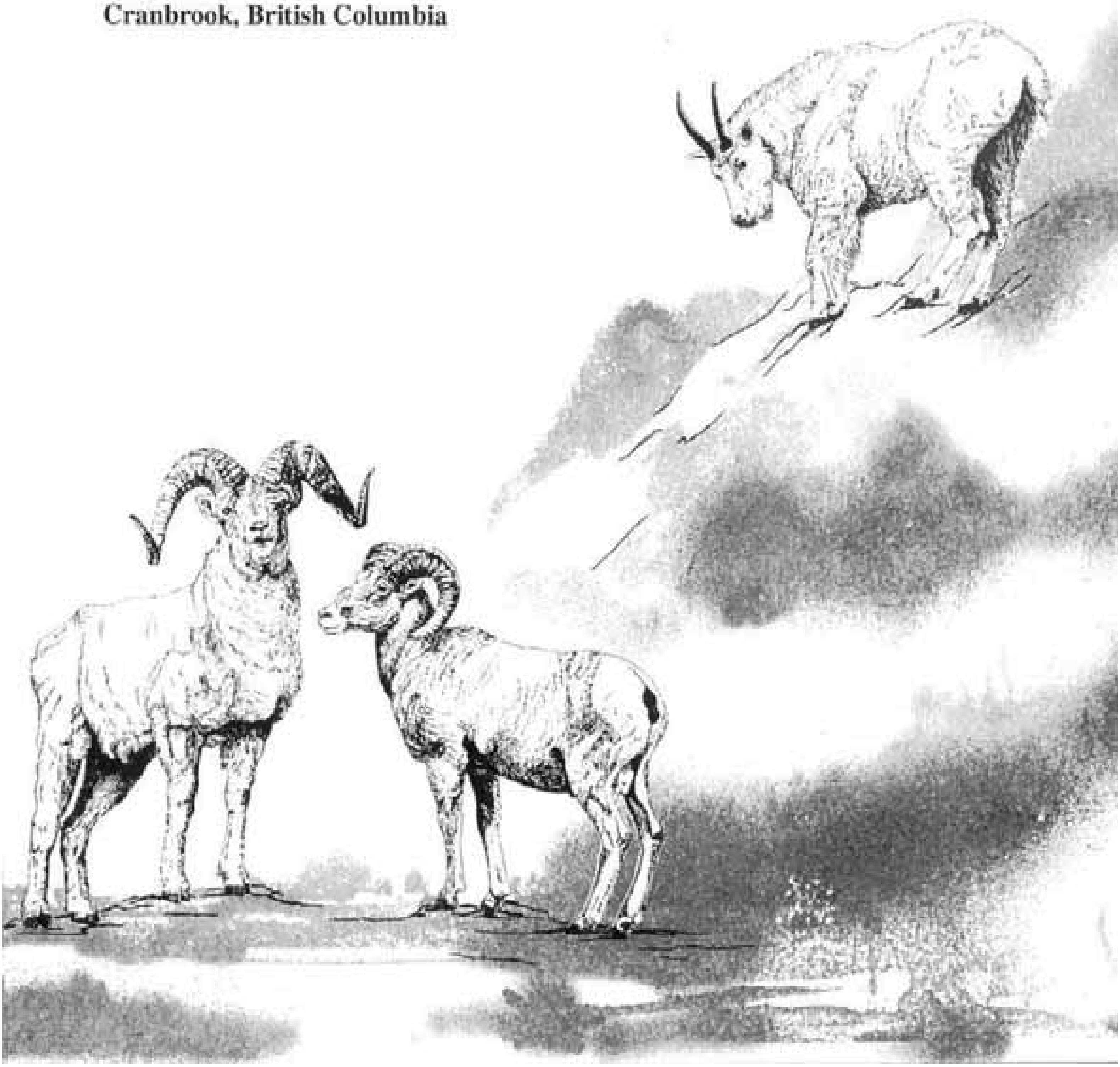
Northern Wild Sheep and Goat Council

Proceedings of the Ninth Biennial Symposium

May 2-6, 1994
Cranbrook, British Columbia



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CRANBROOK, BRITISH COLUMBIA

Editor: Margo Pybus
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Proceedings available from:

Northern Wild Sheep and Goat Council
c/o Kevin Hurley
Wyoming Game and Fish Department
932 Arapahoe
Thermopolis, WY 82443-2115

Price $20.00 (U.S.)
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After 3/31/96, Proceedings available from:

Foundation for North American Wild Sheep
720 Allen Avenue
Cody, WY 82414

The Northern Wild Sheep and Goat Council is a nonprofit professional organization developed in 1978 from the Parent organization - The Northern Wild Sheep Council

The 1994 Symposium was hosted by: British Columbia Environment, Wildlife Branch.

ACKNOWLEDGEMENTS

Anna Fontana, 1994 NWSGC Conference Coordinator
BC Wildlife Branch, Cranbrook

The following publication could only have been completed through the dedication and effort of the Northern Wild Sheep and Goat Council committee, a non-affiliated and nonprofit organization dedicated to improving scientific/technical knowledge regarding wild sheep and goats in North America. As the co-Chair and conference coordinator for 1994, I would like to extend my sincere appreciation and thanks to the many individuals and organizations that participated in making this year's event a success.

A great big 'thank you' to the Foundation for North American Wild Sheep, the East Kootenay Wildlife Association, and British Columbia Environment, Wildlife Branch, all of which were instrumental in providing logistical and financial support.

To Susan Smith and Heather Mackenzie of the Cranbrook, BC Environment office who spent countless hours making sure the mailing list and mailouts were completed promptly and effectively, my sincere appreciation for your help. Thanks also to Clayton Apps for coordinating the audio visual equipment and the taping of the proceedings.

Thank you to Ray Demarchi, Helen Schwantje, Gary Tipper, and Peter Davidson (all of BC Environment) and Chris Smith (Alaska Department of Fish and Game) for hosting the field trip through the East Kootenay Rocky Mountain Trench. Much appreciation to the Canal Flats Wilderness Club and Lake Windemere Rod and Gun Club for hosting the field trip luncheon and sponsoring the banquet.

To Margo Pybus (Alberta Fish and Wildlife), thanks a million for your relentless energy and dedication in coordinating the review and editing of the manuscripts for these proceedings.

Forever a hug and thank you to Kevin Hurley (Wyoming Fish and Game) and Wayne Heimer (Alaska Department of Fish and Game) for their unending advice and support to me personally, and for ensuring that the Cranbrook conference matched the success of previous meetings. Kevin also willingly coordinated the printing and distribution of the proceedings, and was the liaison with the Foundation.

Finally, a heartfelt thanks to the individuals who submitted papers and those who attended the meeting. May we all have the opportunity to re-establish friendships and learn more about wild sheep and goats in Colorado's Rockies in 1996.

Margo Pybus, Proceedings Editor
Alberta Fish and Wildlife

The Editor extends a special thanks to Bill Wishart for his diligence and precision in checking for details. Additional thanks are offered to the following reviewers: J. Bailey, W. Bodie, R. Demarchi, J. Emmerich, M. Festa-Bianchet, V. Geist, J. Gunson, W. Heimer, K. Hurley, L. Irby, M.L. Irby, J. Jorgenson, B. MacCallum, M. Miller, D. Onderka, D. Reed, K. Smith, J. Stelfox, E.T. Thorne, E. Williams, W. Wishart, and D. Worley. Their timely and critical evaluations made my job that much easier. Wayne Heimer cajoled, compiled, and edited the workshop portion of these Proceedings.

I also want to thank the authors for their timely (for the most part) submission of original and revised manuscripts. I trust this final product is deemed worthy of your efforts.

FOREWORD

Papers in these proceedings were presented during the Ninth Biennial Symposium of the Northern Wild Sheep and Goat Council held May 2 - 6, 1994 at Cranbrook, British Columbia.

The papers have been reviewed but not refereed. Each manuscript was read carefully by at least one peer biologist, and suggestions and comments submitted to each author. Not all submitted papers were accepted. Final versions of all papers reflect author's responses to reviewer and editorial comments. Papers were then formatted into the style of the Journal of Wildlife Management. This review process is designed to enhance the timely dissemination of useful information yet provide opportunity for external comment. The reader is responsible for critically evaluating the information contained in these papers - as is always the responsibility of a professional biologist.

CONTENTS

Bienn. Symp. North. Wild Sheep
and Goat Counc. 9:1-6.

EVALUATION OF THE CYTOTOXICITY OF VARIOUS ISOLATES OF *PASTEURELLA HAEMOLYTICA* FROM BIGHORN SHEEP AND OTHER UNGULATE POPULATIONS.

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Abstract: An assay has been developed for the purpose of evaluating the cytotoxic potencies of various isolates of *Pasteurella haemolytica*. The assay allows measurement of the potency of a soluble toxin released by different *P. haemolytica* organisms isolated from a variety of ungulates including bighorn sheep (*Ovis canadensis*), domestic sheep, Dall sheep (*Ovis dalli dalli*), mouflon sheep (*Ovis musimon*), mountain goats (*Oreamnos americana*), domestic goats, and elk (*Cervus elaphus*). Peripheral blood neutrophils were used as target cells for cytotoxin-dependent killing. Cytotoxicity was quantitated by assessing the release of lactate dehydrogenase by neutrophils into the culture medium. Results are shown from a variety of *P. haemolytica* isolates collected from bighorn sheep representing geographically distinct populations, and from other ungulate species including: deer (*Odocoileus* spp.), elk, Dall sheep, mountain goats, mouflon sheep and domestic sheep. Neutrophil susceptibility to cytotoxin-mediated injury is compared among Dall sheep, mountain goats, bighorn sheep, domestic sheep, deer, and elk. The information gained can facilitate management decisions necessary for maintaining healthy bighorn sheep and other wildlife populations.

Respiratory disease caused by pasteurellosis results in mortality in both bighorn sheep and domestic sheep, yet it is reported less frequently in deer or elk (Thorne 1982, Franson and Smith 1988). To our knowledge, bacterial pneumonia has not been reported in Dall sheep or mountain goats. *P. haemolytica* can be isolated from many ruminant species whether respiratory disease symptoms exist or not (Frank 1982, Clark et al. 1985, Miller et al. 1991, Wild and Miller 1991). Bighorn sheep are more susceptible to respiratory infections than domestic sheep (Foreyt 1988, Onderka and Wishart 1988, Onderka et al. 1988, Callan et al. 1991) and this difference in susceptibility can be partially explained by the greater sensitivity of bighorn sheep neutrophils to cytotoxin-dependent killing by *P. haemolytica* organisms (Silflow et al. 1993).

Contact transmission of *P. haemolytica* from domestic sheep to bighorn sheep populations may have devastating consequences to bighorn sheep survival. The observation of mortality losses in free ranging bighorn sheep exposed to domestic sheep is confirmed by the results of experimental trials in which transmission of *P. haemolytica* between these two sheep species were tested on captive bighorn sheep (Foreyt 1988, Onderka and Wishart 1988, Onderka et al. 1988, Callan et al. 1991). These experiments, conducted by three different investigative teams, all resulted in high mortality losses in bighorn sheep but not in domestic sheep. Important questions extending from these results include whether other wild species, such as Dall sheep, mountain goats, deer and elk, also are susceptible to mortality losses due to *P. haemolytica*, and whether Dall sheep, mountain goats, deer or elk serve as a reservoir of *P. haemolytica* which can be transmitted to bighorn sheep. Previous experiments involving deer and elk contact with bighorn sheep did not result in respiratory disease in any of the animals (Foreyt 1992).

The cytotoxin produced by some *P. haemolytica* isolates is an important virulence factor in the development of respiratory disease in many ruminant species. Colonization of the lower respiratory tract with *P. haemolytica* results in exogenous release of a soluble toxin capable of exacerbating the acute inflammation which is characteristic of pasteurellosis (Baluyut et al. 1981, Berggren et al. 1981). Previous studies have focused primarily on the neutrophil as the target phagocytic cell susceptible to cytotoxin mediation (Baluyut et al. 1981, Confer et al. 1990, Czuprynski et al. 1991, Silflow et al. 1993). Studies with the cytotoxin isolated from cattle have shown that, at high concentrations, the cytotoxin causes lysis of the neutrophil resulting in the release of intracellular components which can cause damage to the integrity of the lung (Czuprynski et al. 1991). At low concentrations, the cytotoxin can activate neutrophils to release oxygen intermediates and granule constituents capable of causing host lung damage which may lead to morbidity or mortality losses (Czuprynski et al. 1991). In addition to the neutrophil, cytotoxin mediation occurs in other immune cells, including suppressed proliferation of bovine peripheral mononuclear cells (Czuprynski and Ortiz-Carranza 1992) and lymphocytes (Majury and Shewen 1991), and lethal and sublethal effects on alveolar macrophages from cattle (Markham and Wilkie 1980, Markham et al. 1982) and sheep (Sutherland et al. 1983).

Alveolar macrophages are the phagocytic cells responsible for initial defense of the lung against any infectious or non-infectious agent entering the lower airways (Liggitt 1985). Previous comparisons of bighorn and domestic sheep species revealed no differences in the numbers of phagocytic cells in the alveolar spaces, nor were there any differences in the phagocytic or bactericidal activities of alveolar macrophages (Silflow et al. 1989). During early exposure of the lower respiratory tract to *P. haemolytica*, the first phagocytic cells to encounter cytotoxin are alveolar macrophages. However, we have shown that alveolar macrophages are more resistant to killing by *P. haemolytica* supernatants than are neutrophils (Silflow and Foreyt 1994).

Our objectives were: 1) to measure the potency of cytotoxin released by different *P. haemolytica* organisms isolated from a variety of ungulates on neutrophils, 2) to measure the potency of cytotoxin from a variety of *P. haemolytica* isolates collected from bighorn sheep representing geographically distinct populations, and 3) to compare the sensitivity of neutrophils from different species to cytotoxin-dependent lysis.

METHODS

Animals

Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) from the captive herd at Washington State University were used as a source of neutrophils for the assays performed in this study. For each assay, neutrophils from 3 bighorn sheep (ewes and rams ranging in age from 1-4 years) were tested for cytotoxin-dependent lysis by *P. haemolytica* isolates. In addition, for the experiment to compare different species for neutrophil sensitivity to cytotoxin-dependent lysis, neutrophils were collected from mountain goats (n = 2), Dall sheep (n= 3), domestic sheep (n = 3), deer (n = 4) and elk (n = 6). All animals were clinically healthy when samples were collected.

Neutrophil Collection and Purification

Peripheral blood samples were collected into citrate phosphate dextrose solution (Sigma Chemical Company, St. Louis, Missouri, USA) by jugular venipuncture. Following centrifugation at 850 x g for 15 min, the plasma and buffy coats were discarded. Hypotonic lysis of red cells was accomplished by the addition of 45 ml distilled water for 45 sec followed by the addition of 5 ml of 10X phosphate buffered saline. Following centrifugation at 600 x g for 10 min, the lysis and centrifugation steps were repeated, and the final cell pellets were resuspended in Hanks Balanced Salt Solution (HBSS) + 1% fetal bovine serum (FBS). Cells were quantitated using a hemocytometer, and cell viability was determined by trypan blue exclusion. Typical yields were > 90% neutrophils, and these cells exhibited > 90% viability. For each experiment, cells were adjusted to a concentration of 5×10^6 cells/ml in HBSS + 1% FBS.

Cytotoxin Preparation

Cytotoxins were isolated from culture supernatants using the method of Shewen and Wilkie (Shewen and Wilkie 1982). The bacterial isolates were characterized according to biotype and serotype at the Washington State Disease Diagnosis Laboratory in Pullman, Washington. Individual *P. haemolytica* isolates were streaked onto 5% blood agar plates (Beckton Dickinson Microbiological Systems, Cockeysville, Maryland, USA) and incubated for 18 hr at 37 C. A negative control bacterium, *Enterobacter* (ATCC #35030), was handled identically. Several morphologically similar colonies were used to inoculate 100 ml of brain-heart infusion broth (Difco Laboratories,

Table 1. Summary of the cytotoxicity status of *Pasteurella haemolytica* isolates recovered from a variety of ungulate species.

Species	# isolates tested	# cytotoxic isolates	Biotype/ serotype of cytotoxic isolates
Bighorn sheep	112	29	A2, A5,11, A11, A(UT)[a]
Domestc sheep	23	13	A2, A(UT), T3
Dall sheep	19	6	A2
Mountain goat	4	2	A6
Domestic goat	13	0	NA[b]
Mouflon sheep	16	1	A(UT)
Elk	10	0	NA

[a] UT = serotype untypable due to autoagglutination.
[b] NA = not applicable.

Detroit, Michigan, USA) which was incubated at 37 C until cultures reached early logarithmic growth. To quantitate the number of bacteria, the optical densities of the cultures were measured at a wavelength of 600 nm (OD_{600}) until 1 OD_{600} (8 X 10^8 bacteria/ml) was reached. Bacteria were centrifuged for 10 min at 6000 x g to a pellet, and resuspended in 30 ml of RPMI-1640 media (Gibco Laboratories, Grand Island, New York, USA) containing 7% FBS. Following incubation for 1 hr at 37 C, the bacteria again were centrifuged at 6000 x g for 10 min, and the culture supernatants were removed and filter sterilized in a 0.45 µm filter (Sigma Chemical Company, St. Louis, Missouri, USA). Culture supernatants were dialyzed to exhaustion against distilled water and lyophilized.

Cytotoxicity Assay

We characterized the relative potency of toxins produced by various *P. haemolytica* isolates by adding bacterial culture supernatants to neutrophils in vitro. Cytotoxicity was quantitated by assessing the release of lactate dehydrogenase (LDH) into the culture medium (Korzeniewski and Callewaert 1983). Cytotoxicity was determined at final concentrations of supernatant of 150, 100, 50, 5, 0.5, and 0.05 µg/50 µl. All of the samples were resuspended in HBSS containing 1% FBS prior to the assay. Fifty µl of each supernatant preparation containing cytotoxin was added to the wells of 96-well plates, followed by the addition of 2.5 x 10^5 neutrophils in 50 µl of HBSS containing 1% FBS to each well. Following 1 hr incubation at 37 C, 100 µl of LDH substrate was added. Quantitation of the reduced LDH substrate was based on a Titertek 96-well plate reader (Flow Laboratories, McLean, Virginia, USA) coupled to an on-line IBM-XT computer (International Business Machines, Boca Raton, Florida, USA). All samples were compared to neutrophils treated with a 0.5% solution of the detergent Triton-X (Sigma Chemical Company, St. Louis, Missouri, USA) (maximal release) and untreated cells (background release) and the results recorded as a percentage of LDH released from untreated cells. The potency of the various cytotoxins was determined by comparing the 50% effective dose (ED_{50}). The ED_{50} represents the intersection of supernatant concentration and 50% cell death as determined from the graphic plot of these two factors.

RESULTS AND DISCUSSION

A total of 197 *P. haemolytica* isolates from 7 different ungulate species was tested for cytotoxicity on neutrophils from bighorn sheep (Table 1). For an isolate to be considered cytotoxic, according to our definition, it must have an ED_{50} of < 150 µg/50µl of supernatant. Therefore, any isolates which had supernatants unable to kill at least 50% of the neutrophil population in 1 hr were classified as non-cytotoxic. At least one cytotoxic isolate was recovered from bighorn sheep,

Table 2. Cytotoxicity status of *Pasteurella haemolytica* isolates collected from geographically distinct bighorn sheep herds.

Herd location	Total # isolates	# cytotoxic	Biotype/ serotype of cytotoxic isolates
Sluice Creek, OR	4	1	A5, 11
Lostine, OR	7	0	NA
Central Oregon	8	3	A(UT)
Wenaha, OR	2	1	A11
Hall Mt., WA	3	0	NA
Curlew, WA	6	1	A(UT)
Umtanum, WA	5	0	NA
Swakane, WA	8	1	A(UT)
Wildhorse Is., MT	8	0	NA

[a] NA = not applicable.
[b] UT = serotype untypable due to autoagglutination.

domestic sheep, Dall sheep, mountain goats, and mouflon sheep. To date, no cytotoxic isolates have been identified in domestic goats (n= 13) or elk (n = 10). These results are from a small sample size; however, and should be interpreted carefully. Cytotoxin-producing isolates were identified most frequently following recovery from the lung and viscera of pneumonic animals, but occasionally they were also recovered from pharyngeal swabs of healthy animals. Biotype A isolates were more likely to be cytotoxic than biotype T isolates. We did recover biotype A isolates which were non-cytotoxic including A11, A1,8, A1,2,7,8,11,12, and A(untypable). In our experience, the *Pasteurella* organisms most frequently recovered from an animal which has died of pneumonia have been A2. To date, we have not recovered an A2 organism from a healthy bighorn sheep.

