1983. Mountain sheep responses to aerial surveys.

Wildlife Society Bulletin. 11: 372-375.

Krausman, P. R., J. J. Hevert, and L. L. Ordway. 1985. Capturing deer and mountain

sheep with a net-gun. . Wildlife Society Bulletin. 13: 71-73.

MacArthur, R. A., V. Geist, and R. H. Johnston. 1986. Cardiac responses of bighorn

sheep to trapping and radio instrumentation. Canadian Journal of Zoology.

64:1197-1200.

Murie, A. 1944. The wolves of Mt. McKinley. U. S. Department of Interior., National.

Park Service. Fauna Series 5.

Murphy, E. C. and K. R. Whitten. 1976. Dall Sheep demography in McKinley Park and a

reevaluation of Murie's data. Journal of Wildlife Management. 40:597-609.

Murphy, E. C., F. J. Singer, and L. Nichols. 1990. Effects of hunting on survival and

productivity of Dall Sheep. Journal of Wildlife Management. 54:284-290.

Nichols, L. 1978. Dall sheep reproduction. Journal of Wildlife Management. 43:570-

580.

Pitzman, M. S. 1970. Birth behavior and lamb survival in mountain sheep in Alaska. M.

S. Thesis, University of Alaska, Fairbanks. 116 pp.

Rachlow, J. L., and R. T. Bowyer. 1994. Variability in maternal behavior by Dall's

sheep: Environmental tracking or adaptive strategy? Journal of Mammalogy.

75:328-337.

Simmons, N. M., M. B. Bayer, and L. O. Sinkey. 1984. Demography of Dall's Sheep in

the Mackenzie Mountains, Northwest Territories. Journal of Wildlife Management.

48:156-162.

Singer, F. J., K. R. Whitten, and L. Nichols. 1984. Experiences in darting Dall sheep

from helicopters in Alaska during 1983. Proceedings of North American Wild

Sheep and Goat Council. 499-505.

Thompson, B. C. and B. W. Baker. 1981. Helicopter use by wildlife agencies in North

America. Wildlife Society Bulletin. 9:319-323.

Valkenburg, P., R. D. Boertje and J. L. Davis. 1983. Effects of darting and netting on

caribou in Alaska. Journal of Wildlife Management. 47:1233-1237.

Woodard, T. N., R. J. Gutierrez, and W. H. Rutherford. 1974. Bighorn lamb production,

survival, and mortality in South-Central Colorado. Journal of Wildlife Management

38:771-774.

DALL SHEEP LAMB MORTALITY IN THE CENTRAL ALASKA RANGE

Abstract: Neonatal survival limits population size and growth for some ungulate species. The effects of predation on Dall sheep (*Ovis dalli*) are not well documented in the literature. I captured and radiocollared 62 lambs (< 3 days old) during spring 1995 ($n = 25$) and 1996 ($n = 37$) in the Central Alaska Range Mountains to investigate causes and timing of lamb mortality. I attributed most lamb mortality (96%) to predation. Sixty-five percent of lamb deaths occurred within 60 days of birth; the remainder occurred primarily during winter. Coyotes (*Canis latrans*) accounted for 43% of all deaths, eagles (*Aquila chrysaetos*) 22%, wolves (*Canis lupus*) 4%, other large predators 9%, and unknown canids 17% (i.e., either wolves or coyotes). One lamb (4%) died in a rockslide. Heavier lambs exhibited higher survival ($P = 0.047$) than lighter lambs. Despite the 3-fold increase of the wolf population during my study, I detected no increase in wolf predation of lambs.

Recent declines of $\geq$ 60% in some Alaskan Dall sheep populations prompted interest in a study of Dall sheep lamb survival. Lamb:ewe ratios in the central Alaska Range during June or July 1991, 1992, and 1993 (18:100, 5:100, and 12:100, respectively) were far lower than the average between 1968 and 1987 ($\bar{x}$ = 46:100) (McNay 1990). Survival of wild sheep lambs is thought to be influenced by numerous factors, including predation (Hass 1989), weather (Nichols 1978, Burles and Hoefs 1982, Douglas and Leslie 1986), disease (Woodard et al. 1974, Deforge and Scott 1982, Foreyt

1988), range condition (Hoefs 1984), maternal investment (Rachlow and Bowyer 1994),

timing of birth (Bunnell 1980, Festa-Bianchet 1988), inbreeding depression (Hass 1989),

and human disturbance (Bleich et al. 1994). Murie (1944) and Nette et al. (1984)

documented predation on Dall sheep lambs by golden eagles, but cause-specific mortality

of neonatal Dall sheep has not been vigorously examined. Wolves have also been

suspected to play an important role in Dall sheep population dynamics (Murie 1944,