Geographically distinct herds of bighorn sheep were tested for the presence of cytotoxic *P. haemolytica* isolates. Of 9 different herds tested, cytotoxic isolates were recovered from 5 herds (Table 2). In 4 of these 5 herds testing positive for cytotoxin, all of the animals appeared to be healthy and these 4 herds consisted of California bighorn sheep (*Ovis canadensis californiana*). In 1 case, the cytotoxic isolate was recovered from a Rocky Mountain bighorn sheep which had died of pneumonia, while the remainder of the herd appeared healthy. Whether neutrophils from California bighorn sheep are more resistant to cytotoxin damage than neutrophils from Rocky Mountain bighorn sheep is not known and will be tested in future research efforts.

Neutrophils were collected from 6 different ungulate species and tested for sensitivity to an A2 isolate from a domestic sheep (Table 3). Neutrophils from elk and deer were not sensitive to the cytotoxin at the doses of supernatant routinely used. However, neutrophils from bighorn sheep, Dall sheep, mountain goats and domestic sheep were sensitive to cytotoxin-dependent killing. The order of sensitivity to cytotoxin killing (from most sensitive to least) is Dall sheep, bighorn sheep, mountain goat, domestic sheep.

Testing geographically distinct herds of ungulates for neutrophil sensitivity to *P. haemolytica* cytotoxin requires transportation of blood samples to a location with adequate laboratory facilities. To determine how long after blood collection the neutrophil viability is adequate to use in the cytotoxicity assay, blood samples were collected into anti-coagulant and stored at either 4 C or 22 C for 0, 12, 24, and 48 hrs before neutrophils were isolated and viability was measured. No differences were observed for effects of temperature. Neutrophil viability steadily declined with time, though 90% were still alive by 12 hr post-collection

Table 3. **Relative sensitivity of neutrophils from different ungulate species to cytotoxin lysis by a *Pasteurella haemolytica* isolate (A2) from a domestic sheep. The species are listed in order from most to least sensitive to lysis.**

Species	ED_{50}[a] (µg/50µl)
Dall sheep	3
Bighorn sheep	12
Mountain goat	25
Domestic sheep	58
Elk	NC[b]
Deer	NC[b]

[a] 50% effective dose representing the intersection of supernatant concentration and 50% neutrophil death.

[b] Considered to be non-cytotoxic since the ED_{50} exceeds the highest concentration of supernatant used in the assay.

(Figure 1). In situations where blood samples can be shipped to a laboratory within 24 hr of collection, adequate numbers of viable neutrophils will be available to use in a cytotoxin assay.

Cytotoxin production is a major virulence factor in the pathogenesis of pneumonia, yet the recovery of cytotoxic organisms from healthy animals indicates that it may not be the only factor involved. Others, such as the presence or absence of a capsule, and the role of lipopolysaccharide, should be investigated. In addition, the production of chemotactic signals by bacterial organisms, alveolar macrophages, or both, should be considered. Depletion of peripheral blood neutrophils prior to inoculation of *P. haemolytica* in calves blocked the development of respiratory disease (Slocombe et al. 1985). Therefore, if the chemotactic signals could be prevented or diminished, thus preventing the influx of neutrophils from peripheral blood into alveolar spaces, lung damage could be minimized.

MANAGEMENT CONSIDERATIONS

Since the cytotoxin assay can be performed routinely, wildlife managers and biologists should consider collecting pharyngeal swabs from captured animals to screen for the presence of *P. haemolytica* organisms. Furthermore, the status of cytotoxin production by these organisms should be tested. The information gained may influence

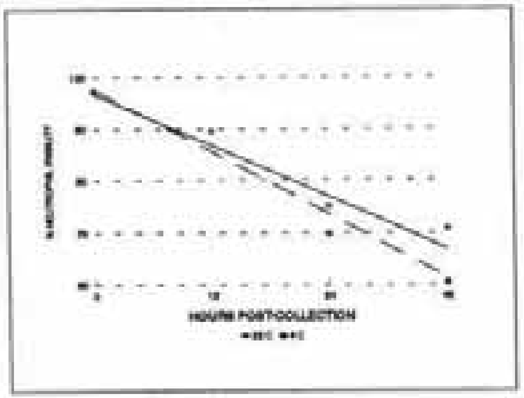

Figure 1. Peripheral blood samples were collected from bighorn sheep (n = 3) into citrate phosphate dextrose solution and stored at either 4 C or 22 C for 0, 12, 24, and 48 hours before neutrophils were isolated and tested for viability.

decisions related to transplantation of animals. Furthermore, the information of the status of a herd regarding the presence or absence of cytotoxic organisms may have epizootiologic value which may be used to predict or anticipate disease risk within a herd.

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and Goat Counc. 9:7-14.

EFFECTS OF CONTROLLED CONTACT EXPOSURE BETWEEN HEALTHY BIGHORN SHEEP AND LLAMAS, DOMESTIC GOATS, MOUNTAIN GOATS, CATTLE, DOMESTIC SHEEP, OR MOUFLON SHEEP

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Abstract: In separate experiments under controlled conditions, captive Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) were placed on pasture with llamas (*Llama glama*), domestic goats, mountain goats (*Oreamnos americana*), cattle, and mouflon sheep (*Ovis musimon*) to determine the effects on the bighorn sheep. In an additional experiment, two domestic sheep and two bighorn sheep were placed together in an isolation facility. Essentially all bighorn sheep, domestic goats, domestic sheep, cattle, mountain goats, and mouflon sheep were pharyngeal carriers of *Pasteurella haemolytica* when the contact experiments began. The most common serotype of *P. haemolytica* reacted in antisera to T3, 4,and 10. *Pasteurella haemolytica* was not isolated from the three llamas used in these experiments nor from 14 additional llamas sampled. Bighorn sheep remained clinically healthy during and after contact with llamas, cattle, mountain goats, and domestic goats, but all bighorn sheep died from acute bronchopneumonia after contact with domestic sheep and mouflon sheep.

Respiratory disease caused by *Pasteurella haemolytica* in Rocky Mountain bighorn sheep is the most important disease affecting their survival in North America. Catastrophic mortality and poor lamb survival from surviving ewes are the two major characteristics associated with these pneumonia episodes in bighorn sheep (Onderka and Wishart 1984, Coggins 1988, Foreyt 1989, 1990). Previous research indicates that bighorn sheep are highly susceptible to respiratory disease (Silflow et al. 1991, 1993), and a variety of factors including lungworms, viruses, bacteria, and stress components can be important in the respiratory disease complex (Spraker et al. 1984, Foreyt 1990).

Experimental contact studies between domestic sheep and bighorn sheep under captive conditions resulted in significant mortality due to pneumonia in the bighorn sheep, and no mortality or respiratory disease in the domestic sheep (Foreyt 1989, 1990, 1992a). *Pasteurella haemolytica*, predominantly biotype A, serotype 2 (A2) was the usual organism isolated from the lungs of the dead bighorn sheep. *Pasteurella haemolytica* A2 is a common organism carried in the pharyngeal area of domestic sheep (Thompson et al. 1977, Frank 1982), but rarely is isolated from healthy bighorn sheep (Dunbar et al. 1990). Experimentally, *P. haemolytica* A2 from healthy domestic sheep inoculated intratracheally into bighorn sheep and healthy domestic sheep, resulted in acute fatal pneumonia in 7 of 8 of the inoculated bighorn sheep, whereas the domestic sheep and non- contact bighorn sheep remained healthy (Foreyt et al. 1994). The inoculum strain of *P. haemolytica* A2 was evaluated by a genomic fingerprinting technique known as ribotyping (Snipes et al. 1992), and the ribotype in the inoculum was the same ribotype recovered from all the dead bighorns. This experiment indicated that some strains of *P. haemolytica* from healthy domestic sheep are lethal in bighorn sheep. Based on all published data, contact between domestic sheep and bighorn sheep must be avoided to prevent the mortality associated with those strains of *P. haemolytica* in domestic sheep that are lethal in bighorn sheep.

The purpose of these studies was to determine the compatibility of bighorn sheep with other ungulates that may potentially have close contact with bighorn sheep in wild or captive situations.

I thank John Lagerquist and the veterinary students at Washington State University for their skillful animal handling, sample collections, and technical assistance. The efforts of Tami Scholz, Dan Bradway, Charlene Teitzel, Joyce Wisinger and Doris Edwards in the bacteriology laboratory of the Washington Animal Disease Diagnostic Laboratory (WADDL) are appreciated. Partial funding for this project was provided by the Washington Department of Wildlife, Oregon Department of Fish and Wildlife, Foundation for North American Wild Sheep, Elvin Hawkins, and Duncan Gilchrist.

MATERIALS AND METHODS

Six experiments were done with Rocky Mountain bighorn sheep at Washington State University, Pullman, Washington, by placing other ungulates with them on common pasture to determine whether the animals were compatible for disease transmission and survival. All animals were grazed together on common pasture for 60 days, unless specified, and were clinically healthy at the initiation of each experiment.

Microbiology Techniques

At the beginning and end of each experiment, pharyngeal swab samples were collected from all animals for bacterial isolations. A harp speculum was used to hold the mouth open and restrain the tongue. After the pharyngeal area was observed, a sterile polyester-tipped applicator swab (Spectrum Laboratories, Inc., Houston, Texas, USA) was used to rub the pharyngeal area briskly, removed, and transported to WADDL, Pullman, Washington. All swabs were streaked onto 5% sheep blood agar plates within 2 hr of collection to maximize isolation of *P. haemolytica* (Wild and Miller, 1991).

Isolation and identification of *P. haemolytica* was accomplished by the methods of Snipes et al. (I992) , but hemolysis on 5% sheep blood agar or growth on MacConkey's agar were not requisites for identification (Onderka et al. 1988; Wild and Miller I991). All *P. haemolytica* isolates were identified to serotype by rapid plate agglutination (Frank and Wessman 1978). If an isolate cross-reacted between or among serotypes, all were listed.

At the beginning of each experiment, nasal swab samples (Marion Scientific Viral Culturette, Marion Scientific, Kansas City, Kansas, USA) were collected for virus evaluation. Specimens were inoculated onto ovine fetal tracheal cells and bovine turbinate cells for two passages at 10-day intervals and were examined daily for cytopathic effect (Castro I992). Additional specimens were tested for respiratory syncytial virus by use of solid phase-enzyme immunoassay (Abbott RSV EIA, Abbott Laboratories, South Pasadena, California). Isolation of *Chlamydia* spp. was not attempted.

Fecal samples from all animals were evaluated for lungworm larvae by a modified Baermann technique (Beane and Hobbs, I983).

Experiment 1 -Bighorn Sheep and Mouflon Sheep.

Six bighorn sheep and 5 mouflon sheep (Table 1) were placed together in a 0.4 ha pen which contained various grasses, and a shelter. Trace mineral salt, alfalfa hay, alfalfa pellets and water were available at all times. The bighorn sheep had been in captivity at Washington State University for approximately one year and consisted of ewes and rams ranging in age from 1 to 3 years. The mouflon sheep were obtained from a private game farm and were rams and ewes ranging in age from 1 to 7 years.

Experiment 2 - Bighorn Sheep and Domestic Goats.

Two bighorn sheep and 3 domestic goats were placed together in the same pen and held under the same conditions as described in experiment 1. The bighorn sheep yearling rams had been in captivity all of their lives while the wether yearling goats were purchased from a local livestock auction.

Experiment 3 - Bighorn Sheep and Mountain Goats.

Nine bighorn sheep and 2 mountain goats were placed together in a 0.8 ha pen which contained various grasses, pine trees and a shelter. Trace mineral salt, alfalfa hay, alfalfa pellets and fresh water were available at all times. The bighorn sheep composed a breeding herd that had been in captivity for approximately 6 years and included a 6 yr-old ram, a 2-yr old ram, and 7 adult ewes. The mountain goats, obtained from a commercial zoo, were 5 mo-old male kids.

Experiment 4 - Bighorn Sheep and Llamas.

Subsequent to experiment 3, the same nine bighorn sheep were placed together with 3 llamas and maintained in the same manner and pen described in experiment 3. The llamas were geldings between 1 and 4 years old that had been donated to Washington State University. A total of 17 llamas were initially sampled in an attempt to find 3 that were carriers of *P. haemolytica*. None was found; therefore, 3 easily accessible llamas were chosen.

Experiment 5 - Bighorn Sheep and Cattle.

Four bighorn sheep and 3 cattle were placed together in the pen described in experiment 1. The bighorn sheep were 8 mo-old lambs (2 males and

2 females) that were obtained from Wildhorse Island on Flathead Lake in Montana one month prior to the experiment. The cattle were Holstein steers that weighed approximately 200 kg each.

Experiment 6 - Bighorn Sheep and Domestic Sheep.

Two yearling bighorn sheep rams and 2 castrated yearling domestic sheep were placed together in an indoor isolation facility 4 x 7 m. Trace mineral salt, alfalfa hay, hay pellets, and fresh water were available at all times.

Evaluation

All animals were observed at least twice daily for signs of respiratory disease. If animals developed respiratory disease, they were euthanized with an intravenous injection of sodium pentobarbital. All dead sheep were submitted to WADDL for complete necropsy evaluation. Bacterial isolations on blood agar were attempted from tissues including tonsil, liver, bronchial lymph nodes, spleen, and lungs. Representative tissues were fixed in 10% buffered formalin, sectioned at 5 μm, and stained in hematoxylin and eosin for microscopic evaluation. A pharyngeal swab sample was collected from most surviving animals approximately 60 days after the animals were placed together.

RESULTS

At the initiation of each experiment, *P. haemolytica* was isolated from all animals except the 3 llamas and 1 bighorn sheep (Tables 1 - 6). The most common isolate of *P. haemolytica* reacted in antisera to T3,4,and 10. Viruses were not isolated from any animal, and lungworm larvae were detected in low numbers (<10 per gram of feces) in approximately half of the bighorn sheep.

All animals survived and remained healthy (Tables 1 - 6) except the bighorn sheep in contact with mouflon sheep (experiment 1) or domestic sheep (experiment 6). All 5 bighorn sheep died on days 41 or 42 after initial contact with the mouflon sheep (Table 1), and the 2 bighorn sheep died on days 6 and 8, respectively, after initial contact with domestic sheep (Table 6). At necropsy, all bighorn sheep were in good body condition with adequate amounts of body fat. Lesions were similar in the 7 bighorn sheep that died and were characteristic of acute, fibrino-hemorrhagic pneumonia and pleuritis. Up to 80% of lung volume was dark red and consolidated with moderate amounts of adherent fibrin. On cut surface, lungs were diffusely edematous with prominent interlobular septa. Regional lymph nodes (mandibular, cervical, tracheobronchial, mediastinal) were moderately enlarged.

Histologically, pulmonary architecture was diffusely and severely altered by large areas of necrosis marginated by densely packed or clumped neutrophils and macrophages. The pleura was markedly thickened by fibrin deposits, and subpleural spaces and interlobular septa were widened by collections of fluid and exudate. Densely basophilic bacterial colonies were mixed with the cellular exudates, especially in terminal bronchioles and remaining air spaces. Adjacent alveolar capillary endothelium was disrupted, and fibrin thrombi were common within these blood vessels.

The primary biotype and serotype of *P. haemolytica* recovered from tissues of dead bighorns was A2, which had not been recovered from the bighorn sheep at the initiation of the experiment. None of the isolates recovered from bighorn sheep at the initiation of the experiments were toxic as determined by the neutrophil sensitivity test (Silflow et al. 1990), but all biotype A isolates recovered from dead bighorn sheep after contact with mouflon sheep were toxic (Table 1). A toxic biotype A untypeable serotype of *P. haemolytica* was recovered from one of the mouflon sheep initially, but no toxic isolates were recovered from mouflon sheep at the termination of the experiment (Table 1). Toxicities were not evaluated from domestic sheep and bighorn sheep in experiment 6, but *P. haemolytica* A2 was detected in both domestic sheep at the initiation of the experiment and in both dead bighorns at necropsy (Table 6). Toxic isolates of *P. haemolytica* were not detected in the domestic goats, mountain goats, llamas, or cattle (Tables 2 - 5).

DISCUSSION

As indicated in these experiments, . *P. haemolytica* is detected commonly from a variety of healthy ungulates including bighorn sheep, cattle, domestic goats, mouflon sheep, and domestic sheep. Pneumonia in bighorn sheep caused by *P. haemolytica* can occur with or without contact with other ungulates (Miller et al. 1991) and it is now clear that some serotypes or strains of *P. haemolytica* carried by some animals are likely to result in fatal pneumonia in bighorn sheep (Foreyt et al. 1994). The current results support previously published research which documented the incompatibility between domestic sheep and bighorn sheep (Onderka and Wishart 1988; Foreyt 1989, 1990, 1992a). Based on current results and previous findings (Callan et al. 1991), close contact between mouflon sheep and bighorn sheep also is likely to result in fatal pneumonia in the bighorn sheep.

Contact experiments between bighorn sheep, domestic goats, llamas, cattle, and mountain goats did not result in respiratory disease or death of any of the animals. Based on our experience with bighorn sheep, *P. haemolytica* A2 is the most serious pathogen of bighorn sheep. Toxicity studies now in progress in our laboratory, indicate that the A biotype of *P. haemolytica*, primarily serotype 2, frequently is toxic to blood neutrophils in vitro and to bighorn sheep in vivo, whereas the T biotype usually is nontoxic to blood neutrophils and to bighorn sheep. Only isolates of *P. haemolytica* biotype T were detected in the cattle and domestic goats used in these experiments, therefore, to fully understand the compatibility status of these animals, similar work should be repeated using cattle and goats that are known carriers of the A biotype.

MANAGEMENT RECOMMENDATIONS

As a result of these and previous studies, specific management recommendations can be made. All contact between bighorn sheep and domestic sheep or mouflon sheep must be prevented or it is likely that the bighorn sheep will die from pneumonia after close contact with these species. Based on available data, bighorn sheep contact with elk (*Cervus elaphus*), deer (*Odocoileus virginianus* and *O. hemionus hemionus*), mountain goats, or llamas apparently does not result in respiratory disease in bighorn sheep (Foreyt 1992b, this study). Trials with domestic goats and cattle did not result in respiratory disease in bighorn sheep under the conditions described in this experiment. However, similar trials need to be conducted with domestic goats and cattle that are carriers of *P. haemolytica* biotype A to determine the effects of those organisms on the health of bighorn sheep.

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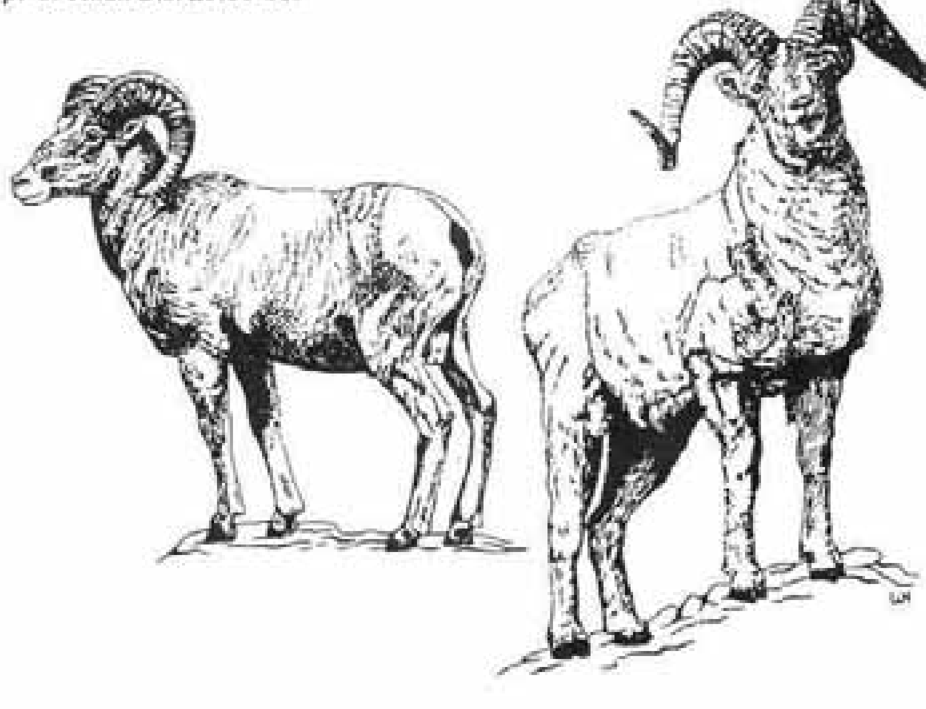

Table 1. ***Pasteurella haemolytica* biotypes and serotypes isolated from bighorn sheep and mouflon sheep that shared the same pasture.**

Animal	Pre-exposure isolates (day 0)	Cytotoxic[a]	Post-exposure isolates[b]	Cytotoxic[a]	Pneumonia	Day of death
Bighorn sheep 1	T3,4	-	A2 (lung)	+	+	42
			T3,4,10(lung)	+		
			A2(liver)	+		
Bighorn sheep 2	T3,4,10	-	A unt[c] (lung)	+	+	42
			T3,4 (lung)	-		
Bighorn sheep 3	T3,4	-	A2 (lung)	+	+	42
			A unt(lung)	+		
			T unt (lung)	-		
Bighorn sheep 4	T3,4,10	-	A2 (lung)	+	+	42
			T3,4,10 (lung)	-		
Bighorn sheep 5	T3,4,10	-	A2 (lung)	+	+	41
Bighorn sheep 6	T3,4,10	-	A2 (lung)	+	+	41
Mouflon sheep 1	T unt	-	T3,4	-	-	NA[d]
			T unt	-		
Mouflon sheep 2	A (unt)	+	T3,4	-	-	NA
			A unt	-		
Mouflon sheep 3	T4	-	T unt	-	-	NA
Mouflon sheep 4	T4	-	T3,4	-	-	NA
Mouflon sheep 5	T4	-	T3,4	-	-	NA
			A unt	-	-	

[a] Based on neutrophil sensitivity test (Silflow et al. 1993).
[b] At necropsy or 47 days after initial contact.
[c] unt = untypeable
[d] NA = not applicable.