Murphy and Whitten 1976, Heimer and Stephenson 1982, Sumanik 1987). Wolf

populations in the Central Alaska Range have periodically been reduced to benefit moose

(*Alces alces*) and caribou (*Rangifer tarandus*) populations. Effects of these wolf

reductions on Dall sheep have been ambiguous (Heimer and Stephenson 1982, Gasaway et

al. 1983). The wolf population using my study area was reduced to benefit a caribou

population during the winters of 1993-94 and 1994-95 and then increased from 9 wolves

(March 1995) to 21 wolves (March 1996) to 32 wolves (March 1997) (Alaska Dep. Fish

and Game, unpubl. data) during my study (May 1995 – May 1997).

Predation on neonate caribou is an important component in the population

dynamics of many Alaskan herds (Whitten et al. 1992, Adams et al. 1995) that are

sympatric with Dall sheep populations. More than 50% of caribou calves born in a given

year may be killed by predators within the first 60 days of life and as many as 70% within

the first year (Boertje and Gardner 1997, Valkenburg 1997). Wolves and bears (*Ursus*

spp.) are the primary predators of moose and caribou in Alaska and can exert controlling

influences over some populations (Gasaway et al. 1983, Van Ballenberghe and Ballard

1994, Boertje et al. 1996). Whether Dall sheep recruitment is similarly limited by

predators is unknown.

My objectives were to: 1) assess possible changes in predation rates of lambs as the wolf population rebounded from a 2-year control program; 2) identify causes and timing of mortality for lambs from birth to 1 yr of age; and 3) identify factors such as sex or mass at birth which may influence survival for individual lambs.

STUDY AREA

I examined lamb mortality in the Central Alaska Range Mountains in a 1320-km^2 area approximately 75 km east of Denali National Park (Fig. 1). This roadless area is accessible by aircraft year-round or by snowmachines during winter months. Most sheep habitat is at 950-2200 m elevation. Vegetation is typically less than 1 m in height and consists mainly of alpine sedge (*Carex* spp.), grasses (*Calamagrostis, Festuca, Bromus, Poa*), *Dryas octopetala*, and shrubs (*Salix* spp. and *Betula* spp.). Some peaks exceed 3000 m, and glaciers occupy the heads of many drainages. 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.

Temperatures vary from 32 C in summer to -50 C during winter. Summers are typically cool and damp with a few periods of hot dry weather. Winter range for sheep is swept clear of snow by strong winds. Dall sheep are adapted to live in cold dry conditions (Nichols 1978).

A large moose population, which primarily occupies lower elevation willow communities, and a herd of 3700 caribou use the area seasonally. Three packs of wolves and an unknown number of coyotes use the study area year-round; grizzly bears and

golden eagles are present and active during summer.

Mature (full-curl) 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 hence were difficult to approach from the ground. Sheep density in 1995 was approximately 1.3/km^2 in the 530-km^2 portion of the study area which is surveyed annually. Overflight by helicopters and fixed-wing aircraft occurs year-round, but is most common during summer and fall.

METHODS

Lamb Capture

I captured and radiocollared neonatal lambs from 12 May to 7 June during both 1995 and 1996. Sheep habitat was searched via helicopter or fixed-wing aircraft to locate ewes with newborn lambs. No adult ewes were radiocollared, so lambs were caught opportunistically. Lamb:ewe ratios were recorded daily to estimate median lambing date. As peak of lambing approached, more lambs were collared each day in an attempt to obtain a representative sample of the cohort. Lambs were captured primarily by hand after a biologist jumped from a hovering helicopter (Scotton and Pletscher, in press).

A radiocollar designed to last 15 months (Telonics, Mesa, Ariz.) was placed on each lamb. Each radiocollar weighed 125 g and was equipped with an elastic, expandable neck band into which 2 folds were sewn. Threads holding the folds were designed to break down over time and tear when pulled upon. As the lamb grew, the collar expanded to fit the lamb and eventually fell off. Pulse rate of these collars doubled when the collar remained motionless for more than 1 h so visual inspection of lambs was not necessary

unless their collar was producing a "mortality signal."

Sex of the lamb was recorded, each lamb was weighed with a hand-held spring scale (to the nearest 0.2 kg), and released as quickly as possible (usually < 3 min). Qualitative indices of age were recorded for each lamb, including condition of the umbilicus (bloody, partially dry, dry, absent), hoof hardness, and color of pelage. Lamb ages were estimated as < 48 h or > 48 h according to these qualitative indices.

Radio signals were monitored from fixed-wing aircraft or helicopter at least daily for the first 20 days following birth. During May and early June most mortaltiy signals were investigated via helicopter within 2 h of detection. From mid June through August, Radiotracking was first weekly, then semi-monthly, and most deaths were investigated within 1 week of detection. Radiotracking occurred monthly from September through April and most deaths were investigated within 1 month of detection. I estimated time of death as the midpoint between when a lamb's radio was last heard alive (on standard pulse) and when it was first heard on mortality mode (fast pulse). Mortalities were usually investigated by 2 experienced field personnel. A bloody collar or trauma and bruising on the carcass were taken as indicators of predation. Mortality sites were closely inspected by field personnel for clues of the cause of death. Hairs, feathers, tracks, scats, and patterns of consumption all helped identify the predator. Remains of lambs were usually brought to camp for further inspection when the cause of death was unclear. In some cases the predator could not be determined definitively, but the cause of death was usually narrowed to 2 species.

Wolf abundance in March 1995 was estimated through intensive aerial surveys

from fixed-wing aircraft following snowfall. Thereafter, all packs contained radiocollared individuals and estimates were obtained by repeated observation from fixed-wing aircraft during February and March 1996 and 1997 (M. McNay, Alaska Dep. Fish and Game, pers. commun.).

Surveys of the sheep population within my study area were flown on 7 June 1995, 9 June 1996 and 17 June 1997 to estimate numbers of adult ewes, lambs, yearlings, and rams > 1yr old and to assess productivity of the population. Surveys were conducted from a Robinson R-22 helicopter flown at similar search intensities each year (0.68 min/km^2, 0.72 min/km^2 and 0.87 min/km^2 respectively).

ANALYSES

I used logistic regression (Feinberg 1980) to examine influences of sex, mass, and year on survival of lambs from date of capture to 60 days and to 1 yr. I used analysis of variance (ANOVA) to test for differences in birth mass associated with birth year, sex, or age at capture. Estimated age at capture influenced mass so the logistic regression model included an interaction term (1 X mass for lambs less than 48 hr old or 2 X mass for lambs 48-72 hr old). This allowed me to test for effects of mass on survival while allowing variation of mass with age at capture. Student's t-test was used to test for differences in mass of male and female lambs, of the same age class. Kaplan-Meier survival estimates (Pollack et al. 1989) were calculated following each radiotracking event. This analysis allowed me to censor individuals whose radiocollar failed or was shed. Survival curves for 1995 and 1996 were compared using Generalized Log-rank tests (Pollack et al. 1989)

RESULTS

Newborn lambs were first observed on 15 May 1995 and 12 May 1996, and were rarely observed after 28 May in either year. Median lambing date appeared to be on or near 20 May both years based on lamb:ewe ratios recorded daily and the presence of new lambs observed in the population. I captured and radiocollared 62 lambs < 3 days old in spring 1995 ($n = 25$) and 1996 ($n = 37$). Three lambs were killed by golden eagles in 1995 before they reunited with their mothers, and hence were excluded from analysis. No lambs died as an indirect result of handling in 1996; however, 3 lambs either shed their collars a few days after capture or predators killed them without leaving any evidence whatsoever. Because ewes were not collared, I could not determine if these lambs were still alive so they were also excluded from mortality analyses.

Twenty-nine female and 30 male lambs were captured; 3 were not sexed. Mass of lambs captured in both years ($n = 60$) varied with estimated age at time of capture (hereafter age-at-capture) ($F_{53} = 9.05$; 1; $P = 0.004$) and year ($F_{53} = 3.6$; 1; $P = 0.063$). Because age-at-capture influenced mass, male and female lambs > 48 hr old and male and female lambs < 48 hr old were compared to test for differences in mass between sexes. Males tended to be slightly heavier in both age-at-capture classes, but differences were not significant (Table 1). Difference in mass between years was a result of capturing a higher proportion of older age lambs in 1996 than in 1995 (58% >48 h old vs. 17% > 48 h old), rather than a difference in mass between years.

Only mass significantly affected probability of survival to 60 days ($X^2 = 3.9$, 4 df, $P = 0.047$) and possibly to 1 yr ($X^2 = 3.5$, 4 df, $P = 0.060$). Lighter lambs tended to suffer

higher mortality than heavier lambs. Age-at-capture did not influence probability of survival ($X^2 = 0.17$, 4 df, P = 0.677), nor did the interaction term of age-at-capture X mass ($X^2 = 1.06$, 4 df, P = 0.30)

The Kaplan-Meier survival estimate to 1 year was 0.64 ± 0.16 (95% CI) for lambs born in 1995 and 0.46 ± 0.12 (95% CI) for those born in 1996. Survival functions (Fig. 2) were not significantly different between years ($X^2 = 1.7$, 1 df, P = 0.15).