Table 2. ***Pasteurella haemolytica* biotypes and serotypes isolated from bighorn sheep and domestic goats that shared the same pasture for 60 days.**

Animal	Pre-exposure isolates (day 0)	Cytotoxic[a]	Post-exposure isolates (day 60)	Cytotoxic[a]	Pneumonia
Bighorn sheep 7	T3,4,10	-	T3,4,10	-	-
Bighorn sheep 8	T3,4,10	-	T3,4,10	-	-
Domestic goat	T unt[b]	-	T3,4	-	-
Domestic goat 2	T3,4	-	T3,4	-	-
Domestic goat 3	T unt	-	T3,4	-	-

[a] Based on neutrophil sensitivity test (Silflow et al. 1993) [b] unt = untypeable

Table 3. ***Pasteurella haemolytica*** **biotypes and serotypes isolated from bighorn sheep and mountain goats that shared the same pasture for 60 days.**

Animal	Pre-exposure isolates (day 0)	Cytotoxic[a]	Post-exposure isolates (day 60)	Cytotoxic[a]	Pneumonia
Bighorn sheep 9	T unt[b]	-	T4	-	-
Bighorn sheep 10	T unt	-	T3,4	-	-
Bighorn sheep 11	unt	-	T3,4,10	-	-
Bighorn sheep 12	T3,4,10	-	T3,4,10	-	-
	T unt	-			
Bighorn sheep 13	T unt	-	T unt	-	-
Bighorn sheep 14	T3,4	-	T3,4	-	-
Bighorn sheep 15	T unt	-	T3,4,10	-	-
Bighorn sheep 16	T4	-	T4	-	-
Mountain goat 1	T3,4	-	ND[c]	NA[d]	-
Mountain goat 2	T3,4	-	ND	NA	-

[a] Based on neutrophil sensitivity test (Silflow et al. 1993).
[b] unt = untypeable.
[c] ND = not done.
[d] NA = not applicable

Table 4. ***Pasteurella haemolytica*** **biotypes and serotypes isolated from bighorn sheep and llamas that shared the same pasture for 68 days.**

Animal	Pre-exposure isolates (day 0)	Cytotoxic[a]	Post-exposure isolates (day 68)	Cytotoxic[a]	Pneumonia
Bighorn sheep 9	T3	-	T3,4	-	-
Bighorn sheep 10	none	NA[b]	T3,4,10	-	-
Bighorn sheep 11	T3,4	-	T3,4,10	-	-
	T3,4,10	-			
Bighorn sheep 12	T3,4,10	-	T3,4	-	-
	T unt[c]	-	T unt	-	-
Bighorn sheep 13	T3,4	-	T3,4,10	-	-
Bighorn sheep 14	T3,4,10	-	T3,4,10	-	-
Bighorn sheep 15	none	NA	T3,4	-	-
Bighorn sheep 16	T3,4,10	-	T unt	-	-
Llama 1	none	NA	none	NA	-
Llama 2	none	NA	none	NA	-
Llama 3	none	NA	none	NA	-

[a] Based on neutrophil sensitivity test (Silflow et al. 1993). [b] NA = not applicable. [c] unt = untypeable.

Table 5. ***Pasteurella haemolytica*** **biotypes and serotypes isolated from bighorn sheep and cattle that shared the same pasture for 60 days.**

Animal	Pre-exposure isolates (day 0)	Cytotoxic[a]	Post-exposure isolates (day 68)	Cytotoxic[a]	Pneumonia
Bighorn sheep 17	T3,4,10	-	T3,4,10	-	-
	T4	-			
Bighorn sheep 18	T3,4	-	T3,4	-	-
	T4	-			
Bighorn sheep 19	T3,4	-	T3,4	-	-
	T3,4,10	-			
Bighorn sheep 20	T4	-	T3,4	-	-
	T3,4,10	-			
Calf 1	T3,4	-	none	Na[b]	-
Calf 2	T3,4	-	T3,4	-	-
Calf 3	T3,4	-	none	NA	-

[a] Based on neutrophil sensitivity test (Silflow et al. 1993).
[b] NA = not applicable.

Table 6. ***Pasteurella haemolytica*** **biotypes and serotypes isolated from bighorn sheep and domestic sheep the shared the same isolation facility.**

Animal	Pre-exposure isolates (day 0)	Post-exposure isolates[a]	Pneumonia	Day of death
Bighorn sheep 1	T3	A2 (liver)	+	6
		A2 (lung)		
Bighorn sheep 2	T3	A2 (lung)	+	8
		T3 (lung)		
Domestic sheep 1	T3,4,10	T3,4	-	NA[b]
	A2			
Domestic sheep 2	A2	T3,4	-	NA

[a] At necropsy or 14 days after initial contact.
[b] NA = not applicable.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 9:15-19.

RESIDUAL EFFECTS OF PNEUMONIA ON THE BIGHORN SHEEP OF WHISKEY MOUNTAIN, WYOMING

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Abstract: During the winter of 1990, approximately 25% of bighorn sheep (*Ovis canadensis canadensis*) in the Whiskey Mountain herd died during a major pneumonia epizootic. Lamb production declined below average levels the following 2 years, resulting in sub-normal yearling recruitment in 1992 and 1993. Low recruitment, coupled with harvest and trap removals of approximately 190 sheep since the die-off, further reduced the herd to an estimated 1,000 animals in 1993. Concurrent with declining population size, utilization of herbaceous forage on crucial wintering sites declined from pre die-off levels of 75% to 59% and 60% in 1992 and 1993, respectively. *Pasteurella haemolytica* and *Moraxella* spp. were isolated from the pharynges of several animals trapped in 1993 and 1994 and seroprevalence to respiratory syncytial virus, parainfluenza 3, and chlamydia remained high. However, seroprevalence was essentially the same as 1991 and years prior to the 1990 epizootic.

The Whiskey Mountain area in west-central Wyoming supports one of the largest wintering concentrations of Rocky Mountain bighorn sheep in North America. Bighorns from this area have been used as transplant stock for the past 50 years, being released throughout Wyoming and 5 other western states. The herd also is becoming increasingly important as a source of economic revenue to businesses in nearby cities and counties of Wyoming due to it's accessibility for winter viewing and sport hunting opportunities.

During the winter of 1990, about one fourth of the Whiskey Mountain herd died in a major pneumonia epizootic. Effects on population size, lamb production, and yearling recruitment during and 1 year after the die-off were described in Ryder et al. (1992). This paper documents herd reproductive performance, winter forage utilization, and disease seroprevalence in years 2 and 3 following the epizootic.

We thank C. Thompson, Wyoming Game and Fish Department, for assistance in collecting herd composition data since 1992. We also appreciate the help of A. Boerger-Fields, J. Cavender, K. Mills, and C. Stith, Wyoming State Veterinary Laboratory, in analyzing tissue samples and providing valuable advice on this project. E. T. Thorne reviewed the manuscript and made several helpful comments.

STUDY AREA

Summer ranges of the Whiskey Mountain bighorn sheep herd are distributed throughout the Fitzpatrick Wilderness, Wind River Mountains (Thorne et al. 1979). Winter habitats, comprising the Whiskey Mountain Wildlife Habitat Management Area (WHMA), are located immediately south and east of Dubois, Wyoming. The WHMA is managed by the Whiskey Mountain Technical Committee, an interagency group consisting of personnel from the Wyoming Game and Fish Department, U. S. Bureau of Land Management, and U. S. Forest Service (Whiskey Mountain Bighorn Sheep Technical Committee 1991). Seasonal migrations between summer and winter ranges vary from 5-48 km (Thorne et al. 1979). Geology, climate, and vegetation of the area were summarized by Butler (1977).

Within the WHMA, bighorns have historically wintered on 3 "key" sites including Sheep Ridge, BLM Ridge, and Torrey Rim. The combined number of animals utilizing these sites varies between 600-900 annually. Other wildlife, livestock, and human uses of the study area were described in Ryder et al. (1992).

METHODS

Bighorn sheep wintering on the Whiskey Mountain WHMA were surveyed from a vehicle in December 1992 and 1993 using 8X40 binoculars and window-mounted 20-5X telescopes. During the same periods, animals wintering off the WHMA at high elevations were surveyed using Bell Jet Ranger helicopters. All animals observed were classified as to sex and age (Geist 1968). Data from ground and aerial surveys were combined each year to determine herd composition.

The effect of herd composition changes each year on population size was determined using Version 7.05 of the computer model POP-II (Bartholow 1992). Simulations were directed at data alignment from 1986-1993 using harvest mortality, post-hunting season sex and age ratios, and trapping/transplanting removals.

Forage production/utilization data presented in this paper were collected by clipping all herbaceous vegetation within standard Daubenmire quadrats in spring and fall each year (Butler 1977). These data were collected along 150 m transects permanently located on BLM Ridge, Torrey Rim and Sheep Ridge. Following clipping, vegetation was dried and weighed to determine the amount of forage produced (fall) and utilized (spring) by bighorn sheep on these 3 key wintering sites.

Swabs of the pharyngeal area of bighorn sheep were collected in January 1993 and 1994 during processing of captured animals under dropnets. These were either plated within several hours onto Columbia blood agar with 5% sheep blood or were placed in modified Cary and Blair medium (Port-A-Cul, Becton-Dickinson, Cockysville, Maryland) for transport to the laboratory. Transported samples were plated within 48 hours of collection. Plates were incubated aerobically in 5% CO_2. Isolates were identified using standard techniques (Lennette et al. 1985, Carter and Cole 1990).

Blood was collected by jugular venipuncture into clean glass tubes, allowed to clot, and serum was removed within 48 hours and frozen until tested. Sera were tested by virus neutralization (Carbrey et al. 1971) for antibodies against bovine virus diarrhea virus (BVDV), respiratory syncytial virus (RSV), parainfluenza 3 virus (PI3V), and by complement fixation for antibodies against chlamydia (Texas Veterinary Medical Diagnostic Laboratory, College Station, Texas).

RESULTS

Herd Composition

For 2 years following the 1990 epizootic, lamb production fell below the 1986-90 average of 38 lambs:100 ewes (Table 1). Consequently, yearling recruitment declined by 50% in 1992 and 58% in 1993 from previous years (1986-91 mean = 24 yearlings:100 ewes). Production rebounded in 1993 to 23 lambs:100 ewes.

Survival rates of lambs to the yearling age class varied prior to, during, and after the pneumonia die-off (Table 1). From 1986-90, an average of 67% of the previous years lambs survived to age 1. During the epizootic year of 1990, only 45% of the lambs observed in December survived to the yearling age class in 1991. Following the die-off, survival rates of lambs to age 1 averaged 82% in 1992 and 1993.

Sex ratios remained relatively constant from 1986 through 1991 (mean = 39 rams:100 ewes), varying by only 1-2 animals (Table 1). In 1992, as a result of low 1991 lamb production and continued removal of older aged animals through hunter harvest, ratios dropped to 36 rams:100 ewes. The decline continued in 1993, following another poor recruitment and high male harvest year, to 32 rams:100 ewes.

Forage Utilization

From 1986-1989, forage utilization averaged 75% on the 3 "key" wintering sites (Table 2). Utilization increased during each of these years, corresponding to increasing sheep numbers. No forage data could be collected during the die-off year of 1990 due to snow cover, but the population peaked at 1,474 animals. One year after the epizootic, herd size and forage use declined to 1,151 and 71%, respectively. In 1992 and 1993, herd size and forage utilization declined to their lowest levels since prior to 1986 (means of 1,000 animals and 60%).

Bacteriology and Serology

In 1993, pharyngeal swabs collected from 29 bighorn sheep yielded *Pasteurella haemolytica* from 27 animals and *Moraxella* sp. from 1 animal. Of 9 pharyngeal swabs cultured in 1994, 5 contained *P. haemolytica*, 3 *Moraxella* spp., and 1 did not contain significant bacterial isolates. There was no serologic evidence of antibodies against

Table 1. Age and sex composition of Whiskey Mountain bighorn sheep, 1986-93.

Year	Rams: 100 Ewes	Lambs: 100 Ewes	Yearlings: 100 Ewes	Survival rates[a]
1986	40	27	22	61
1987	38	38	16	5
1988	39	47	28	73
1989	39	32	38	80
1990	39	44	20	63
1991	41	10	20	45
1992	36	12	8	80
1993	32	23	10	83

[a] Percentage of previous year's lambs surviving to yearling age classes.

BVDV in contrast to high prevalence of antibodies against PI3V, RSV, and chlamydia (Table 3).

DISCUSSION

Onderka and Wishart (1984) reported reduced lamb production and recruitment for 2 years (23 lambs:100 ewes and 18:100, respectively) following a pneumonia die-off in southern Alberta. In another Alberta study, only 13% of the lambs born the year of a die-off survived to age 1 (Festa-Bianchet 1988). Lamb survival 2-3 years later averaged 38%. Coggins and Matthews (1992) reported lamb:ewe ratios of 11 and 10:100 for 2 years following a die-off of sheep in Oregon. The 1990 pneumonia epizootic resulted in similar changes in population performance at Whiskey Mountain. Observed reductions in lamb production were similar to that reported by Coggins and Matthews (1992), but lower than that observed by Onderka and Wishart (1984). Survival rates were higher than those reported by Festa-Bianchet (1988).

Forage utilization rates appear directly related to bighorn sheep population size on Whiskey Mountain. Although body condition did not appear to be a factor in the 1990 pneumonia outbreak (Ryder et al. 1992), forage utilization on "key" wintering sites approached 90% 1 year prior to the die-off. Similarly, herd size was estimated to be higher than at any other time. We recommend forage utilization rates continue to be monitored yearly as they may provide a means of predicting an impending pneumonia outbreak.

Bacteriologic and serologic data indicate potential respiratory pathogens continue to circulate within the Whiskey Mountain bighorn sheep herd. The rate of isolations of *P. haemolytica* is greater than in past years and probably reflects use of improved transport and isolation techniques (Wild and Miller 1994). Isolation of *Moraxella* sp. may also be improved by use of the modified Cary and Blair transport medium.

While some strains of *P. haemolytica* are associated with pneumonia (Onderka and Wishart 1988, Foreyt 1989), others apparently circulate in healthy animals (Dunbar et al., 1990, Ward et al.,

Table 2. Herbaceous forage utilization (%) and estimated population of Whiskey Mountain bighorn sheep, 1986-93.

Year	Torrey Rim	BLM Ridge	Sheep Ridge	WHMA average	Population estimate
1986[a]	ND	ND	ND	ND	1,242
1987	58	62	63	61	1,254
1988	64	88	78	77	1,326
1989	86	94	85	88	1,320
1990[a]	ND	ND	ND	ND	1,474
1991	62	70	81	71	1,151
1992	65	40	72	59	1,018
1993	64	49	69	60	1,000

[a] ND = No data were collected due to snow cover.

Table 3. Serologic results of testing Whiskey Mountain bighorn sheep for evidence of exposure to respiratory pathogens, 1990-94.

Pathogen[a]	1989-90	1990-91	1991-92	1992-93	1993-94
BVDV	0/12[b]	Nd[c]	0/27	ND	0/19
PI3V	11/12 (16-256)	ND	27/27 (16-1024)	13/14 (8-256)	19/19 (16-1024)
RSV	11/12 (16-512)	ND	27/27 (16-1024)	14/14 (8-512)	21/21 (8-256)
Chlamydia	12/12 (16-64)	ND	25/27 (16-64)	8/14 (16)	13/16 (16-32)

[a] BVDV = bovine virus diarrhea virus; PI3V = parainfluenza 3 virus; RSV = respiratory syncytial virus.

[b] Number of animals positive for antibodies/number of animals tested (range or titres).

[c] ND = No data were collected

Queen et al. 1994). Similarly, *Moraxella* spp. are usually considered to be commensals of the upper respiratory tract and not primary pathogens (Timoney et al. 1988). *Moraxella* spp. have been isolated from healthy sheep in this herd (Thorne et al. 1982) and a recent survey of healthy bighorn in Idaho found this bacteria in 6 of 14 samples (Queen et al. 1994). However, *Moraxella* spp. was isolated from pneumonic bighorn sheep from Whiskey Mountain in 1991 (Ryder et al. 1992). Additional study and characterization of the bacteria isolated from Whiskey Mountain will be necessary to understanding their role as pathogens in this herd.

Antibodies against viral and chlamydial respiratory pathogens continue to be present at high prevalence. An earlier study of the Whiskey Mountain herd showed seroprevalence to PI3V to be 77% (23/30 tested) in 1976 and 1977 (Thorne et al. 1979). A previous study failed to incriminate these potential pathogens in cases of pneumonia in Whiskey Mountain sheep (Ryder et al. 1992) and seroprevalence prior to the epizootic was essentially the same as in years following the die-off. There is no direct evidence that these agents are of primary importance in pneumonia in this bighorn sheep herd.

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A HEALTH PROTOCOL FOR DOMESTIC SHEEP USED ON FOREST GRAZING ALLOTMENTS IN ALBERTA AND BRITISH COLUMBIA

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Abstract: The health and condition of domestic sheep used on forest grazing allotments in Alberta and British Columbia (BC) are evaluated before the sheep leave the home farm and periodically throughout the grazing season. The protocol is designed to minimize potential disease problems by ensuring only healthy sheep, in good body condition, are used for forest grazing. It reflects a cooperative relationship among wildlife, forestry, and agricultural managers in conjunction with the forest and sheep industries. Our experience may provide a model for similar situations in other jurisdictions. Although the protocol generally is successful, in 1993 a case was identified where sheep were found in extremely poor body condition and infected with contagious ecthyma (=orf), a viral disease transmissible to humans and wildlife. Forty-five sheep were destroyed and 198 were removed from the site. It is contingent upon government officials, in conjunction with the sheep industry and the forest products companies, to monitor flocks throughout the grazing season in order to ensure compliance with the rules. Wildlife managers should be aware of disease situations on forest grazing allotments and, where problems arise, should monitor wild populations subsequent to removal of domestic sheep.

Sheep silviculture can be an efficient, safe, cost-effective method of improving reforestation success in forest plantation programs. Competition from native grasses and aspen regrowth can severely impair the growth and survival of young conifer seedlings and domestic sheep feed selectively on the competitors, providing opportunity for conifers to realize more efficient growth (O'Brien and Bailey 1987, Sharrow et al. 1989). Other methods of reducing competition, such as, scarification and herbicides, are viewed as less "environmentally-friendly" and may not provide the same level of success or cost-effectiveness (Newsome et al. 1993). In addition, benefits accrue to the domestic sheep industry as far as providing additional income and grazing opportunities, particularly for sheep raised in dryland regions.

From a wildlife perspective, domestic sheep on forest grazing allotments have been seen as a potential attractant for predators, a source of disease transmission to free-ranging populations, and possible competitors for wild ungulates (Green 1992). This paper will focus on some of the disease concerns and how they have been addressed in relation to sheep silviculture in Alberta and BC.

To date, the role of domestic sheep in affecting the health of wildlife species has been variable, although there is ample evidence that some bighorn sheep (*Ovis canadensis*) populations declined subsequent to introduction of domestic sheep onto traditional bighorn ranges (Foreyt and Jessup 1982, Coggins 1988, Coggins and Matthews 1992). In the past, domestic sheep grazed extensively on traditional wildlife range without apparent disease problems in wild populations; however, concurrent surveillance of free-ranging individuals was not conducted.

This paper focuses on the health and welfare of the domestic sheep, before and after they reach the grazing allotment, as a factor that may affect the potential for disease transfer. The paper is presented in three parts: a protocol that averts many potential problems, a disease outbreak that provides evidence that the protocol is not 'fool-proof', and a discussion of the general approach to sheep grazing on forest allotments.

THE PROTOCOL

Alberta and BC have taken great care to avert disease problems on forest allotments. In each province, representatives from various government agencies (including forestry, wildlife, and agriculture), the sheep industry, and provincial veterinary associations developed strict protocols to address the concerns of all parties. The protocols evolved during 10 years of sheep silviculture in BC. Currently, only veterinary-inspected and government-approved sheep can be sent to a grazing allotment.