Causes of Death

Twenty-two of 23 lamb deaths that occurred during my study were attributed to predation. Coyotes were the most common cause of death among radiocollared lambs, accounting for 43% of total lamb mortality. Eagles accounted for 22% and wolves for 4% of deaths. Undetermined canids (wolves or coyotes) accounted for an additional 17% of deaths (Table 2). If these unknowns are all attributed to wolves, their percentage climbs to 22%; conversely, if they are attributed to coyotes, they would account for 60% of deaths. I observed coyotes in sheep habitat (i.e., above brush line, in rocky terrain and among cliffs) frequently during the study, but wolves were observed there only once. Golden eagles were observed perched in or soaring above sheep habitat daily and were observed hunting lambs.

Timing of Deaths

Fifty-seven percent of lambs deaths in 1995 and 70% in 1996 occurred during the neonatal period (1 to 60 days). Coyotes, eagles, Grizzly bears (*Ursus arctos*), wolverines (*Gulo gulo*) and wolves all killed some lambs during this period. Eagles only killed lambs < 40 days old. Death of collared lambs occurred in all months except August, March and

April. All of the post-neonatal deaths were attributed to coyotes, wolves, or unknown canids (either coyotes or wolves).

Lamb:ewe ratios obtained from the annual surveys of the study area in 1995 (44:100), 1996 (51:100) and 1997 (40:100) were closer to the long term average of 46:100 (McNay 1990) than the lamb:ewe ratios from 1991 - 1993. Overall abundance increased from 1995 to 1996, then declined between 1996 and 1997 (Table 3). Lamb and ewe abundance both followed a trend similar to total sheep abundance (i.e. increase from 1995 to 1996, decrease from 1996 to 1997). The number of yearlings classified in 1996 (95) and 1997 (93) followed years with 109 and 137 lambs observed in the study area. These data indicate an 87% survival rate for lambs from 7 June 1995 until the following June, and a 68% survival rate for lambs from 9 June 1996 until the following June. These estimates do not include early mortality accounted for by the Kaplan-Meier estimates, but do follow the general trend of higher survival for lambs born in 1995 than those born in 1996.

DISCUSSION

Thirty-two percent of lambs captured in 1995, and 52% of those captured in 1996 were killed by predators before they reached 1 yr of age. Estimates of mortality are probably biased low. Some perinatal mortality may have occurred between birth and collaring and gone undetected (Ozoga and Clute 1988, Whitten et al. 1992), and some lambs excluded from analysis (shed collars n = 6, or failed radios n = 2) may actually have been killed by predators. Coyotes are the most significant predator of lambs in this area, accounting for 43% of lambs deaths. Coyotes killed lambs during the winter as well as the

neonatal period. Golden eagles are also important, but probably kill few lambs older than 60 days. Wolves, despite their abundance in the area, do not seem to exert strong pressure on juvenile sheep. Wolves accounted for only 1 known death during the 2 years, although they may have been involved in the deaths of 4 more lambs, which were killed by either coyotes or wolves. Wolves would be responsible for the same number of deaths caused by eagles if all unknowns were attributed to wolves and none to coyotes.

This pattern of mortality on Dall sheep lambs is in sharp contrast to nearby caribou populations that inhabit the same mountain range. Adams et al. (1995, 1996) and Valkenburg (1997) found wolves and grizzly bears to be the primary predators of neonatal caribou and the primary limiting factors of the Denali and Delta caribou herds. Coyotes were insignificant predators of caribou in both of these studies, possibly due to interspecific competition with bears and wolves on the caribou calving grounds. Incidences of wolves killing coyotes have been noted where the two species are sympatric (Thurber et al. 1992, Paquet 1992) and interference competition may dictate the movements of coyotes.

Hass (1989) studied a closed Bighorn sheep (*Ovis canadensis*) population in Montana and found that coyotes were primarily responsible for the high (75%) lamb mortality. Coyotes were first documented in Alaska in 1899 (Sherman 1981). One study of coyotes has been conducted in Alaska. Thurber et al. (1992) indicated coyotes on the Kenai Peninsula primarily ate snowshoe hares (*Lepus americana*), porcupines (*Erithizon dorsatum*) and other small mammals.

The overall incidence of coyote predation on Dall sheep in Alaska is unknown.