The protocols are specific as well as far-ranging. They include assessment of the whole herd health of each source flock as well as the specific animals used for silviculture. Prior to transport, sheep are inspected by approved veterinarians for their general health and condition as well as for specific diseases, in particular, sheep foot rot, pseudo-tuberculosis, contagious ecthyma (CE), and internal and external parasites. Any animal with evidence of disease is not approved for sheep silviculture. Immunizations and specific treatments for parasites are identified and must be administered no more than 6-8 weeks prior to transportation to the forest site. Treated animals must be held in isolation and on pastures that have not contained sheep or goats for at least 2 weeks.

All adult sheep used on grazing allotments must be shorn, have their feet trimmed, and stand for one hour in a footbath of 20% zinc sulfate solution within 4 weeks of departure. If clean pasture is not available after treatment, the sheep must walk through a second footbath as they are loaded for shipment to the site. Pregnant ewes are not allowed. Small lambs (under 22.5 kg [50 lbs]) are not recommended. Each sheep must be identified with an owner mark and a government-issued eartag. A health certificate signed by the owner, the contractor, and the veterinarian must be provided to BC or Alberta Agriculture 10 days prior to shipping the sheep and a copy of the certificate must accompany the sheep in transit and be available at the forest site.

The guidelines require that government inspectors visit each grazing allotment within 2 weeks of the sheep arriving at the site. In addition, occasional random inspections are conducted throughout the grazing season. Any sheep that does not meet health requirements in terms of disease or body condition must be isolated and treated. If treatment is not possible, the animal must be returned to the home farm or killed and properly disposed.

Concerns regarding disease and parasites in sheep dogs or guardian dogs also have been addressed. All dogs used on forest grazing sites must have a valid vaccination certificate for parvovirus, canine distemper, Adenovirus type II, and rabies. Each dog must be treated with an effective anthelminthic 3 weeks prior to arriving at the site and treated again before returning home.

These restrictions are designed to ensure that domestic sheep used on grazing allotments are as disease-free as possible and in the best physical condition. A healthy animal, in good condition, will be better able to withstand the rigours of forest grazing, be more resistant to disease, be less attractive to predators, and less likely to contaminate the environment. However, problems do still arise. It is human nature that rules are not always followed.

THE PROBLEM

In 1993, a problem arose when a group of approximately 1000 sheep mustered from various owners in Alberta and BC was allowed to deteriorate on a grazing allotment near Fort St. John in northern BC. Some sheep with mild clinical signs of CE (otherwise known as soremouth or orf) were seen. In addition, new sheep, unaccustomed to forest grazing, were added to the flock late in the season when the food available was of relatively poor quality. As a result, suitable forage was limited and the sheep were unable to maintain adequate body condition. Contagious ecthyma manifested in the stressed sheep and spread within the flock. These breaches of the protocol were not reported and infected or weak sheep were not isolated or removed. Six hundred sheep from the infected flock were shipped to another allotment in an attempt to decrease the sheep density on the primary site. This action exposed another large flock of sheep and contaminated a second site with CE virus.

When provincial officials (RF and HL) inspected the 2 sites, they found a number of severely debilitated and emaciated sheep. Extensive oral and foot lesions also were present on some sheep. Forty-five emaciated and diseased sheep were considered unfit for travel and were killed at the site. Pox virus was identified in lesions seen on a sample of these sheep examined at the Alberta Agriculture Diagnostic Laboratory in Fairview, Alberta. An additional 198 sheep, considered unfit for sheep silviculture, were ordered off the sites and returned to their owners.

Contagious ecthyma is an infectious pox virus disease primarily infecting domestic sheep and goats (Karstad 1981). In North America, infections in free-ranging bighorn sheep (Connell 1954, Blood 1971, Samuel et al. 1975, Lance et al. 1981, Jessup et al. 1991), mountain goats (*Oreamnos americanus)* (Carr, 1968, Samuel et al. 1975, Hebert et al. 1977), Dall sheep *(Ovis dalli)* (Smith et al. 1982, Zarnke et al. 1983), and musk-ox (Zarnke et al. 1983) have been described. In addition, caribou (*Rangifer tarandus*), moose (*Alces alces*), mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), wapiti (*Cervus elaphus*) and pronghorn antelope (*Antilocapra americana*) have been infected experimentally (Lance et al. 1983, Zarnke et al. 1983). Infection with a pox virus similar to CE was considered contributory to death in 2 free-ranging mule deer fawns (Williams et al. 1985). Contagious ecthyma is a zoonotic disease and can infect humans (Carr 1968, Erickson et al. 1974, Jessup et al. 1991).

The virus is quite common and cannot be diagnosed in carrier animals (Jubb and Kennedy 1970). It is an opportunistic invader when animals are in poor condition or have cuts and abrasions in the mouth. Thus, crusted lesions often occur in the nose and oral regions and may spread to other body regions as they become contaminated. For example, infected lambs may contaminate a ewe's udder. Scabs which fall from the lesions contain virus particles that can remain infective for more than 20 years (Livingston et al. 1960).

DISCUSSION

It is important to keep such problems in perspective. In 1993, approximately 44,000 domestic sheep were used on 34 forest grazing allotments in BC. Significant disease or health concerns occurred on only 5 allotments. Three of these involved persistent foot rot and 2 involved CE. Other than the case at Fort St. John, these problems were dealt with as outlined in the health protocols and the situations were resolved. We can assume that, given the nature of the vegetation on forest allotments, some sheep will damage the oral mucosa, thereby increasing the risk of CE. The protocol appears to provide a reasonable approach to managing the problem.

Contagious ecthyma also must be kept in perspective. The disease tends to be minor and self-limiting in adult animals but can cause severe lesions that impair feeding and growth (and perhaps survival) in young bighorns, Dall sheep, and mountain goats (Samuel et al. 1975, Hebert et al. 1977, Dieterich et al. 1981, Zarnke et al. 1983). Most reports of the disease in wild sheep and goats have been associated with human-related foci of infections, such as artificial salt blocks (Blood 1971, Samuel et al. 1975), contaminated hay (Jessup et al. 1991), or salt residues remaining at oil and gas well sites (Morgantini, Spruce Grove AB, pers. comm.) The disease is not considered a major mortality factor in bighorn sheep (Lance 1982) and it is unlikely that it would establish in free-ranging cervids (Lance et al. 1983). There is a zoonotic concern for persons handling infected animals and, although the virus causes painful blisters (Jessup et al. 1991), it generally is self-limiting and lesions are fully resolved within a month (Erickson et al. 1974).

MANAGEMENT IMPLICATIONS

A cooperative working relationship among resource managers and industry provided the basis for the protocol described herein. Benefits generally accrued to all parties and time-consuming destructive confrontation was avoided. The protocol may be applicable to similar situations in other jurisdictions.

We believe that prevention is the best treatment. Implementation of a strict health protocol before and after sheep arrive at the grazing site can help limit the potential for disease outbreaks and, thus, limit the risk associated with disease transfer from domestic to wild stock. It improves the general welfare of the sheep and also may minimize the attraction of predators to the site. Healthy sheep also provide more effective grazing pressure.

The guidelines will not prevent all disease situations and should not be considered the solution to all the disease concerns of wildlife managers. However, they can preclude the use of animals with overt disease conditions and those in poor body condition. In order to be fully effective, adherence to the protocols must be monitored throughout the grazing season. The sheep industry and forest companies also must recognize the value of maintaining healthy sheep on the allotments and, thus, provide additional incentive for evaluation of the sheep.

Ideally, domestic sheep should not be grazed on range used by bighorns or mountain goats, in order to minimize the immediate potential for disease transfer to wild populations. However, forest grazing allotments contaminated with scabs from domestic sheep infected with CE could remain a potential focus of infection for many years after the sheep have left. The areas could be used subsequently by wild sheep and goats or for human recreational purposes. Wildlife managers are encouraged to maintain contact with agriculture and forestry officials in order to be aware of areas of sheep silviculture and to remain informed regarding the health of the sheep on each allotment. In areas where disease occurs, particularly CE, wildlife managers should monitor free-ranging populations for the presence of lesions. The virus could become a factor in the health of young bighorn sheep or mountain goats, a particular concern in remnant or introduced populations under stress.

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EVALUATION OF LUNGWORM, NUTRITION, AND PREDATION AS FACTORS LIMITING RECOVERY OF THE STILLWATER BIGHORN SHEEP HERD, MONTANA

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Abstract: The Stillwater bighorn sheep herd is currently at a low of approximately 30 animals. From November 1991 to August 1993, lungworm levels (*Protostrongylus* spp.), nutrition, and predation were evaluated on the winter range in relation to the recovery of the Stillwater bighorn herd. A total of 259 fecal pellet groups was collected and analyzed for lungworm larvae. Although during both years, the prevalence of lungworm larvae increased in the spring to 60% or more, the average level of infection suggested that lungworm does not play a significant role in limiting the herd. Fenbendazole medicated salt, as administered in the last four years, appeared to have been effective in controlling protostrongylid lungworm numbers. Fecal pellets were analyzed for nitrogen content as an index of nutrition. Results suggest that nutrition is not a limiting factor to the Stillwater herd. Mountain lion (*Felis concolor*) predation may play a role in limiting sheep overwinter survival. Bacterial pneumonia resulted in approximately 50% of the known mortalities in the winter of 1992-1993; however, since November of 1991, approximately 56% of the mortalities have been from unknown causes. Although protostrongylid lungworm and nutrition do not appear to be limiting factors in the recovery of the Stillwater herd, additional monitoring of these factors, as well as the study of predation, should continue. Future studies should be conducted to identify mortality factors for the Stillwater bighorn sheep herd on the summer range.

The number of bighorn sheep in North America has declined drastically since the turn of the century (Buechner 1960). These declines have often been attributed to the lungworm-pneumonia disease complex (Honess and Frost 1942, Buechner 1960, Forrester and Senger 1964, Forrester 1971). The lungworm-pneumonia complex is indeed very "complex", and is often associated with other physiological stress factors, such as bacterial and viral infection, poor nutrition, inclement weather, multiple parasitism, overcrowding, predation, and human caused disturbances (Forrester 1971, Hudson and Stelfox 1976, Hibler et al. 1982, Foreyt and Jessup 1982, Onderka and Wishart 1984, Belden et al. 1990, Foreyt 1990). Some authors have suggested that due to the complex nature of pneumonia and to the incomplete understanding of most predisposing factors or stresses, the lungworm-pneumonia complex be renamed "stress-related pneumonia" (Spraker et al. 1984, Festa-Bianchet 1988). Therefore, until the many factors involved in the pneumonia complex are better understood, it is necessary to examine any possible predisposing or stress factors that may be present in bighorn sheep populations.

Festa-Bianchet and Samson (1984) concluded that parasites may be both a cause and result of stress. In many cases of pneumonia, *Protostrongylus* spp. clearly are a predisposing or stress factor for bighorns (Couey 1950, Buechner 1960, Worley et al. 1976, Wishart et al. 1980, Silflow and Foreyt 1988), especially in the case of summer lamb mortality due to transplacentally derived lungworm infections (Hibler et al. 1976, Schmidt et al. 1979, Spraker et al. 1984). Most bighorn sheep are infected with lungworm (Forrester and Senger 1964). Both prevalence (the proportion of hosts infected) and the intensity of infection (indicated by the first-stage larval output per gram of feces (LPG)), are used to measure the parasite pressure on bighorns (Forrester and Senger

1964, Gregory and Blackburn 1991). Lungworm levels may be affected by other factors, such as herd density and nutrition (Schwantje 1986, Festa-Bianchet 1988).

Nutrition may be important in relation to pneumonia-induced mortality (Honess and Frost 1942, Forrester and Senger 1964, Foreyt and Jessup 1982, Samson et al. 1987). Although current information suggests that nutrition is not necessarily a causal factor in relation to pneumonia (Jessup 1981, Foreyt and Jessup 1982, Bailey 1986, Ryder et al. 1992), the pneumonia complex is multi-factorial, and poor nutritive condition may be one predisposing or stress factor (Samson et al. 1987, Dunbar 1992). Additionally, nutrition has been shown to influence other important population parameters of bighorn sheep (Honess and Frost 1942, Hebert et al. 1984). Fecal nitrogen has been shown to be an effective measure of bighorn nutrition and population condition (Hebert et al. 1984, Irwin et al. 1993).

Predation may constitute an additional source of mortality, and may be related to the condition of the sheep (Buechner 1960, Hibler et al. 1982, Harrison and Hebert 1988). In some cases, predation may disproportionately affect one segment of a herd. Rams, during or just after the rut may be more susceptible to predation than other classes (Geist 1971, Harrison and Hebert 1988). Williams (1992) found that bighorns were an important prey item for mountain lions; however, Geist (1971) stated that lamb mortality due to predation was unlikely due to the precipitous terrain in which lambing occurs.

The Stillwater bighorn sheep herd, one of the last 12 native herds in Montana (Thorne et al. 1985), was reported to have peaked in the late 1940s and early 1950s at more than 100 animals (Buechner 1960, Pallister 1974). However, the Stillwater herd has recently been in decline since the early 1980s, with lamb recruitment averaging 20% from 1982-1988, and no recruitment at all in 1987 (Farmer 1992). Compared to the estimate of 50% recruitment needed for population growth, it is obvious that the Stillwater herd may have a problem maintaining a minimum viable population (Lawson and Johnson 1982). Stillwater lambs born in the summer are not arriving on the winter range and from 1989 to 1992, known summer lamb mortality was at least 50% (Farmer 1990, 1993). The Stillwater bighorn sheep herd currently consists of an estimated 30 sheep.

The Stillwater herd has been periodically tested for lungworm. In 1964, it had one of the highest average levels of infection of herds surveyed in Montana at 900 LPG and 100% prevalence (Forrester and Senger 1964). Stewart (1975) recorded *Protostrongylus* spp. levels at an average of 5.5 LPG in 91% of Stillwater sheep samples. However, in the mid to late 1980s, average LPG levels again increased to approximately 100 LPG in more than 80% of samples tested. One lamb was known to have died in 1988 from lungworm-pneumonia (Farmer 1988).

Efforts were made in 1989 to treat the Stillwater herd with fenbendazole medicated alfalfa pellets. Although several researchers have reported medicated pellets as palatable to sheep (Huschle and Worley 1986, Foreyt et al. 1990), the Stillwater herd apparently did not find them so (Worley unpublished). An older captive ewe who was accustomed to pelletized feed was even released into the Stillwater herd, hoping she might induce other sheep to eat the medicated feed (Farmer 1990). Later, salt blocks and loose medicated salt were placed on the winter range, with no response (Worley and Seesee, unpublished). However, with the use of apple pulp as an attractant, sheep were finally observed consuming 0.5% fenbendazole medicated salt on the winter range early in the summer of 1990. Salt was also placed on the summer range (Farmer 1991). Initial findings the following winter suggested that fenbendazole consumption had been adequate, with average lungworm LPG values below 1. Additionally, a young ewe who died from a fall in spring of 1991 had very low lungworm levels (Farmer 1991). The Stillwater sheep have had continued access to medicated salt on the winter range every year since 1990.

Beginning in 1986, periodic measurements of Stillwater sheep fecal nitrogen values were made to assess the nutritional status of the herd. Although sampling was not done regularly and sample sizes were at times small, nitrogen values were generally within the range described by Hebert et al. (1984). Irwin et al. (1993) suggested that fecal nitrogen values below 1.3% may be indicative of nutritional deficiencies. For winter range samples from 1986 - 1991, (n=18), 17% of Stillwater fecal samples contained less than 1.3% fecal nitrogen (Farmer 1992).

The Stillwater area has resident populations of bobcats, coyotes, black bears, mountain lions, and eagles. Prior to the late 1980s, predation was not considered a problem for the Stillwater bighorn herd. However, populations of both coyotes and mountain lions appeared to be increasing. Although this increase was not quantitatively documented, reports of both species in the area increased. The first documented predation loss was in 1990; a mountain lion killed the captive ewe introduced earlier that year (Farmer 1991). Predation may affect bighorns directly through mortality or indirectly by harrassment or displacement of animals (Farmer 1986).

The objectives of this study were to examine three factors possibly limiting the recovery of the Stillwater herd: 1) measure the prevalence, intensity and seasonal patterns of *Protostrongylus* spp. infection and determine the effectiveness of a free-choice medicated salt program in a free-ranging bighorn herd; 2) measure fecal nitrogen as an index to herd nutrition and condition; and 3) attempt to learn the cause of known mortalities in order to estimate the extent of predation on the herd..

This study was completed as part of a Master's degree at Montana State University, and was primarily funded by the Biology Department. Additional funding was provided by the Veterinary Molecular Biology Department and Stillwater Mining Company. Montana Department of Fish, Wildlife and Parks Research Laboratory in Bozeman assisted with necropsy services. We would also like to thank the members of the Stillwater Management Committee, especially Shawn Stewart of the Montana Dept. of Fish, Wildlife and Parks; Pat Farmer of Western Technology and Engineering, Inc.; and Jim and Ellen Langston for their hospitality and assistance. Dr. R. Lund, Agriculture Experiment Station Statistician, Montana State Univ., provided statistical advice; and Hoechst-Roussel Agri-Vet Co. provided medicated salt. We would also like to thank Bill Chapman of Sagebrush Aero; and Michael Jones, Mike Felzein, and Kevin Jones for field assistance.

STUDY AREA

The study area is located at the Stillwater Mining Co. facility near Nye, Stillwater County, Montana, approximately 80 miles (130 km) southwest of Billings. The Stillwater herd's primary winter range is approximately a 3 square mile (5 square km) parcel contained within the permit area for the Stillwater Mine. The elevation of the primary winter range is approximately 5,000 feet (1600 m) above sea level, with most bedding areas located about 600 feet (200 m) higher on a rocky outcrop referred to as the "reef". The secondary winter range on the West Fork of the Stillwater and summer ranges west of the Stillwater drainage were also included in this study.

METHODS

Attempts were made to collect feces at 2-3 week intervals on the primary winter range where the main habituated segment of the herd is located. Additionally, collections were made on the West Fork winter range during the winter of 1991-1992. All known bedding and activity areas were searched, and all fresh pellets known to be from sheep were collected. Also, samples from individually recognizable sheep were obtained from direct observation. Although larvae of *Protostrongylus* spp. are known to remain viable in samples that are several months old (Buechner 1960, Hibler et al. 1982), no samples were collected that were estimated to be more than a few weeks old. In the field, pellets were classified according to age and sex of the donor when possible. The samples were placed inside reclosable plastic bags and were placed in a refrigerator as soon as possible.

The Baermann technique (Forrester 1971, Hibler et al. 1982) was used to extract larvae from seven gram samples of feces. Samples were left in small funnels (10 cm diameter) for 24 hours. Approximately 10 ml of fluid containing first-stage *Protostrongylus* spp. larvae were withdrawn into petri dishes for examination. Larvae were counted under a 25 x dissecting microscope; results were expressed as first-stage larvae per gram of feces (LPG). These data were also used to calculate prevalence of *Protostrongylus* spp. Fecal analysis data are not reliable in assessing parasitism in individual animals due to large variation in larval shedding rates; however, it is useful in consideration of levels of parasitism in the herd as a whole (Forrester and Senger 1964).

Nitrogen analysis was performed by the Montana State University Chemistry Station Laboratory on monthly composite samples. Thirty pellets, 2 each from 15 pellet groups, were randomly subsampled from the pellet groups

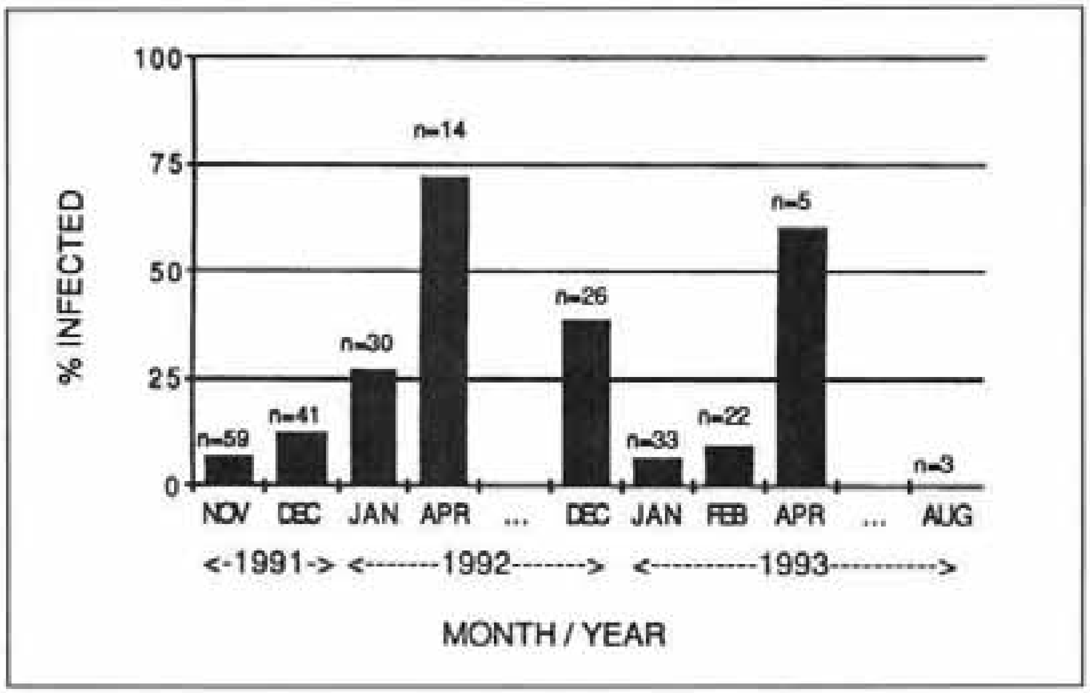

Figure 1. Prevalence of *Protostrongylus* spp. in the Stillwater bighorn sheep herd: November 1991 to August 1993. (** Sample sizes represent total number of samples examined.)

collected for lungworm analysis. The Kjeldahl method was used, and total fecal nitrogen values are given on a percent dry weight basis.

Mortality data were collected when a collared sheep died, during fecal pellet collection ground surveys, and by Stillwater Mine personnel. Ground surveys included all areas of known sheep activity on the winter range. Surveys of the winter range were also conducted a few times during the summer, as several sheep visit the winter range during the summer, presumably to obtain salt. Fresh carcasses were examined at the MDFWP laboratory in Bozeman, Montana State University, and the state of Montana Department of Livestock Diagnostic Laboratory.

Statistical analysis was done on MSUSTAT, version 5.10, developed by Richard E. Lund, Montana State University, Bozeman, MT 59717-0002. Loglinear fit for p-way tables (LOGLIN) analysis was performed to test for a relationship between age and prevalence of *Protostrongylus* spp. Chi-square analysis was used to evaluate all other lungworm data. Statistical significance was determined at $p<0.05$.

RESULTS

Lungworm

Sheep of all age and sex classes were observed using the medicated salt. The number of sheep observed using salt at any one time and the frequency of salt use suggested that most, if not all, Stillwater sheep were using salt. No sheep were observed coughing.

The prevalence of *Protostrongylus* spp. generally increased over the sampling period for each year. As shown in Figure 1, the trends were similar between years, except for the value for December 1992. Each of the 3 samples from August 1993 were negative. The increases in prevalence in both years became statistically significant in late winter and early spring ($p<0.05$) (Table 1). . No difference was found between the prevalence of lungworm in males and females for either winter. There was no difference between the prevalence of lungworm in sheep less than 2 years old and adults. All 26 samples from males and females from the West Fork segment of the herd were negative for lungworm larvae.

The average LPG values of the positive

samples for the Stillwater herd were all below 4 LPG (Figure 2). The maximum LPG values recorded were 11 and 13 LPG in December 1992, from a 2 year old ram and a 6 year old ram, respectively. No difference was found in the LPG distributions between age or sex categories.

Fecal Nitrogen

There did not appear to be any difference in the fecal nitrogen values among years, and there was an increase in spring in both years (Figure 3). Fecal nitrogen values from the West Fork were the same as those of the main herd for adjacent sampling periods. No values were less than 1.5% fecal nitrogen.

Mortality

The causes of mortality in the Stillwater herd are summarized in Table 2. Mountain lion predation and bacterial pneumonia each accounted for 22% of the mortality; the remaining causes were unknown. The mortality study only included sheep on winter range, and therefore does not include summer lamb mortality (except for two lambs found dead on the winter range during summer). The cause of death of these lambs was not determined.

Bacterial and viral isolations were obtained from the two sheep that died from pneumonia.

Table 1. Differences between months for prevalence of *Protostrongylus* spp. in the Stillwater bighorn sheep herd: November 1991 to August 1993.

Month	P-value
Nov 91 to Dec 91	0.352
Dec 91 to Jan 92	0.119
Nov & Dec 91 to Jan 92	0.012*
Jan 92 to Apr 92	0.005*
Nov & Dec 91 to Apr 92	0.000*
Apr 92 to Dec 92	0.046*
Dec 92 to Jan 93	0.002*
Jan 93 to Feb 93	0.672
Feb 93 to Apr 93	0.008*
Dec 92 to Apr 93	0.371
Apr 93 to Aug 93	0.090

* indicates statistical significance at $p<0.05$

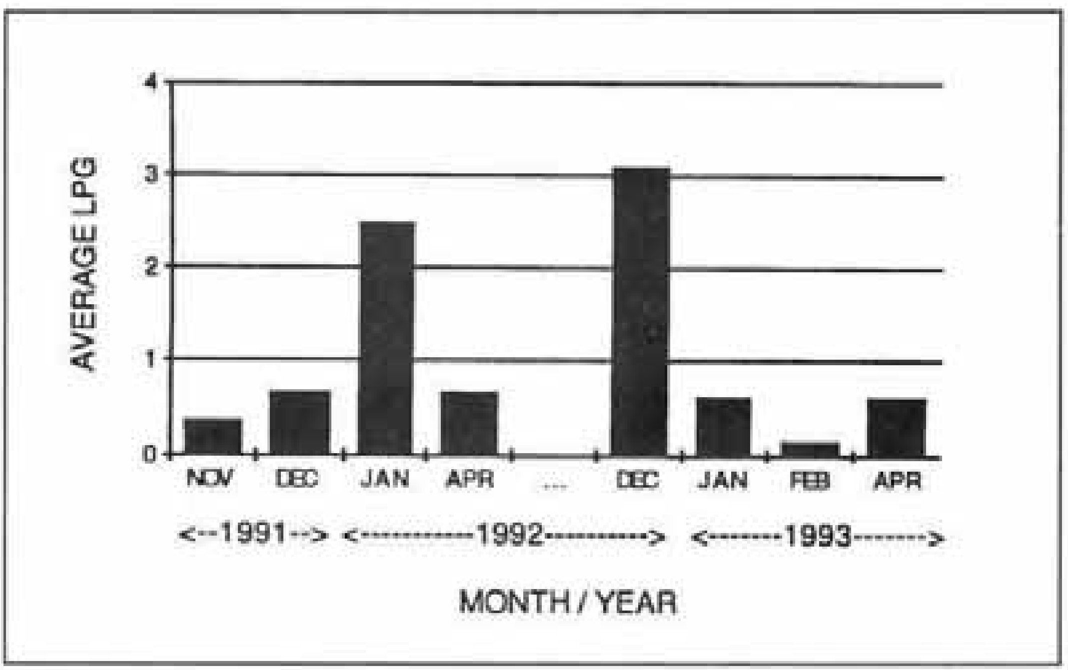

Figure 2. Average larvae per gram (LPG) of *Protostrongylus* spp. larvae in positive fecal samples from the Stillwater bighorn sheep herd: November 1991 to April 1993.

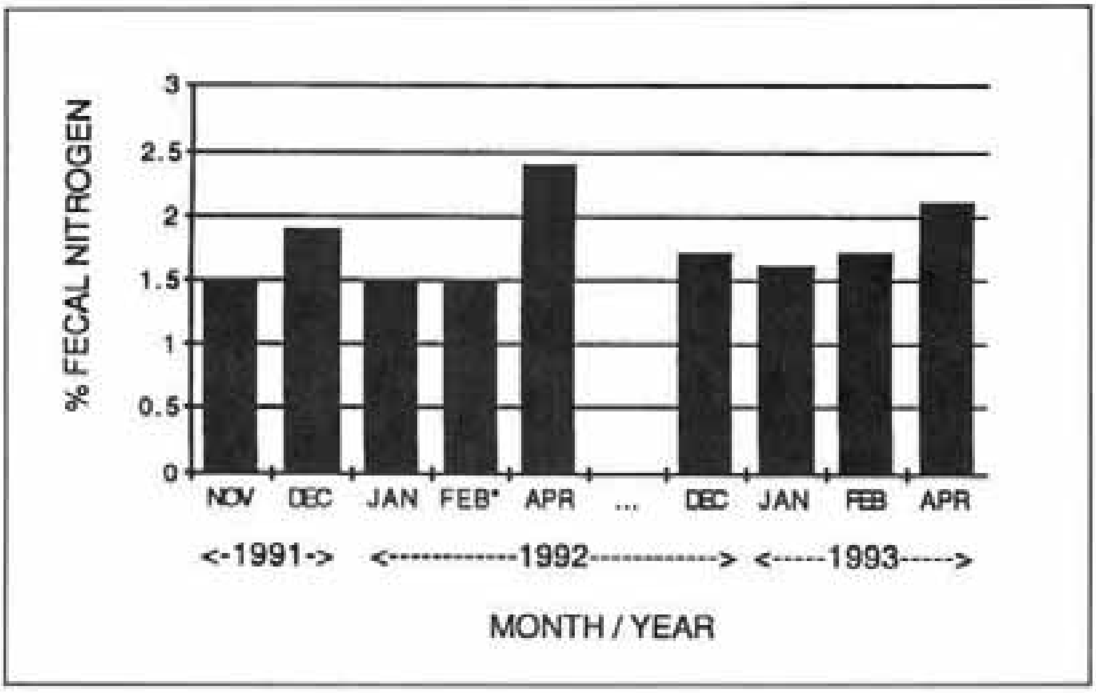

Figure 3. Percent fecal nitrogen for composite samples in the Stillwater bighorn sheep herd: November 1991-April 1993. (West Fork sample)

No *Pasteurella* spp. bacteria or viruses were isolated from an adult ram; however, *Moraxella* spp. was recovered. *P. hemolytica* and a noncytopathic Bovine Viral Diarrhea (BVD) virus were isolated from a female lamb. No other carcasses found were in a condition to obtain bacterial or viral information.

DISCUSSION

Lungworm

In evaluating the prevalence data for the Stillwater herd, sample size must be considered. However, in this case, sample sizes are inherently small since there are so few sheep in the herd. With small samples, prevalence may be skewed higher, and zero values may be underestimates of the population value (Gregory and Blackburn 1991). Nevertheless, in this study, an average of 26 samples were collected each month. In a population of an estimated 30 sheep, confidence in the results should actually be greater due to the probability of sampling a significant portion of the herd. The April and August samples were the smallest. Thus, if confidence in results is reduced due to sample size, only April and August should be most affected. However, the overall effect of sample size was tested by performing the analysis on doubled sample sizes; no changes in significance ($p<0.05$) resulted.

The prevalence of *Protostrongylus* spp. in the Stillwater herd has been effectively suppressed over the winter with fenbendazole medicated salt. However, in April of both years, dramatic increases occurred, bringing the prevalence in the Stillwater much closer to that of unmedicated herds. The results of this study differ from those in the Ural-Tweed herd (unmedicated), where prevalence was high in January and February. The December 1992 value differs from both the December 1991 and Ural-Tweed values, and may be suspect. However, both studies reported high prevalence occurring in April (Yde et al. 1988). As in this study, Yde et al. (1988) did not find differences in prevalence among age or sex classes. If there were any seasonal trends of differences, it is likely that fenbendazole may have masked them.

Although results from this study did not suggest a relationship between prevalence and intensity, it is interesting that unusually high values for both parameters occurred in December 1992. Logically,

Table 2. Causes of death for known mortalities in the Stillwater bighorn sheep herd: November 1991-August 1992.

Season/year	Sex and age class	Cause of death
Winter 91-92	unknown--?♀ #25?	mountain lion predation
Winter 91-92	unknown	unknown
Spring 92	lamb of the year ♀	unknown--carcass intact
Spring 92	♀ #97	unknown--carcass intact
Summer 1992	lamb of the year	unknown
Winter 92-93	♀ #24	mountain lion predation
Winter 92-93	lamb ♀	bacterial *P. haemolytica*
Winter 92-93	♂ #96	bacterial pneumonia--no *Pasteurella*
Unknown	adult ♀	unknown--whole carcass not found

an increase in the number of sheep infected with and shedding lungworm larvae should result in an increase in the level of infection in individual sheep. However, the increase in average LPG for the month of December was probably skewed higher due to two ram samples. When those 2 samples were excluded from the data, the average LPG for December was less than 1 LPG. Nevertheless, the presence of those two rams did not significantly affect the prevalence value for December.

Overall, no seasonal trends were apparent in LPG values in the Stillwater herd. Several authors have reported spring increases in lungworm larval output (Forrester and Senger 1964, Festa-Bianchet and Samson 1984, Fougere-Tower and Onderka 1988). However, Arnett et al. (1993) suggested that larval output of adult sheep may decline from November to April. Spring increases in LPG would not be expected in the Stillwater herd since sheep crave and increase their use of salt in the spring (Lawson and Johnson 1982). Regardless of the expected trend, fenbendazole likely masked it. Any expected differences in LPG distributions in age or sex categories would also likely be negated by fenbendazole.

Although Stillwater LPG levels were clearly below any physiological stress threshold, it is unlikely that even with consistent winter range medication, *Protostrongylus* spp. would be completely eliminated from the herd. First, in order for fenbendazole to eliminate all adult lungworms in bighorns, multiple doses are required (Huschle and Worley 1986). Second, use of salt may be sporadic by and among individual sheep (Huschle and Worley 1986, Worley and Seesee 1990). Third, fenbendazole is effective against adult lungworms, but may be less effective against somatic stored larvae (Schmidt et al. 1979, Foreyt et al. 1990). Fourth, concentrations of bighorns on a small, repeatedly used winter range may result in more lungworm exposure (Wishart et al. 1980). Finally, the Stillwater area was reported to have a relatively dense population of intermediate host snails (Forrester and Senger 1964). Therefore, the results of this study suggest that the Stillwater herd is as lungworm-free as can be expected in any free-ranging medicated herd.

Fecal Nitrogen

Fecal nitrogen results indicated that the Stillwater herd is not suffering nutritional deficiencies. The values were within the range described by Hebert et al. (1984), and the sheep appeared to respond to spring "green-up" with the April increase in fecal nitrogen. No fecal nitrogen values were recorded below 1.3%, indicating that the nutritional status is satisfactory (Irwin et al. 1993). It appears that the management of the Stillwater herd has been successful in maintaining optimal nutritional condition.

Mortalities

Only two summer mortalities were recorded on the winter range; both were lambs. Generally, lack of radio-collared animals made carcass collection difficult. In many cases, cause of death was obscured by deterioration of the carcass. However, if the carcass was completely intact and appeared undisturbed (as indicated in Table 2), it is unlikely that predation was the cause of death.

One ewe mortality (♀ # 97) may have been influenced by humans and mine activity. This sheep did not associate with others in the herd and displacement from the primary winter ranges could have increased exposure to some mortality factors. She wintered in a talus/scrub juniper drainage at an elevation of approximately 1000 to 2500 feet (330 - 830 m) above and approximately 2 miles (3.2 km) south-southwest of the primary winter range. Predation was unlikely as the carcass had not been disturbed or moved since death. Unfortunately, no further information could be obtained. No other mortalities could be attributed directly or indirectly to human disturbance. No sheep on the primary winter range appeared to be under nutritional stress.

As sheep move to winter ranges, their strong affinity for escape terrain may be lessened (Pallister 1974, Stewart 1975). Although mountain lion predation resulted in winter range mortality, limited studies with radio-collared lions did not indicate that summer range predation is significant in the Stillwater herd (Shawn Stewart, MDFWP, pers. comm.)

Pasteurella spp. are the most commonly reported pneumonia-related respiratory pathogens in bighorn sheep (Foreyt 1990) and were probably responsible for the death of 1 lamb. The absence of *Pasteurella* in 1 ram may be due to deterioration of the carcass.

MANAGEMENT IMPLICATIONS

The use of the fenbendazole medicated salt resulted in very low levels of *Protostrongylus* spp. And it does not appear that lungworm is a significant limiting factor to the recovery of the Stillwater herd. However, increases in prevalence in spring to levels near those of unmedicated herds may indicate residual low lungworm levels in sheep and on the range. Continued placement of medicated salt may prevent the herd from becoming re-infected at a level inducing physiological stress. Fenbendazole remains the drug of choice due to its demonstrated efficacy and low toxicity (Hibler et al. 1982, Foreyt et al. 1990). Fecal nitrogen values indicated that the Stillwater herd is not limited by nutritional constraints. Previous management actions were successful in maintaining adequate nutritional condition in this herd. Predation did not play a role in limiting Stillwater bighorn sheep overwinter survival. However, observed levels of predation were not excessive except when considering the small size of the herd. Continued monitoring of the Stillwater herd is needed to assess the role of bacterial pneumonia, as well as other factors related to a small remnant bighorn herd.

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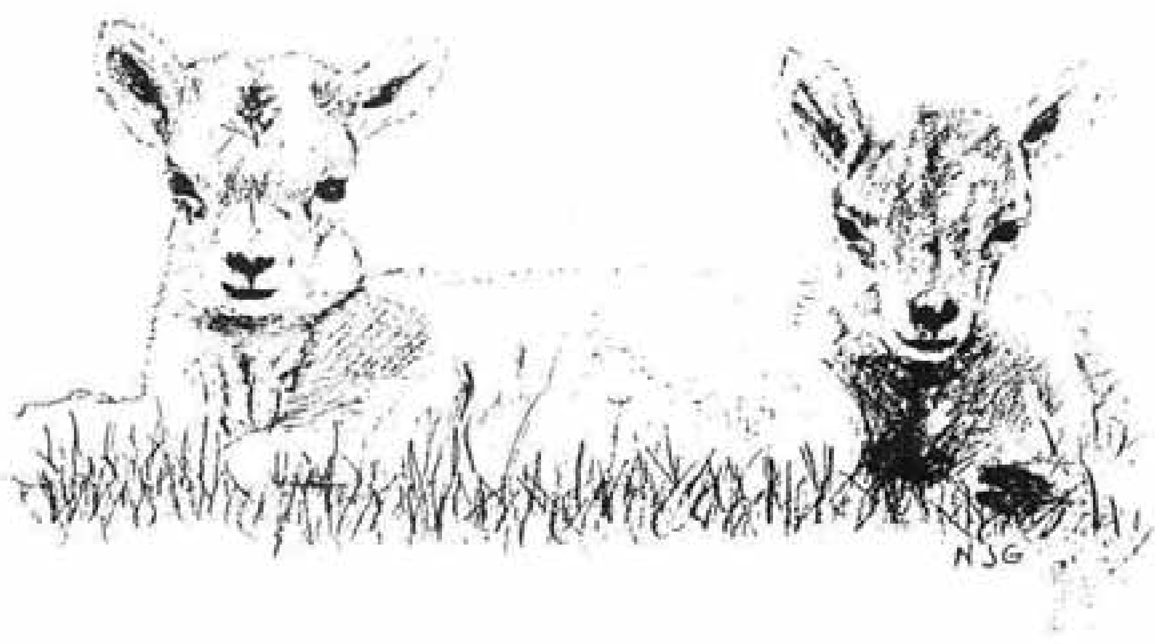

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ANALYSIS OF 1992 DALL SHEEP AND MOUNTAIN GOAT SURVEY DATA KENAI NATIONAL WILDLIFE REFUGE

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Abstract: The Alaska Department of Fish and Game (ADFG) and the U.S. Fish and Wildlife Service (FWS) cooperated in evaluating alternative methods of estimation of Dall sheep (*Ovis dalli*) and Rocky Mountain goat (*Oreamnos americanus*)numbers on the 800,000 hectare (1.97 million-acre) Kenai National Wildlife Refuge (KNWR) during the summer of 1992. The techniques included double sampling to correct for visibility bias. We compared the accuracy of population estimates obtained by the standard census, by a double sampling and logistic regression approach and by estimates obtained using the Gasaway ratio technique. Our study illustrated that the standard, and even very intense aerial surveys may miss sheep. Group size emerged as a significant variable explaining visibility bias. The ratio and product estimator appeared to be a biased under-estimator of size. The variance estimator for the logistic estimator appeared more appropriate. Simulations using logistic regression and ratio estimation provided an indication of the effect of sample size on survey results.

Dall sheep and Rocky Mountain goat surveys by the Alaska Department of Fish and Game (ADFG) are typically conducted using Piper PA-18 aircraft flown at low altitudes with intensive circling of sheep or goat groups. No attempt is made to correct for animals or groups of animals missed using this technique, since sightability of sheep and goats is generally assumed to be high (Loranger and Spraker 1992). Unfortunately, surveys designed to count all the animals present in an area often underestimate animal abundance (Caughley 1977) and generally lack information necessary to estimate the accuracy and precision of the counts. A major reason for inaccuracies in aerial surveys is the lack of an estimate of the number of animals missed or visibility bias (Caughley 1974, 1977).