Coyotes killed lambs throughout my study area and throughout the year. Burles and Hoefs (1982) noted increased predation by coyotes on adult Dall sheep in Kluane Park, Yukon Territory, Canada during a deep snow winter. Coyotes are present in many mountain ranges of Alaska and may influence sheep populations over a broad geographic area. How the wolf reduction program influenced coyote abundance is also unknown. Coyotes may have been more numerous in my study area because wolf numbers had been suppressed during a recent wolf control program. However, M. McNay (ADF&G, pers. comm.) suggested that coyotes are also abundant in areas where wolf reductions have not occurred and coyotes remained common in the study area after wolves recovered to pre-control numbers (M. McNay, ADF&G, pers. comm.). Paquet (1992) thought coyotes could coexist with wolves more easily in areas where prey was abundant.

Adams et al. (1995, 1996) suggested that killing caribou calves is unprofitable for wolves until nursery bands appear (after the peak of calving) and wolves have the opportunity to make multiple kills in a short time. If this is true, hunting lambs is surely unprofitable for wolves because opportunities for multiple kills probably rarely exist and the food value of a lamb (4.2 kg) is even lower than a caribou calf (8.6 kg). Furthermore, the risk involved in catching lambs among cliffs is probably higher than for catching caribou calves. Where abundant alternate prey (moose or caribou) exist, hunting Dall sheep lambs may be an unprofitable venture for wolves. Adams et al. (1995) suggested that lambs or moose calves may replace caribou calves as preferred prey for wolves after caribou calves become larger and more difficult for wolves to catch, but my data do not support the hypothesis that lambs are targeted once caribou calves become older.

Coyotes, however, may profit from hunting sheep lambs. Catching a 4.2 kg or larger lamb may be worth some risk to a 15 kg coyote, which is likely more adept than a 45 kg wolf at negotiating rocky, steep sheep habitat. This may especially be true if wolves avoid sheep habitat during early summer, thus decreasing the chances of interspecific encounters between wolves and coyotes.

Lamb survival appeared lower in 1996 than 1995 (0.48 and 0.68, respectively), though not statistically ($P = 0.15$). I could not attribute higher mortality in 1996 was not attributed to the increased number of wolves within the study area. Wolves accounted for a maximum of 3 mortalities in 1995 and a maximum of 2 in 1996 (if all unknowns in 1995 and 1996 were actually wolf kills and not coyote kills). Kills of lambs by wolves did not increase despite the increased number of wolves using the study area. Effects of this larger population of wolves on adult sheep are unknown, however, due to the lack of collared adult sheep.

Eagles killed 5 radiocollared lambs during the study, and an additional 3 not included in the analysis. The death of the 3 unattended lambs illustrates their vulnerability to eagles when the ewe is not present to defend them. Little information on golden eagle food habits in Alaska is published. Evidence from this study and the presence of lamb remains in some nests in Denali National Park (C. McIntyre, USNPS, pers. comm.) indicates that eagles may be a significant component of Dall sheep population dynamics. If predation by eagles is a function of prey availability, they may rely more heavily on lambs in years when abundance of other prey species such as arctic ground squirrels (*Spermophilus parryii*) is low.

Lighter lambs tended to suffer higher mortality than heavier lambs. A difference of 0.4 kg in the birth mass of a lamb represents nearly 10% of its body mass and may be biologically significant to its odds of avoiding predation. Mean birth mass was strongly correlated with mean neonatal survival of caribou calves from 1987-91 in an ecologically similar area 100 km to the west (Adams et al. 1996). Mean birth mass may be an indicator of the overall health of a population. Lighter calves within those years did not suffer any higher mortality than heavier calves (Adams et al. 1996). Though nearly all lambs deaths were attributed to predation, the fact that light lambs died at a higher rate than heavy lambs suggests some proportion of this mortality may be compensatory. Lighter lambs may be less vigorous and more susceptible to predation.

Annual aerial surveys that include yearling classifications may be useful for determining lamb survival from mid-June until mid-June the following year. Such a survey, could not assess neonate mortality, but would provide a cost-effective index of "productivity" for a population.

The decline of the Central Alaska Range sheep population between 1989 and 1993 may have been due to factors other than predation of lambs. For example, summer weather may influence adult ewe body condition through quality and quantity of forage. Cameron and Ver Hoef (1994) concluded that body condition was closely correlated with reproductive performance in caribou. Lenart (1997) found that warm, dry summer weather in Interior Alaska decreased quality and quantity of caribou forage at high elevation sites, similar to those occupied by sheep. Hoefs (1984) documented high sheep natality rates in spring following a summer with high rainfall and high forage productivity.

Horn and body growth among rams was found to be limited by nutrition in Dall rams in Canada (Hoefs and Nowlan 1997). Ewes are likely also limited by nutrition on the same range. Summer weather may affect ewe body condition and hence offspring weight at birth.