In an evaluation of the effects of several factors on the accuracy of aerial surveys, Caughley et al. (1976) found speed, height above ground, the width of survey strips, and observers had significant effects on survey results. Samuel et al. (1987) found that visibility of elk in northcentral Idaho was significantly influenced by group size and vegetation cover. Other studies of visibility bias in aerial surveys have reported affects from species (Broome 1985), season of the year (Gasaway et al. 1985), sex, terrain, past experience with aircraft (Singer and Mullen 1981), and age specific behavior (Miller and Gunn 1977).

Adjustments of aerial survey data for visibility bias can be made. Samuel et al. (1987) offered a sightability model for predicting the probability of observing elk groups during winter aerial counts. Eberhardt and Simmons (1987) suggested "double sampling" as a way to calibrate aerial observations. McDonald et at. (1990a) in the Arctic National Wildlife Refuge (ANWR) and McDonald et al. (1990b, 1991) in the Wrangell-St. Elias National Park (WRST) found a significant relationship between group size and the ability of a low intensity fixed-wing survey to detect Dall sheep.

This study was conducted by the ADFG and FWS to compare three methods of estimating Dall sheep and Rocky Mountain goat numbers on the 800,000 hectare (1.97 million-acre) Kenai National Wildlife Refuge (KNWR) during the summer of 1992. The study also compared estimates obtained using counts from all survey units with estimates made from a simulated probability sample of a subset of sample units. The specific objectives of this study included:

1. compare estimates of the abundance of Dall sheep and Rocky Mountain goats within defined

habitat in the KNWR obtained by the double sampling and logistic regression approach (McDonald et al. 1990a), the Gasaway ratio technique (Gasaway et al. 1986), and the ADFG standard aerial survey; and,

2. to simulate the results of a sample survey using stratified subsampling of the KNWR.

METHODS

Survey Procedures

We conducted aerial counts in late June and early July 1992 of Dall sheep and Rocky Mountain goats on specified habitats on and immediately adjacent to the KNWR. We subdivided existing Dall sheep and Rocky Mountain goat count areas used by the ADFG for annual population trend and composition surveys into 27 survey units totaling 1732.1 km^2 (668.8 mi^2). Boundaries of survey units consisted of physiographic features which we assumed severely limited movement among units between repeat surveys.

Survey units were placed into one of three strata based on sheep density: 1) high; 2) medium; and 3) low. The high density stratum contained 8 units totaling 478.9 km^2 (184 mi^2); the medium density stratum contained 6 units totaling 448.3 km^2 (173.1 mi^2); and, the low density stratum contained 13 units totaling 804.7 km^2 (310.7 mi^2). We based the stratification on available historical data from ADFG surveys and/or an overflight of the survey areas. All survey units were digitized on the KNWR's Geographical Information System. Our study utilized 3 aerial surveys, each using a two-person (pilot/ observer) crew in a Piper PA-18 fixed-wing aircraft. The first survey was a comparatively extensive, "stand-off" survey (0.38 min/km^2 (1 min/mi^2)) designed to avoid disturbance to animals and provide more safe operating conditions for the fixed-wing aircraft. The second survey was a relatively intensive, "standard" survey (1.2 min/km^2 (3 min/mi^2)) flown at low altitudes with intensive circling typical of surveys employed by the ADFG. The second survey utilized a different survey crew from the stand-off survey. A third, "intensive" survey (2.3 min/km^2 (6 min/mi^2)) was conducted in a randomly selected sample of units. The third survey was conducted immediately following the second survey using the same pilot-observer team.

We recorded the total number of sheep or goats in each group and plotted their location on 1:63,360 USGS topographic maps of the survey units. We determined the age and sex composition of each group as closely as possible. The elapsed time between surveys was $\leq$ 2 hours and we assumed that animals did not cross unit boundaries between any of the surveys.

The survey crews flying the stand-off and standard surveys compared mapped locations and descriptions of groups immediately following survey flights. The survey crews used proximity of map locations and age and sex composition of sheep or goats to identify unique groups observed by one or both surveys. Groups seen by the standard survey were considered "marked", and these groups were either seen or missed by the stand-off survey. Decisions regarding pooling of original groups recorded and marked on maps to account for movement, aggregation, and segregation between surveys were based on deductive judgement of the survey crews. When in doubt, crews used a conservative approach (i.e. they assumed groups were seen by both surveys) in determining if groups were seen by both surveys. Thus, it was unlikely that incidental movement of sheep between surveys resulted in sheep recorded as seen by the intensive and not the less intensive surveys. This approach yielded a conservative estimate of the population size as it likely overestimated the probability that a given group was detected during the less intensive survey.

Population Estimates Using Logistic Regression

We assumed the standard survey detected a random sample of sheep and goat groups present, "marked" their location, and gave an exact count of numbers present in detected groups. The stand-off survey either detected or did not detect the marked groups. We used logistic regression to estimate visibility bias inherent in the less intensive, standoff survey (Eberhardt and Simmons 1987, Samuel et al. 1987). The logistic model considered only the variable group size (McDonald et al. 1990b, 1991) with a significance level of $p = 0.05$. The standard survey missed some groups seen by the stand-off survey, but those groups did not enter the calculation of visibility bias in any way. Standard errors and sampling distributions of density estimates were calculated using the Jackknifing procedure (Manly 1991).

To complete the Jackknife procedure we let n denote the number of primary units in the sample and fit one logistic model using data from all survey units in a stratum. We then calculated the visibility bias, adjusted all stand-off survey counts and estimated the density of Dall sheep. The calculations were repeated n times dropping each unit from the logistic regression one-at-a-time. These n+1 estimates of density were then used in the Jackknife procedure to compute n pseudo-estimates of density:

$$D_{pk}=n*D_t-(n-1)*D_{tk}$$

where D_{pk} was the pseudo-estimate of the population size with one unit dropped, D_t was the estimated population size with all units present, D_{tk} was the estimate of population size with the kth unit dropped.

Finally, we completed the Jackknife procedure by averaging these n pseudo-estimates to arrive at a single estimate of density. The standard error of estimated density was computed from the variation in the n pseudo-estimates. The total number of sheep or goats in the survey area was computed by multiplying the Jackknifed estimate of density by the total area. McDonald et al. (1991) described the above Jackknife procedures in detail. Confidence intervals based on the Jackknife procedure were computed as if the n pseudo-values are a simple random sample of size n using the standard t-distribution with n - 1 degrees of freedom.

Logistic regressions were run on PC-SAS (SAS Institute, Inc. 1985) using the CATMOD procedure, VMS SAS (SAS Institute, Inc. 1986) using the LOGIST procedure, and SOLO (BMDP Statistical Software, Inc. 1988) using logistic regression. All programs gave comparable results.

Population Estimates Using The Ratio Estimation Procedure

We used the intensive and standard surveys and standoff and standard surveys to construct a ratio estimate of the total sheep and goats (Gasaway et at. 1986). The following formulas (Cochran 1977, Reed et al. 1989) were used to compute the ratio estimators.

$Y_{i,h}$ and $X_{i,h}$ represented the number of sheep observed in unit i of strata h by the intensive and standard flights respectively. R_h was defined as:

$$\hat{R}_h = \frac{\sum Y_{i,h}}{\sum X_{i,h}}$$

$X_{2,h}$ represented the number of sheep observed by the standard flights in strata h including those units which were not double sampled.

The ratio estimator of the total for strata h, was:

$$\hat{Y}_{R,h} = \hat{R}_h \times \hat{X}_{2,h}$$

The variance of the ratio and ratio estimator were then used to arrive at an estimate of the standard error for each stratum. The estimates of the total and standard error were then computed using the standard formulas for stratified random sampling from Cochran (1977).

Sampling Simulations Using Logistic Regression

We simulated estimates of population size and generated 80% confidence intervals, from a stratified random sample of the low, medium, and high density strata using standoff and standard survey counts. We drew a random sample of n_1 units from 13 units in the low density stratum, n_2 units from 6 units in the medium density stratum, and n_3 units from 8 units in the high density stratum. We then corrected for visibility bias using logistic regression to estimate the number of sheep in each stratum and the total survey area. We drew another sample of the same size in each strata and repeated the process 1000 times. The standard deviation of the 1000 estimates of total sheep was used to compute the "simulated" 80% confidence interval based on the given sample size. Sample sizes were then allowed to vary within each stratum from a minimum of 2 to a maximum of 1 less than the number of units in that stratum. This generated 264 simulations for sheep and 264 simulations for goats.

Sampling Simulations Using Ratio Estimates

We used simulated double sampling to generate ratio estimates (Cochran 1977) of the total number of sheep in the KNWR for different sampling intensities. We generated ratio estimates for standoff versus standard and standard versus intense surveys. All high and medium density units and 5 of 13 low density units were double sampled in the standard and intense surveys. Simulated stratified random samples of sizes 3 through 8, 3 through 6, and 4 through 5 were drawn from the high, medium and low density strata respectively. The low density stratum had 3 empty units, prohibiting computation of the ratio of standard and

Table 1. The total area (km^2) of strata and estimated number and density of Dall sheep by stratum from counts made during standoff surveys, corrected for visibility bias using counts from standard surveys made in the Kenai National Wildlife Refuge, 1992.

Density strata	No. of units	Total area	Density	Total sheep
High	8	478.9	1.6860	807
Medium	16	448.3	0.5083	228
Low	13	804.7	0.1062	85
Total		1731.9	0.6472	1120[a]
Jackknifed estimate			0.6432	1114[b]

[a] Corrected for visibility bias but not Jackknifed.

[b] Corrected for visibility bias and mathematical bias by the Jackknife procedure resulting in a standard error for density of 0.09758 and total sheep of 169.

intensive counts for some samples of size 3. Therefore, the minimum sample size used in that stratum was 4. From each sample drawn, a subsample of 3 units in each stratum was selected at random for double sampling. This procedure was repeated 1000 times for each combination of strata sample sizes. The standard deviation of the 1000 estimates of total sheep was used to compute the "simulated" 80% confidence interval for the given sample size for each pair of surveys. We did not complete ratio simulations for goat surveys because of the large number of units without observations.

RESULTS

The standoff and standard surveys covered the same 27 units with an area totaling 1768.7 km^2 (683.1 mi^2). During the standoff survey the observation crew counted 850 sheep in 109 groups and 410 goats in 72 groups. During the standard survey the observation crew counted 1032 sheep in 149 groups and 456 goats in 84 groups. The standoff survey crew missed 57 sheep groups and 33 goat groups seen by the standard survey crew. However, the standard survey missed 17 sheep groups and 23 goat groups seen by the standoff survey crew. During the intense survey the observation crew counted 1056 sheep and 264 goats in 19 units totaling 1242 km^2 (479.7 mi^2). The ratio of sheep and goats seen during the standoff versus standard surveys was 0.82 and 0.9 respectively and standoff versus intensive was 0.91 and 0.77 respectively. The ratio of sheep and goats seen during the standard versus intensive surveys was 0.93 and 0.98 respectively.

The probability that the standoff survey crew would see a group of sheep increased considerably ($p = 0.0001$) as group size increased. We used this relationship to adjust the number of Dall sheep counted during the standoff survey for visibility bias, resulting in an estimate of 1114 $\pm$ 222 (80% C.I.) total sheep in the survey area (Table 1). The probability that the standoff survey crew would see a group of goats also increased ($p = 0.0166$) as group size increased. Using this relationship to adjust the number of goats counted during the standoff survey for visibility bias, we estimated 541 $\pm$ 190 (80% C.I.) total goats in the surveyed area (Table 2).

The survey crew conducting the standard survey conducted the intensive survey in 19 survey units. The intensive survey counted slightly more sheep and goats (1056 and 264) than the standard survey (984 and 260). Nevertheless, during the intensive survey the survey crew failed to detect some sheep and goats seen during the standard survey in some units. The medium density stratum had 3 out of 6 units with standard counts greater than intense survey counts. Using the ratio of Dall sheep and Rocky Mountain goats seen during standard to intense surveys, we estimated 1114 $\pm$ 218 (80% C.I.) sheep and 464 $\pm$ 152 (80% C.I.) goats, respectively. Using the ratio of Dall sheep and Rocky Mountain goats seen during standoff and standard survey, we estimated 1042 $\pm$ 204 (80% C.I.) sheep and 471 $\pm$ 156 (80% C.I.) goats,

Table 2. The total area (km²) of strata and estimated number and density of Rocky Mountain goats by stratum from counts made during standoff surveys, corrected for visibility bias using counts from standard surveys made in Kenai National Wildlife Refuge, 1992.

Density strata	Area	Density	Total goats
High	478.9	0.2090	100
Medium	448.3	0.1768	79
Low	804.7	0.4599	370
Total	1731.9	0.3173	549[a]
Jackknifed Estimate		0.3124	541[b]

[a] Corrected for visibility bias but not Jackknifed.

[b] Corrected for visibility bias and mathematical bias by the Jackknife procedure resulting in a standard error for density of 0.0837 and total goats of 145.

Table 3. Selected examples of simulated standard error and 80% confidence intervals for estimation of animal numbers using the logistic model and the standard survey to calibrate a stratified random sample of units included the standoff survey in the Kenai National Wildlife Refuge in 1992.

Sample size by stratum			Sheep simulated				Goats simulated			
L[1]	M[2]	H[3]	CI			SE	CI			SE
2	2	2	1028	+/-	447	303	421	+/-	485	328
2	2	8	1119	+/-	197	144	504	+/-	411	301
2	6	2	1051	+/-	395	286	400	+/-	434	314
7	3	2	1030	+/-	382	280	423	+/-	229	168
7	3	3	1103	+/-	254	187	499	+/-	175	129
7	3	4	1107	+/-	206	153	511	+/-	168	124
7	3	5	1114	+/-	176	131	510	+/-	165	123
7	3	6	1103	+/-	142	106	515	+/-	166	124
7	3	7	1108	+/-	122	91	509	+/-	159	119
7	3	8	1110	+/-	100	75	512	+/-	156	117
13	6	8	1114	+/-	0	0	514	+/-	0	0

[1] L = low

[2] M = medium

[3] H = high

Table 4. Selected examples of simulated and 80% confidence intervals for ratio estimation of animal numbers using a stratified random sample of units included in all surveys and using more intensive surveys to calibrate the less intensive surveys and the corresponding logistic estimation for Dall sheep in the Kenai National Wildlife Refuge in 1992.

Sample size by stratum			Standard vs standoff simulated			Intensive vs standard simulated			Logistic simulated		
L[1]	M[2]	H[3]	80% CI			80% CI			80% CI		
4	3	3	1047	+/-	246	1118	+/-	253	1103	+/-	270
4	3	8	1044	+/-	128	1113	+/-	125	1104	+/-	126
4	6	3	1048	+/-	237	1115	+/-	232	1113	+/-	250
5	3	3	1044	+/-	238	1113	+/-	248	1095	+/-	272
5	3	4	1042	+/-	198	1112	+/-	206	1110	+/-	218
5	3	5	1042	+/-	172	1113	+/-	175	1111	+/-	180
5	3	6	1052	+/-	150	1121	+/-	154	1104	+/-	154
5	3	7	1046	+/-	141	1117	+/-	135	1115	+/-	133
5	3	8	1042	+/-	119	1113	+/-	118	1112	+/-	108
5	6	8	1052	+/-	104	1117	+/-	62	1116	+/-	67

[1] L = low
[2] M = medium
[3] H = high

respectively. The point estimates and precision of the logistic model procedure (1114 ± 222) and ratio procedure using standard and intensive counts (1114 ± 218) were essentially identical. Both estimates were higher than the ratio estimate using standoff and standard survey counts (1042 ± 204).

We estimated a minimum number of sheep and goats by combining counts of independent animals from the standoff and standard surveys. The standard survey crew counted 1032 sheep and 456 goats and missed 65 sheep (17 groups) and 49 goats (23 groups) observed by the standoff crew. Based on these counts we concluded that a minimum of 1097 sheep and 505 goats existed in the surveyed area at the time of the standoff survey.

The standoff and standard surveys included an inventory of all units within the study area. By drawing a large number of stratified random samples of counts made during these two surveys, we simulated estimates of sheep and goats which could be expected using the logistic model if the surveys sampled only a portion of the units. Table 3 provides an example of the results of these simulations.

The broadest confidence interval was obtained with the minimum sample size in each stratum (i.e. n_1, n_2, and n_3 = 2). The narrowest confidence interval was obtained with the maximum sample size in each stratum (i.e. $n_1 = 12$, $n_2 = 5$, and $n_3 = 7$). Point estimates both increased and decreased when sample sizes increased. Increasing the sample in any stratum improved the precision of the estimate. The simulated confidence intervals may be used to compare the expected precision as a function of the corresponding sample sizes. This may help in choosing a sampling strategy for future studies.

An example of population estimates and confidence intervals obtained by simulating double sampling and ratio estimates are contained in Table 4. We used simulations to correct the standard survey counts using the intensive survey counts and standoff survey counts using the standard survey counts. These estimates were compared to estimates and confidence intervals generated using the logistic model for estimating the visibility correction factor generated in simulations. A total of 48 combinations of strata sample sizes was possible. With small sample sizes the ratio estimate, regardless of surveys compared, appeared more precise than the logistic model estimate. However, as sample size increased, the precision of the logistic model estimate improved to the point of exceeding the apparent precision of the ratio estimators. In all cases the logistic model estimate of sheep and goat numbers exceeded the estimate derived from the ratio estimator.

DISCUSSION

The intensity of the KNWR standoff (fixed-wing) survey (0.38 min/km^2; 1 min/mi^2) was greater than the standoff (fixed-wing) survey in the WRST surveys (0.21 min/km^2; 0.54 min/mi^2) reducing the likelihood that sheep and goats would be missed by the KNWR standoff survey. Nevertheless, the standoff and even the much more intense standard and intense surveys conducted during our study missed sheep and goats. Our results illustrate that sheep and goat estimates based on the relatively intense standard survey used by the ADFG, and even very intense aerial surveys may be improved by adjustments for visibility bias.

As in the other aerial surveys of Dall sheep using double sampling and logistic regression (McDonald et al. 1991 and McDonald et al. 1990a) group size emerged as a significant variable explaining visibility bias for both sheep and goats. Corrections for visibility bias using the logistic regression model and the ratio estimation procedure resulted in essentially identical point estimates and precision for sheep and goats when using standard and intensive survey counts. However, this is not surprising since these 2 surveys missed few sheep and the data are likely biased because the same crew conducted both surveys.

When comparing the 2 methods, it seems more appropriate to compare estimates made from the surveys using the independent standoff and standard surveys. The point estimate obtained with the ratio of standoff and standard counts is lower than the minimum number of sheep known to be in the study area. The point estimate obtained with the logistic estimator is slightly higher than the minimum estimate and likely more realistic. The ratio and product estimator appears to be a biased underestimate of size, as could be expected since ratio estimators typically contain some mathematical bias.

We also feel the variance estimator for the logistic estimator for both sheep and goat is more appropriate. Several factors associated with the 3 surveys may have contributed to the lower variance of the ratio estimator. First, the intensity of all 3 surveys resulted in relatively few sheep being missed. For example, the standoff survey, the least intensive effort, missed less than 20 percent of the sheep and 10 percent of goats of the total seen by the standard survey. This similarity in counts resulted in a ratio between any 2 survey counts ($\hat{R}$) approaching 1. Second, in the logistic procedure, area is used as an auxiliary variable while, for the ratio estimator, equal unit size is assumed, even though units are of different sizes. Third, the formulas for calculation of variance used with the ratio estimator assume independent counts, however the counts made in the double sampling design are dependent.

The standoff and standard surveys covered all units. However, it may be desirable to sample populations rather than survey all units. Simulations using logistic regression and ratio estimation provided an indication of the effect of sample size on survey results. While increasing the sample size in any stratum improved the precision of the estimate using both estimating procedures, increases in sample size within the medium and high density strata had the greatest effect on precision. As with the point estimates the ratio estimator appeared to have a lower variance. The above reasons offered for this reduced variance also apply to the simulations. In addition, in cases where the standoff survey actually counted more sheep and goats than the standard survey the point estimate and variance would be artificially reduced. Even with the bias likely in calculating the precision of the ratio estimate the logistical model provides a more precise estimate of animal numbers with larger sample sizes.

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AERIAL SURVEY AND DALL SHEEP POPULATION SIZE: COMPARATIVE USEFULNESS OF EXTERNAL AND INTERNAL POPULATION DYNAMICS FOR MANAGEMENT PURPOSES

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Abstract: Survey flights over Dall sheep (*Ovis dalli*) ranges are the traditional and typical extent of population data collection for this species in Alaska. Many factors which introduce variability in these aerial surveys have been identified, and managers have often been reluctant to act based on these vaguely variable data. Development of statistical techniques to place bounds about Dall sheep population estimates offered some hope for greater confidence in Dall sheep survey data. However, the promise of these techniques is yet to be realized in Alaska. In the context of practical management, statistical confidence in the validity of population estimates is of secondary importance to the fact that even the best aerial population size estimates fail to elucidate internal population dynamics. The internal dynamics of composition and mortality effectively predict or explain fluctuations in population size and realizable harvests while total population estimates simply reflect changes which have already taken place. Even given accurate annual population estimates with statistically valid confidence limits, total population estimation techniques chronicle past population changes, and track them with an accuracy which is barely narrower than the recorded range of population fluctuations. This paper demonstrates the efficacy of using internal dynamics from previously published data, and discusses the disadvantages of strict reliance on aerial survey data for management purposes. Recommendations for improvements in population trend assessment are offered.