Winter snowfall and winds probably influence availability of forage produced the previous summer. Lambing success rate (measured as summer lamb:ewe ratios) was inversely related to winter snow depth and positively correlated with average wind speed in South-central Alaska and Canada (Nichols 1978, Burles and Hoefs 1982). The poor lamb production or survival until July from 1991-93 in the central Alaska Range may have been a result of the deep snow winters of 1990-91 and 1992-93 and the dry summers of 1990 and 1991 (Boertje et al. 1996). Low pregnancy and natality rates were documented for a sympatric caribou herd during 1990, 1991, and 1993 (Boertje et al. 1996). Low pregnancy rates among ewes, or low birth weight (and subsequent poor survival) of lambs in those years could explain the lack of lambs observed during July 1991, 1992, and 1993.

MANAGEMENT IMPLICATIONS

Coyotes and eagles were the main predators of Dall sheep lambs in this study area, which is the first documentation of the timing and causes of lamb mortality in Alaska. Despite a 3-fold increase in the wolf population, no increase in predation of lambs by wolves was observed. Wolves killed lambs at a lower rate than either coyotes or eagles.

Birth mass positively affected lamb survival. If birth mass is a function of female body condition, population productivity may be strongly influenced by the previous summer or winter weather conditions. Because Dall sheep inhabit high elevation habitat

with a consistently short growing season, they may be more prone to severe declines due to nutritional stress than caribou or moose. Stochastic weather events will undoubtedly influence dynamics of Dall sheep populations through both production and availability of forage.

Predation limits the growth rate of low-density Dall·sheep populations, like this one, thus lengthening the recovery period after severe declines. Wolves were not a major factor in the survival of neonatal sheep here, but may be in areas where moose and caribou are scarce. The effect of wolves on the adult segment of this population of sheep is still unknown. With the knowledge that coyotes are an influential factor in this predator-prey system, additional research should be directed at wolf-coyote and coyote-sheep dynamics.

ACKNOWLEDGMENTS

LITERATURE CITED

ADAMS, L. G., F. J. SINGER, AND B. W. DALE. 1995. Caribou calf mortality in Denali

National Park, Alaska. Journal of Wildlife Management 59:584-594.

_____, B. W. DALE, AND L. D. MECH. 1996. Wolf Predation on caribou calves in Denali

National Park, Alaska. Pages 245-260 *in* L. N. Carbyn, S. H. Fritts, and D. R.

Seip, eds. Ecology and conservation of wolves in a changing world. Canadian

Circumpolar Institute, University of Alberta, Edmonton.

BLEICH, V. C., R. T. BOWYER, A. M. PAULI, M. C. NICHOLSON, AND R. W. ANTHES.

1994. Mountain Sheep *Ovis canadensis* and helicopter surveys: Ramifications for

the conservation of large mammals. Biological Conservation 70:1-7.

BOERTJE, R. D., AND C. GARDNER. 1997. Factors limiting the Fortymile Caribou Herd.

Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration.

Research Progress Report W-24-5.

_____, P. VALKENBURG, AND M. E. McNAY. 1996. Increases in moose, caribou, and

wolves following wolf control in Alaska. Journal of Wildlife Management

60(3):474-489.

BUECHNER, H. K. 1960. The bighorn sheep in the United States, its past, present, and

future. Wildlife Monograph 4:1-174.

BUNNELL, F. L. 1980. Factors controlling lambing period of Dall's sheep. Canadian

Journal of Zoology. 58:1027-1031.

BURLES, D., AND M. HOEFS. 1982. The influence of winter severity on Dall sheep

productivity in southwestern Yukon- a preliminary assessment. Proceedings of

Sixth Biennial Symposium North American Wild Sheep and Goat Council. 3:67-84.

CAMERON, R. D., AND J. M. VER HOEF. 1994. Predicting parturition rate of caribou from autumn body mass. Journal of Wildlife Management 58:674-679.

DEFORGE, J. R., AND J. E. SCOTT. 1982. Ecological investigations into high lamb mortality. Desert Bighorn Council Transactions. Pages 65-76

DOUGLAS, C. L., AND D. M. LESLIE JR. 1986. Influence of weather and density on lamb survival of desert mountain sheep. Journal of Wildlife Management 50:153-156.

FEINBERG, S. E. 1980. The analysis of cross-classified categorical data. Massachusetts Institute Tech. Press, Cambridge. 198pp.

FESTA-BIANCHET, M. 1988. Birthdate and survival in bighorn lambs (Ovis canadensis). Journal of Zoology., London. 214:653-661.