Ideally, modern management of wild mountain sheep for maximum sustained use would be based on detailed knowledge of the size and internal dynamics (production, recruitment, age structure, and age/sex-specific mortality) of the sheep populations being managed. Historically, these data have been generally considered unobtainable or prohibitively expensive to gather. As a result, managers have "made do" with less specific information, simple estimates of population size and trend.

The dominant methodology for gathering sheep population size and trend information throughout North America has been aerial survey. In most cases, serial estimates of population size have been used to define population trends. Where population size has not been considered definable by aerial survey, sheep managers have "settled for" indices of population trend such as minimum numbers of sheep seen, sheep seen per hour of survey effort, trend in number of animals harvested, or range use indicators.

Aerial survey and census of wild mountain sheep are dominated by factors which introduce variability to the results. The most basic of these factors is the choice between fixed or rotary-wing aircraft. For Dall sheep in Alaska, experience defined the Piper PA-18 Supercub as the aircraft of choice more than 20 years ago, but sporadic efforts to develop helicopter use for sheep surveys still continue. Once aircraft type has been chosen, a hierarchy of factors affecting data quality becomes operative.

These factors range from those which are clearly controllable through those that are somewhat manageable to factors beyond direct control of the manager. Controllable factors include aircraft type and survey intensity (time spent per area). Factors which are somewhat manageable include pilot and observer experience, level of pilot effort, observer enthusiasm/attitude, and factors which are negotiable with the aircraft pilot (e.g., flight speed, aerial technique relating to flight routes and terrain, lighting aspect, and distance above ground level). Factors which are virtually unmanageable include weather, light conditions, and sheep distribution among habitats where sheep are easier or more difficult to see. Finally, the composite effect of other work schedules and priorities must be balanced with relatively narrow meteorological and biological "windows" during which survey conditions are ideal.

This constraint often necessitates compromises among the hierarchy of factors listed above, resulting in less-than-ideal survey conditions and raising further questions about the verity of results. This complicates decisions by the sheep manager and those involved in the management process at higher organizational levels. The result is that no one is compelled to believe any 2 aerial sheep counts are truly comparable or that they accurately represent the biological situation with respect to population size or trend.

In addition to the inherent variability just discussed, counting methodologies include counting as many sheep as possible while flying in the mountains, counts with rigorously-defined flight paths and search intensities, the use of marked animals to define discrete populations and survey efficiency, and elaborate statistical sampling schemes and biometric analyses. This evolutionary spectrum of techniques resulted from incremental efforts to increase the credibility of aerial survey results. Statistically driven sampling schemes have been the most recent and high-profile efforts to increase this credibility.

The biostatistical approach to increasing the credibility of a single population estimate produced by an aerial survey has required generation of statistical variance within internal subsets of the survey data and using this variance to calculate a confidence interval about the estimate. In essence, this procedure predicts the precision of a theoretical sample of population estimates which would result if the survey could be replicated. To date large-scale surveys have been impossible to replicate because of their expense and the fact that the uncontrollable variables listed above preclude survey duplication. Small-scale repeat surveys with high precision were reported by Nichols (1976), but this technique has not been widely applied.

In spite of the difficulty in establishing the accuracy of these procedures, considerable effort has gone into development of statistically bounded single population estimates for several Dall sheep populations in Alaska (McDonald et al. 1990, Strickland et al. 1992, Strickland et al. this symposium). While progress has been made in placing confidence intervals about the individual sheep population estimates, some estimates, particularly those in the Wrangell Mountains (Strickland et al. 1992), seem implausibly high. Additionally, developmental work on this technique has shown fiscal constraints limit the practicality of narrowing the confidence interval to less than approximately plus or minus 20% of the estimated population size at the 90% level of confidence, the typical measure of precision.

If the ideal data set for maximum sustained yield management should include not only population size but also measures of internal dynamics of the managed population (defined earlier), a complete survey and inventory program cannot be limited to aerial population estimates. This paper defines the differences in management utility between external population dynamics (derivable from aerial estimation of total population size) and internal population dynamics (as listed earlier). Additionally, results from 2 Dall sheep monitoring programs in Alaska will be compared. One program focused exclusively on annual aerial surveys. The other program also monitored internal population dynamics and checked the predicted changes in population size based on these dynamics against external population dynamics derived by a repeated aerial survey.

METHODS

External Population Dynamic Monitoring

External dynamics of sheep populations in the Chugach Mountains were monitored by annual survey flights from 1976 through 1993. D. Harkness maximized efforts to limit variability in data collection. In July of each year, the same highly experienced pilot/observer team, B. Wiederkehr and D. Harkness, conducted the survey using the same aircraft (a PA-18-Supercub). Survey intensity (time spent in the area) generally was consistent from year to year at about 6 hours of flight time (~0.75 min/km^2 [2 min/mi^2]). Aerial technique also was consistent over the course of data collection. During these surveys, the number of Dall sheep counted was recorded, with sheep identified as lambs, ewe-like sheep (which include ewes, yearlings, and young rams which still look like ewes when viewed from an airplane), and rams of legal size depending on applicable regulatory definition.

Integrated Population Monitoring Using Internal Population Dynamics

In July 1980 an initial ewe population size estimate using ewes marked with neckbands to assess observability was generated for the well-defined sheep ranges in the Robertson River study area (Heimer and Watson 1986a). This estimate was based on intense aerial searches (1.5 min/km^2

[4 min/mi^2]) using a PA-18-150hp Supercub with a highly experienced pilot/observer team - B. Lentsch and W. Heimer). During this census, sightability of ewe-like sheep was established at 76% based on resighting 48 of the possible 63 marked ewes present in the count area. The number of ewe-like sheep was corrected for ewe-like sheep-not-seen by expanding the total observed by the proportion of known marked ewes sighted.

The actual number of ewes among the estimated number of ewe-like sheep was calculated using ground-based observations of population composition. Sheep were classified as lambs, ewes, yearlings, and rams of Classes I-IV (Geist 1971) using 8X binoculars and 15-60X spotting scopes at distances of less than 33m (100 yds) at the main mineral lick in the study area during the last 2 weeks in June. Mortality among marked ewes was calculated from mineral lick resightings over the next 4 years (Heimer and Watson 1986a). These data were used to elucidate the effects of internal dynamics on ewe population size. They were entered into a simple (yearling recruitment "in"/ewe mortality "out") model to predict the true ewe population size prior to a second aerial count scheduled for July 1984.

In June 1983 and 1984, trapping and marking resumed using established methods (Heimer 1974, Heimer et al. 1980), and resulted in 74 marked ewes (including some yearlings) present in the population for the 1984 aerial survey. The 1984 aerial survey duplicated the 1980 count as exactly as possible, including the same aircraft and pilot/observer team, search intensity, flight routes, and mark/resighting methodology.

RESULTS

External Population Dynamic Monitoring

Numbers of ewe-like sheep, lambs, young rams, and legal rams were recorded for each survey (Table 1).

Integrated Population Monitoring Using Internal Population Dynamics

In 1980 resighting of 76% of the known neckband-marked ewe-like sheep in the population during an intense aerial search of the area was used to produce a population estimate of 588 ewe-like sheep. Using reconciled aerial search and ground composition data, the ewe population was calculated to contain 456 true ewes (of which 63, or 13.8% were marked) and 132 yearlings of both sexes. Half of these yearlings (66) were assumed to be females so the midsummer ewe population was estimated to be 522 ewes of all ages.

Beginning with this ewe population size, using the internal dynamics of the ewe population as input, the population model predicted a mid-summer 1984 population size estimate of 550 ewes (Table 2).

Observation of 62 of the possible 74 marked ewes during the aerial count of 1984 produced a sightability correction factor of 0.84. When reconciled with ground composition data from spring 1984, a corrected population size of 550 ewes was calculated, indicating we marked approximately 13% of the ewe population.

The population of 550 ewes estimated from aerial counting in 1984 was identical to the population size predicted from the population model.

DISCUSSION

The traditional aerial survey approach to Dall sheep population inventory should be recognized as a compromise between having no data and having the complete data set required for information-based management. Prior to the biological discoveries and technological advances which allow insight into internal population dynamics, aerial survey of almost any type was the most attractive alternative. It became the standard technique, and eventually the traditional one.

Aerial survey or population estimation serves best when rigorously pursued each year. Heimer (1992) argued that population trend cannot be used reliably without annual assessment because "noise" caused by variations in environmental resistance from year to year may falsely indicate trend (or stability) if population assessments are intermittent. The data in Table 1 represent the most outstanding example of aerial survey consistency available in Alaska. These data indicate a period of stability at about 1000 sheep (1976-1979), a period of growth (1979-1988), and a period of stability at about 2200 sheep (1989-present); the population appears to have doubled in size since 1979. During the increase, the number of ewe-like sheep counted increased from about 600 to about 1250. There is no doubt more sheep have been seen during later counts, but the cause or causes of these higher counts are uncertain. Possibilities, ranging from an actual population increase with $r = 0.09$ (which is theoretically possible) to increased

Table 1. Game Management Unit 14C (Chugach Mountains) Dall Sheep Survey Data 1976-1993 courtesy of D. Harkness, Alaska Department of Fish and Game.

Year	Ewe-like sheep	Lambs	Lambs:100 ewe-like sheep	Young rams	Legal rams
1976	609	130	21	152	86
1977[a]	621[b]	21	--	--[b]	34
1978	596	135	23	141	88
1979	514	161	31	143	85
1980	740	182	25	171	70
1981	820	239	29	151	82
1982	967	193	20	231	79
1983	1006	89	29	292	118
1984	1048	357	34	269	158
1985	979	294	30	299	138
1986	1206	356	30	329	172
1987	1228	352	29	427	162
1988	1219	334	27	379	204
1989	1355	387	29	456	214
1990	1224	259	21	440	218
1991	1228	410	33	416	228
1992	1324	344	26	419	235
1993	1200	259	22	360	203

[a] Poor counting conditions.
[b] Young rams included with ewe-like sheep due to poor counting conditions.

Note: Prior to 1979 legal rams were 3/4 curl, from 1979-1988 legal rams were 7/8 curl, from 1989-1993 any sheep was legal. In this table rams recorded as legal from 1989-1993 were 7/8 curl or larger.

Table 2. Ewe population sizes, female yearling recruitment and overall ewe mortality for Dall sheep in the Robertson River area of the Alaska Range 1980-1984.

Year	End of winter adult ewe population	Yearling ewe recruitment from previous year[a]	Summer ewe population size	Winter ewe mortality % (years)[b]
1980	456 adults +	66 yearling ewes = (from 1979)	522 ewes	0% (1980-1981)
1981	522 adults +	84 yearling ewes = (from 1980)	606 ewes	22% (1981-1982) (-133 ewes)
1982	473 adults +	85 yearling ewes = (from 1981)	558 ewes	2% (1982-1983) (-12 ewes)
1983	546 adults +	38 yearling ewes = (from 1982)	584 ewes	17% (1983-1984) (-99 ewes)
1984	485 adults +	65 yearling ewes = (from 1983)	550 ewes	

[a] Calculated by multiplying half of yearlings:100 ewes ratio by the number of hundreds of ewes (Heimer and Watson 1986a).
[b] Calculated from resighting of collared ewes at mineral lick (Heimer and Watson 1986a).

counting skills by the pilot/observer team, could account for the increase.

Unfortunately, because of the absence of yearling recruitment, age structure, and mortality data, these possibilities cannot be rigorously evaluated. However, an actual population size increase based on the lambs:100 ewe-like sheep ratios appears to be improbable.

Calculation of the lambs:100 ewe-like sheep ratios for the period of early stability (mean = 25 lambs:100 ewe-like sheep), population growth (mean = 28 lambs:100 ewe-like sheep), and stability at high population (mean = 26 lambs:100 ewe-like sheep) reveals a remarkable stability. This level of lamb production (an overall mean of 27 lambs:100 ewe-like sheep, range = 20-34) would scarcely be adequate to support more than population maintenance in other areas of Alaska (Heimer and Watson 1986a,b). If the increases in sheep counted accurately reflected an increase in population size, mortality from countable-aged lambs through old-aged ewes must have been consistently lower than ever recorded in a pristine ecosystem.

Use of simple Lotus input/output simulation indicates the population increase between 1979 and 1988 would have required internal dynamics equivalent to those listed below:

1. A constant recruitment of 40 yearlings:100 producing ewes (given the estimated number of ewes of reproductive age calculated from typical composition data for growing sheep populations by Heimer and Watson (1986b) and the approximately 600 ewe-like sheep counted at the end of the early stable period),

2. A constant mortality of 3% or less on all age classes of ewes from yearling age through age 12 years during the growth period, and

3. Few ewes survive past their twelfth winter.

These conditions would be unusual. Seldom have single-year yearling:100 ewe ratios been recorded at 40:100 in Alaska, and it is certainly impossible to average 40 yearlings:100 ewe-like sheep with a mean lambs:100 ewe-like sheep ratio of 27:100 with little or no ewe mortality.

Measured mortality among ewes under age 9 averages 3% per year under normal conditions on ideal continental ranges (Watson and Heimer 1984). Once ewes exceed 9 years of age, mortality increases to an average of 50% per year (Heimer 1973, Watson and Heimer 1984, Heimer and Watson 1986a). It is not unusual for ewes older than 12 years to produce lambs (Heimer and Watson 1986a). Still, production of lambs recorded in Table 1 appears inadequate to produce the observed population growth. The consistency of the lambs:100 ewe-like sheep ratios throughout the survey period, coupled with 2 periods of stability on either side of unprecedented growth, suggests either emigration or a dramatic increase in survey area or efficiency during the 1979-1988 period.

Aerial monitoring of sheep populations, along with the best possible aerial sheep classification, does not provide sufficient data to answer biological questions. Even if these population estimates had relatively narrow statistical bounds, the data would still provide no clue as to how the measured increase was achieved.

In the Chugach Mountains where these data were gathered, no biological harm resulted from this failure to account for or offer a hypothesis to explain the population increase. That is, the existing sheep management program was not compromised because these populations are managed under a restrictive permit system. Conversely, a great deal of management benefit accrued as a result of these annual surveys because the public was content with the level of effort on the part of its managers. Furthermore, other user-focused benefits resulted from the surveys as hunting opportunities were shared from managers to users.

However, in a more typical management situation with maximum sustained yield harvest as the management goal, determination of the cause (particularly if low mortality) could have made cropping of ewes an unusually attractive option in the absence of normal environmental resistance. Without biological insight to the mechanisms of internal population dynamics, such management actions can be implemented only at high risk.

In contrast, the integrated population monitoring program using aerial population estimation along with data on the internal dynamics of the monitored population produced remarkable agreement between predicted and estimated population sizes over a 4-year period in sheep populations of the Alaska Range. I caution the reader against the inference that the technique is without error. Still, the remarkable exact prediction of the ewe population size suggests use of internal population dynamic data to predict external population sizes is workable. The fact that 2 major population adjustments took place during this period further suggests the potential predictive power of this procedure. The more striking fluctuation was associated with the unusually difficult winter of 1981-1982 (Watson and Heimer 1984). Mortality during this winter centered on old-aged ewes which had already exceeded normal life expectancy. Because this internal dynamic was understood, the 22% decrease in ewe population during winter of 1981-1982 was interpretable as a normal population adjustment, loss of "lingering" cohorts of old ewes from the population, and not a catastrophic population crash. Management was simplified by this knowledge.

Annual assessment of population composition allowed accurate prediction of a relative scarcity of mature rams 7 years after the low yearling recruitment of 13 yearlings:100 ewes in spring 1983, even though the lamb production had been nominal (29 lambs:100 ewes) in spring 1982. Harvest from this count area is conservatively managed for trophy production by a limited entry lottery permit for full-curl (or 8-year-old) rams. Consequently, unexpected failure to meet an anticipated harvest goal 7 years later with attendant hunter dissatisfaction was precluded. Nevertheless, benefits accrued to both managers and the hunters because hunters were aware of the likelihood of slightly decreased trophy ram abundance before going afield in 1990. Because of constant presence of managers in the field and the intermittent aerial surveys, identical ancillary benefits produced by the exclusive aerial monitoring of external population dynamics in the Chugach Mountains were also produced by the integrated program.

This comparison suggests the integrated program is equivalent to simple aerial surveys for providing benefits for managers and users and superior for answering biological questions. This should not be surprising, it has long been understood that variations in cohort size will affect age structure (Murphy and Whitten 1976); and that older-aged cohorts are more vulnerable to mortality during difficult winters (Watson and Heimer 1984).

Still, the questions, "How much information is needed?" and "Can we afford to gather it?" must be asked. If management needs are limited to maintaining a visible presence as active managers of monitored populations, the traditional aerial survey program may suffice if human costs are not a consideration (see subsequent discussion). Similarly, if management objectives do not focus on maximum sustained yield to attain harvest objectives which may be compromised by occasional production or recruitment failures or unexpected mortality, aerial survey may be adequate. However, if accurate biological monitoring to predict harvest or adjust regulations for quantifiable management objectives is desirable, or if increasing biological knowledge is an objective of management, the integrated program will be more beneficial.

In spite of the benefits produced by monitoring external population dynamics, we should recognize that even the most sophisticated, accurate statistical sampling schemes can only provide more confidence in individual population estimates based on aerial survey data. Deciding whether this confidence is warranted requires examination of basic assumptions concerning precision and accuracy. As presently conceived and practiced, statistically bounded population estimates provide a theoretical inference of precision but no assurance of accuracy.

Precision defines the consistency of repeatable measurements, but does not necessarily assure the set of precise measurements is accurate - only that the measurements are consistent with each other. In their quest for accuracy, it seems that sheep managers and biometricians have assumed that measurements with an acceptably defined level of precision (90% confidence) will be accurate (Strickland et al. 1992). That is, biologists seem to have assumed that accuracy is a function of precision.

There is no assurance this assumption is correct, and the incredibly high population estimates for the Wrangell Mountains (Strickland et al. 1992) raise serious questions about their accuracy (although they are acceptably precise). Still, the assumption is understandably attractive because its converse is, by definition, true. It is mathematically certain that high precision is generated by repeatedly making accurate measurements of stable parameters. Hence, precision among measurements is a function of measurement accuracy if the measured parameter is static. At the present time, there is no actual link between the theoretical precision projected for an estimated Dall sheep population size and the accuracy of the population estimate. In the jargon of remote sensing, we would say, "There is no 'ground truth' for aerial survey data."

The lack of verification that bounded population estimates are accurate becomes disconcerting when we recall the assailability of Dall sheep count accuracy was the reason for development of statistically acceptable aerial sampling procedures in the first place. These circumstances define a curious relationship between perceived and actual accuracy, a relationship which managers may profitably reconsider.

Additionally, managers should recognize

inherent variability in sheep population size from year to year may exceed the projected resolution capability of the statistically bounded population estimate. Given that variations in Dall sheep populations of 20%-25% (Watson and Heimer 1984, Heimer 1992) can be independent of long-term population trend (Heimer 1992) without serious management consequence, it seems unlikely that continued statistical refinement of aerial population estimation techniques will realistically meet management needs. If sheep populations vary by plus or minus 20%-25% without severe management consequences, the management relevance of a very expensive technique having a 90% chance of documenting changes, which must be greater than plus or minus 20%, is unclear. Hence, the question of whether accuracy is a function of precision or vice versa becomes moot because inherent variability in population size from year to year may exceed the resolving power of the technique at any time.

The best we can hope for from biostatistical approaches to population estimation is an accurate (or perhaps precise) chronicle of external population dynamics and longer-term trend providing that population estimates are made with sufficiently high frequency. Even if such estimates were affordable and hence available, they do not hold the promise of allowing managers to accurately anticipate population changes which will affect future harvest success, changes which are certain to result from the internal dynamics of sheep populations.

Each approach has its unique costs. Monitoring external population dynamics from aircraft requires relatively large investments of operational funding, particularly if biologists use helicopters. Aerial survey also carries a little-recognized human cost. Flying in mountainous terrain is dangerous and takes a surprisingly high toll in the lives of managers and pilots.

The proceedings of this symposium list since 1970 the deaths of Jim Erickson and his pilot (fixed-wing Dall sheep survey-Alaska); Harold Mitchell, Wesley Prediger and their pilot (helicopter bighorn work-British Columbia); Orval Pall, his pilot, and another observer (fixed-wing bighorn radiotelemetry-Alberta). Other sheep and goat management-related deaths of which I am aware include Spencer Linderman and his pilot (fixed-wing goat survey-Alaska) and the deaths of 10 others engaged in aerial searches for missing biologists. These 20 deaths (and perhaps others) have taken place during the last 24 years. To be coldly mathematical, these data establish an average death rate associated with aerial counting of sheep and goats of 1 human life every 14.4 months. The hazard of flying near mountains is further illustrated by the even greater number of deaths among guides and hunters who also use aircraft to search the mountains for sheep and goats.