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

GASAWAY W. C., R. O. STEPHENSON, J. L. DAVIS, P. E. K. SHEPHERD, AND O. E. BURRIS. 1983. Interrelationships of wolves, prey, and man in interior Alaska. Wildlife Monograph 84:1-50.

HASS, C. C. 1989. Bighorn lamb mortality: predation, inbreeding, and population effects. Canadian Journal of Zoology 67:699-705.

HEIMER W. E., AND R. O. STEPHENSON. 1982. Responses of Dall sheep populations to wolf control in interior Alaska. Proceedings of sixth biennial symp North American

wild sheep and goat council. 3:320-329

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

HOEFS, M. AND U. NOWLAN. 1997. Comparison of horn growth in captive and free-ranging Dall's rams. Journal of Wildlife Management 61:1154-1160.

LENART, E. A. 1997. Effects of weather on caribou forages, productivity and nutrition within the range of the Chisana Herd. M. S. Thesis, University of Alaska Fairbanks.76pp.

MCNAY, M. 1990. Annual report of survey-inventory activities Dall Sheep, Alaska Department of Fish and Game, project W-23-2.

MURIE, A. 1944. The wolves of Mt. McKinley. U.S. Department of the Interior, National Park Service. Fauna Serv. 5. 283pp.

MURPHY, E. C., AND K. R. WHITTEN. 1976. Dall Sheep demography in McKinley Park and a reevaluation of Murie's data. Journal of Wildlife Management 40:597-609.

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

NICHOLS, L. 1978. Dall sheep reproduction. Journal of Wildlife Management 43:570-580.

OZOGA, J. J., AND R. K. CLUTE. 1988. Mortality rates of marked and unmarked fawns. Journal of Wildlife Management. 52:549-551.

PAQUET, P. C. 1992. Prey use strategies of sympatric wolves and coyotes in Riding Mountain National Park, Manitoba. Journal of Mammalogy. 73:337-343.

POLLACK, K. H., S. R. WINTERSTEIN, C. M. BUNCK, AND P. D. CURTIS. 1989. Survival

analysis in telemetry studies: the staggered entry design. Journal of Wildlife

Management 53:7-15.

RACHLOW, J. L., AND R. T. BOWYER. 1994. Variability in maternal behavior by Dall's

sheep: Environmental tracking or adaptive strategy? Journal of Mammalogy

75:328-337.

SCOTTON, B. D., AND D. H. PLETSCHER. In press. Evaluation of a capture technique for

neonatal Dall sheep. Wildlife Society Bulletin.

SHERMAN, M. 1981. Big game in Alaska: a history of wildlife and people. Yale University

Press, New Haven.

SUMANIK, R. S. 1987. Wolf ecology in the Kluane Region, Yukon Territory. M. S.

Thesis, Michigan Technological University.

THURBER. J. M., R. O. PETERSON, J. D. WOOLINGTON, AND J. A. VUCETICH. 1992.

Coyote coexistence with wolves on the Kenai Peninsula, Alaska. Canadian Journal

of Zoology. 70:2494-2498.

VALKENBURG, P. 1997. Investigation of regulating and limiting factors in the Delta

Caribou Herd. Alaska Department of Fish and Game. Federal Aid in Wildlife

Restoration. Final Report. Projects W-23-5 through W-24-4. Juneau. 45pp.

VAN BALLENBERGHE, V., AND W. B. BALLARD. 1994. Limitation and regulation of moose

populations: the role of predation. Canadian Journal of Zoology 72:2071-2077.

WHITTEN, K. R., G. N. GARNER, F. J. MAUER, AND R. B HARRIS. 1992. Productivity and

early survival in the Porcupine Caribou Herd. Journal of Wildlife Management

56:201-212.

WOODARD, T. N., R. J. GUTIERREZ, AND W. H. RUTHERFORD. 1974. Bighorn lamb production, survival, and mortality in South-Central Colorado. Journal of Wildlife Management 38:771-774.

Table 1. Mean masses of lambs, by sex, at time of capture (1995 and 1996 cohorts combined).

Age	Weight		P value (Students t-test)
	Male	Female	
< 48 hr old	4.1 kg ($n = 22$)	4.0 kg ($n = 9$)	0.11
48-72 hr old	5.0 kg ($n = 5$)	4.3 kg ($n = 16$)	0.57

Table 2. Timing and causes of mortality among radiocollared Dall sheep lambs in the
Central Alaska Range, May 1995 through April 1997.

Cause of death	Age Class 1-60 days			Age Class 61-365 days			Total
	1995-96 n = 22	1996-97 n = 34	Subtotal	1995-96 n = 16	1996-97 n = 23	Subtotal	Number deaths
Coyote	1	5	6	1	3	4	10
Eagle	1	4	5	0	0	0	5
Wolf	0	0	0	1	0	1	1
Bear	1	0	1	0	0	0	1
Wolverine	0	1	1	0	0	0	1
Unknown (wolf/coyote)	1	0	1	1	2	3	4
Rockslide	0	1	1	0	0	0	1
Total	4	11	15	3	5	8	23

Table 3. Results of Central Alaska Range post-lambing sheep surveys, 1994 – 1997

Year	No. Ewes	No. Lambs	No. Yrlg's	No. Rams	Lamb:ewe ratio	Hours flown	Total sheep
1994[a]	211	72	NA	125	34:100[a]	4.8	442
1995[b]	249	109	61	167	44:100[b]	5.8	586
1996[b]	267	137	95	158	51:100[b]	6.0	657
1997[b]	212	85	93	177	40:100[b]	7.3	567

[a] survey flown with a supercub; yearlings not classified; lamb:ewe ratio contains yearlings
[b] surveys flown with R-22 helicopter; yearlings classified; ratios do not contain yearlings
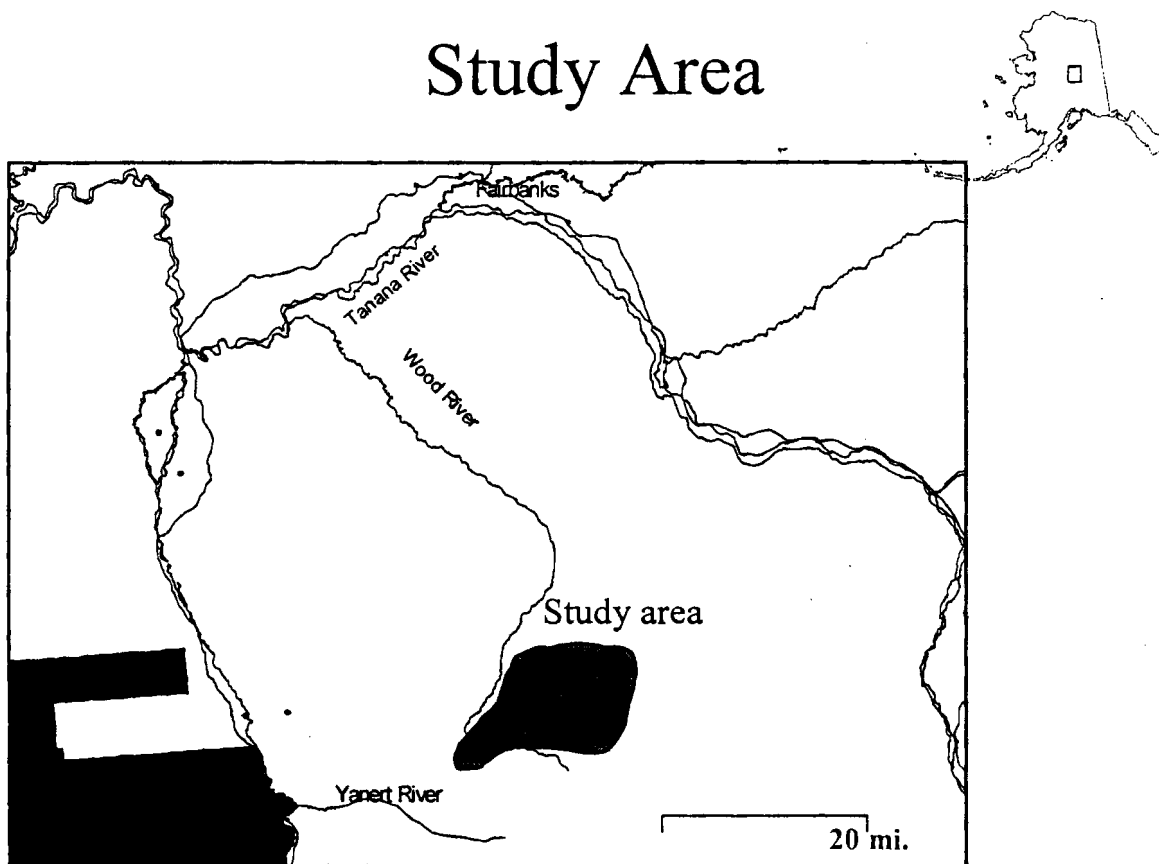
Study Area

Figure 1. The study area is a 530 km^2 portion of the Alaska Range approximately 75 km south of Fairbanks, AK.

Figure 1. Kaplan-Meier survival estimates for lambs born in 1995 and 1996 (Pollack et al. 1989). A period of high early mortality in May and June was followed by a second period of low but constant mortality until March.