In contrast to aerial survey, the integrated program is less hazardous and requires scant operational funding but lavish expenditure of time. If professional managers were to spend the requisite amount of time on the ground with sheep, salary costs could exceed those of fixed-wing surveys, and perhaps approach those of helicopter use. However, I have had success limiting salary expenditures through the use of volunteers in capture operations and ground-based data gathering. There have been minor injuries associated with sheep capture, but the human (and fiscal) costs of ground-based methodology have been insignificant compared with aerial efforts. Some aerial survey is unavoidable in the integrated program, but the quality of information and the reduction in time spent at risk while flying in the mountains increases the benefits associated with the calculated risks of the required aerial counting to more acceptable levels.

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UTILITY OF SUMMER FIXED-WING AERIAL SURVEYS IN PREDICTING LAMB:EWE RATIOS OBSERVED ON WINTER RANGE

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Abstract: I investigated the efficacy of using fixed-wing aircraft to survey sheep during the summers of 1984 - 1990 in southwestern Montana. The area surveyed served as summer range for 150-300 sheep which occupied at least 3 distinct winter ranges. Observations on 9 summer surveys were used to calculate lamb:ewe ratios for individual winter ranges and an overall lamb:ewe ratio. These values were compared to lamb:ewe ratios developed from winter ground surveys for individual winter ranges and for all winter ranges combined. Even with moderately detailed information on summer distribution from radio telemetry studies, the information I collected in summer did not adequately predict sheep numbers or lamb:ewe ratios on winter ranges following the summer aerial surveys. The funds I spent on these surveys could have been better spent on other activities.

Managers of bighorn sheep (*Ovis canadensis*) populations traditionally have relied on lamb:ewe ratios to forecast population trends and/or relative herd health (Geist 1971). Jorgenson (1992) and Festa-Bianchet (1992) suggest that lamb:ewe ratios have limited predictive utility, but this index may be the only readily attainable value for assessing the status of some herds. In the northern Rocky Mountains, sheep tend to congregate on predictable wintering areas where the ages and sexes of sheep can be ascertained relatively easily. If lower than "normal" lamb:ewe ratios indicate potential problems, most managers would prefer to know this before winter. In areas with low density sheep herds dispersed over inaccessible terrain, options for summer monitoring are limited to periodic ground sampling, helicopter surveys, or fixed-wing surveys. The fixed-wing survey would be the most desirable of these options from the standpoint of manhours and rental costs if valid estimates of lamb production could be made.

I tested the efficacy of using lamb to ewe ratios derived from sheep classified on fixed-wing summer flights as predictors of winter lamb:ewe ratios for several herds in the upper Yellowstone River Valley of Montana. These herds include sheep wintering along the Yellowstone River at Cinnabar Mountain (CM) and Point of Rocks (PR) and small bands wintering at high (2000-3000 m) elevations in the Gallatin Range above an area known as the Tom Miner Basin (TM). These winter ranges are used by sheep which summer over an area of approximately 400 km^2. The total population within this area differed from approximately 150-300 individuals during 1984-90. The tests involved variants of the null hypothesis of "no relationship between summer and winter lamb:ewe ratios" for bands associated with specific winter ranges and for all winter ranges combined.

Funding for flights was provided by the Boone and Crockett Club and the Montana Department of Fish, Wildlife, and Parks. Ground survey data were collected by a number of people including: K. Alt, S. Geymer, T. Lemke, J. Swenson, and the participants in the annual interagency sheep count. Thank you.

METHODS

Summer movement patterns for ewe bands in the upper Yellowstone area were identified using radio telemetry in 1978-84 (Keating 1982, Irby et al. 1986). From 1984 - 1990, 9 summer flights were made in July or August to classify sheep in summering areas identified via radio telemetry. One flight per summer was scheduled for 5 of the years and 2 flights per year were made in 1985 and 1989. During each flight, a Piper Supercub was flown at the lowest elevations permitted by wind conditions on the day of the flight. The pilot and the observer attempted to classify all sheep sighted (lambs, ewes, males with less than 3/4-curl horns, males with >3/4-curl horns). Sheep that were identified as females and lambs were used to calculate lamb:ewe ratios.

Lamb:ewe ratios for summer areas used by sheep from specific winter ranges were compared to lamb:ewe ratios obtained the following winter using paired t-tests (H_o:no difference between summer and winter lamb:ewe ratios for specific herds and for all herds in the area) and regression analysis (H_o: no predictive relationship between lamb:ewe ratios observed in summer and those observed in winter for specific herds and for all herds). A 2-factor regression analysis (winter lamb:ewe ratios = mean + summer range lamb:ewe ratio effect + the effect of summer sample size [indexed as the minimum number of individual ewes observed in summer divided by the minimum number of individual ewes observed in winter multiplied by 100] + error) was used to determine if predictability was influenced by the sample size used to calculate summer lamb:ewe ratios. Summer ratios frequently were based on smaller sample sizes than those obtained in winter because of the dispersed distribution of sheep in summer. All statistical tests were run on MSUSTAT (Lund 1989).

High variability associated with ratios calculated from small samples can obscure general trends; therefore, I placed lamb:ewe ratios in general productivity classes (0-30% = poor production; 30-50% fair production; >50% = good production) and compared summer and winter classifications.

RESULTS

Nine flights yielded total counts of 31-127 sheep (Table 1). These values included 25-88% of the total number of ewes on which overall winter lamb:ewe ratios were based. The paired flights in 1985 and 1989 were used to develop a combined "best" estimate (including groups missed in one flight but seen in the other) for tests (Fig. 1).

Paired t-tests (using the single "best" estimates for 1985 and 1989) indicated that lamb:ewe ratios in summer tended to be higher than in winter, but no differences were significant at $\underline{P} < 0.05$ (CM: t = 1.79, $\underline{P}$ = 0.13; TM: t = 2.16, $\underline{P}$ = 0.10; PR: t = 0.49, $\underline{P}$ = 0.64; Overall: t = 1.94, $\underline{P}$ = 0.10).

The value of summer lamb:ewe ratios in predicting winter lamb:ewe ratios was low for CM (R^2 = 0.09, $\underline{P}$ = 0.55), TM (R^2 = 0.01, $\underline{P}$ = 0.85), PR (R^2 = 0.16, $\underline{P}$ = 0.37), and overall (R^2 = 0.28, $\underline{P}$ = 0.22). Adjusting the regression for the number of ewes that were used to calculate summer lamb to ewe ratios via a 2-factor regression did not improve the predictive values of models (R^2 range = 0.14 to 0.38; $\underline{P}$ range = 0.38 to 0.80). There was also no predictive relationship between total number of sheep sighted on summer aerial surveys and the minimum population estimates based on ground observations the following winter (R^2 range = 0.03 to 0.19; $\underline{P}$ range = 0.37 to 0.75).

When production based on lamb:ewe ratios was arbitrarily classified as poor, medium, or good, summer classifications agreed with winter classifications in 3 of 6 years for the CM herd, 1 of 5 years for the TM herd, 4 of 7 years for the PR herd, and 4 of 7 years for all herds combined.

DISCUSSION

Low intensity aerial surveys during mid summer using fixed-wing aircraft did not prove to be an accurate means of predicting lamb:ewe ratios during the following winter for bighorn herds in the upper Yellowstone River valley. The failure presumably was due to inadequate sample sizes. Sheep on summer ranges in this area are widely dispersed at low densities and do not hesitate to use timbered habitat types. When these factors are combined with high winds that preclude low elevation searches in many areas, results tend to be poor. Knowledge on distribution of sheep gained from radio telemetry studies helped identify search areas but did not insure consistent sighting of sheep.

Biological uses of the data collected during summer aerial surveys during 1984-90 were limited. The data suggest that poor recruitment in bighorn herds in the upper Yellowstone area was not due to lamb mortality in late summer or early autumn. Winter lamb:ewe ratios tended to be lower than mid summer ratios, but differences were inconsistent and too small to explain the low proportion of adult ewes that brought lambs to winter ranges.

Lamb:ewe ratios on winter ranges in the study area during the 1970's were generally high (Keating 1982) indicating that these sheep ranges were capable of sustaining higher productivity. Several factors that were prevalent in the upper Yellowstone area during the 1980's have been reported in the literature (Woodgerd 1964, Stelfox 1976, Lawson and Johnson 1982, Festa-Bianchet 1988, Dunbar 1992) as explanations for a pattern of low lamb:ewe ratios by mid summer. During the 1980's, the age structure of females became progressively skewed towards old ewes; drought, fires, and high elk (*Cervus elaphus*) numbers could have contributed to nutritional stress; blood and

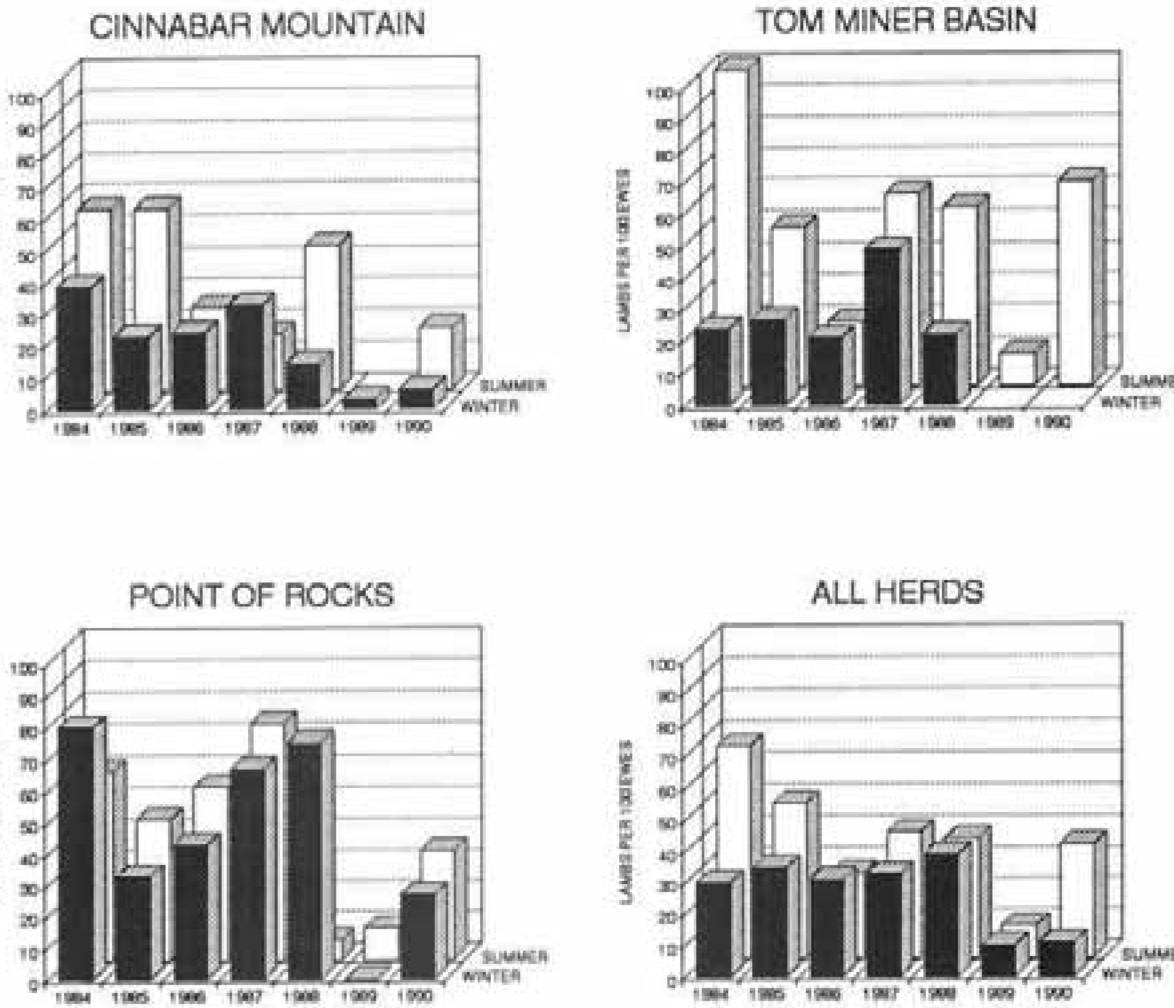

Figure 1. Summer and winter lamb to ewe ratios for Cinnabar Mountain, Tom Miner Basin, Point of Rocks, and all herds combined, 1984 - 1990.

Table 1. Summer and winter counts used to develop lamb:ewe (L:E) ratios.

	Summer				Winter			
Survey Date	Ewe	Lamb	Total	L:E	Ewe	Lamb	Total	L:E
Cinnabar Mountain (CM)								
10 July 84	7	4	13	57	40	8	71	20
19 July 85	7	0	15	0	44	18	83	41
18 August 85	6	4	23	67	44	18	83	41
21 July 86	31	8	39	26	46	15	93	33
28 July 87	23	4	27	17	47	9	80	19
19 July 88	22	10	32	45	44	17	89	39
26 July 89					30	4	47	13
27 July 89					30	4	47	13
15 July 90	16	3	20	19	34	2	60	6
Tom Miner (TM)								
10 July 84	3	3	10	100	21	5	47	24
19 July 85	14	7	26	50	26	7	54	27
18 August 85	0	0	7	0	26	7	54	27
21 July 86	35	7	57	20	28	6	45	21
28 July 87	5	3	12	60	37	18	69	49
19 July 88	23	13	36	56	9	2	15	22
26 July 89	6	0	15	0				
27 July 89	21	2	35	10				
15 July 90	11	7	21	64				
Point of Rocks (PR)								
10 July 84	5	3	14	60	10	8	27	80
19 July 85	0	0	36		15	5	30	33
18 August 85	22	10	32	45	15	5	30	33
21 July 86	11	6	27	55	14	6	32	43
28 July 87	12	9	22	75	3	2	12	67
19 July 88	18	1	19	6	4	3	13	75
26 July 89	10	0	16	0	8	0	18	0
27 July 89	2	1	8	50	8	0	18	0
15 July 90	23	8	31	35	11	3	22	
TOTAL								
10 July 84	15	10	37	67	71	21	145	30
19 July 85	21	7	44	33	85	30	167	35
18 August 85	28	14	62	50	85	30	167	35
21 July 86	77	21	127	27	88	27	170	31
28 July 87	40	16	61	40	87	29	161	33
19 July 88	63	24	87	38	57	22	117	39
26 July 89	16	0	31	0	38	4	65	10
27 July 89	23	3	43	13	38	4	65	10
15 July 90	50	18	74	36	45	5	82	11

fecal samples indicated chronic disease and parasite infections in the population (Worley, D., Montana Department of Fish, Wildlife, and Parks, pers. comm.) and falling prices for coyote (*Canis latrans*) pelts and restrictions on lion (*Felis concolor*) hunting could have resulted in increased predation. The fixed-wing surveys provided no insight into which, if any, of these factors were important.

In summary, unless you are flying for the thrill of low level mountain flying, save your money. Fixed-wing aircraft were not an effective means of sampling dispersed sheep populations in southwest Montana during summer, even when we had much more detailed information on summer distribution than is available for most sheep herds.

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A METHOD USED FOR ESTIMATING MOUNTAIN GOAT NUMBERS IN THE BABINE MOUNTAINS RECREATION AREA, BRITISH COLUMBIA

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Abstract: A mark-recapture method was used to estimate the mountain goat population size in the Babine Mountains Recreation Area in northwest British Columbia. Mountain goats were marked using a Rebel 90 paint-ball gun fired from a helicopter. Marks on individual goats ranged from single hits to flanks marked by brushing against rocks that were hit with paint balls. A total of 28 goats was marked. The study area was surveyed 1 week after marking and population size was estimated using the Peterson mark-recapture estimate. Assumptions of the Peterson estimate with respect to this technique are discussed.

Mountain goats (*Oreamnos americanus*) are most often associated with high elevation open habitat such as alpine meadows, grassy talus slopes, cliffs and rocky ridges (Banfield 1974). Consequently, mountain goat inventories typically consist of censusing goats seen in those open habitats (Hatler and Hazelwood 1985, van Drimmelen 1985, Barichello et al. 1989). However, some individuals use forested or partially forested habitats (Joslin 1986a, van de Wetering 1989) and are not counted during census of open terrain. Because the entire population is not censused, a minimum population size is obtained.

Correction factors have been used widely for wildlife population estimates to correct for animals not seen during surveys (Smith and Bovee 1984, Gasaway et al. 1986, Jones 1988, Seip 1990) based on both qualitative and quantitative information. An intuitive estimate of the proportion of the population not seen (a best guess) is often used when information for more quantitative approaches is lacking (Jones 1988). Quantitative correction factors vary depending on the type of survey being conducted. In Alaska, a sightability correction factor for stratified random block moose (*Alces alces*) surveys was developed based on intensively resurveying a portion of several blocks (Gasaway et al. 1986). Mark-recapture estimates, based on the proportion of marked animals seen during surveys, are also often used to correct for animals not seen during surveys (Smith and Bovee 1984, Seip 1990).

For the mark-recapture technique, animals may be marked with radiocollars, visual collars, eartags, paint or any other marks that are visible during future surveys. Marking animals with radiocollars is desirable since all radio-collared animals can be located, whether they are within or outside the survey area, and the proportion of marked animals in the survey area can be determined. Radio-collared goats have been used for goat inventories in southeastern Alaska (Smith and Bovee 1984) and Montana (Joslin 1986a). However, a sample of radio-collared animals is expensive to obtain. Marking animals with paint or dye is a less expensive method for obtaining a marked sample. Aerial application of dye has been used on mountain goats in Alaska (Nichols 1980), Dall sheep (*Ovis dalli dalli*) in the Northwest Territories (Simmons 1971), and caribou (*Rangifer tarandus*) and moose in Newfoundland (Mercer et al. 1989).

For the Babine Mountains Recreation Area mountain goat inventory, we investigated a technique for marking goats with paint, using a paint-ball gun fired from a helicopter. The technique had been tested on moose in central British Columbia, but marks were too small to be conspicuous during surveys (H. Langin, pers. comm.). No other attempt at using a paint-ball gun for marking ungulates was found.

Because 'ferry' time by helicopter from Smithers to the Babine Mountains Recreation Area was only 5 minutes, the area was ideal for economically testing the marking technique on mountain goats. This paper outlines the techniques used to mark mountain goats and the resulting population estimate for the Babine Mountains Recreation Area.

The objectives of the project were:

1. To test a method for marking mountain goats using a paint-ball gun fired from a helicopter.
2. To determine the size of the mountain goat population in the Babine Mountains Recreation Area using the Peterson mark-recapture estimate.

The survey was conducted by BC Parks in co-operation with BC Environment, Fish and Wildlife Branch. Funding for the mountain goat inventory was provided by BC Parks. George Schultze operated the paint gun during the marking expedition. Tom Brooks (Canadian Helicopters) piloted the helicopter for the marking expedition and the surveys. Dave Ciriani kindly loaned us his paint-ball gun to mark the goats. Rick Marshall, Herb Langin, Daryll Hebert, Jean Carey, Dale Seip, and Dave Hatler provided advice on our marking technique and survey design. Kent Jingfors and Ian Hatter provided comments on an earlier draft of the manuscript.

STUDY AREA

The Babine Mountains Recreation Area is located in northwestern B.C., 16 km northeast of Smithers (Fig.1). It covers 32,400 ha of the southern Babine Ranges in the South Skeena Mountains Ecosection (Demarchi 1993). The Recreation Area consists of primarily Alpine Tundra (AT) and Engelmann Spruce-Subalpine Fir (ESSF) biogeoclimatic zones, and the mountains rise up to 2400 m from the Babine-Stuart Plateau to the east, and the Nechako Plateau to the south and west (BC Parks 1991). Vegetation in the ESSF zone consists primarily of subalpine fir (*Abies lasiocarpa*), Engelmann spruce (*Picea engelmanni*), black huckleberry (*Vaccinium membranaceum*) and false azalea (*Menziesia ferruginea*). The AT zone is characterized by krummholz and alpine scrub at lower elevations and herb meadows, dry alpine communities, grass slopes, exposed rocky slopes and glaciers at higher elevations. A forested valley (Harold Price Creek and north Reiseter Creek drainages) separates the southern Babine Mountains from the northern Babine Mountains which lie north of the Recreation Area. For survey purposes, the Recreation Area was divided into 2 zones separated by the Driftwood and Cronin Creek drainages.

METHODS

Marking Technique

Goats were marked in the Babine Mountains Recreation Area between 0700 and 1000 on June 16, 1991, 1 week prior to the survey. A Bell 206 helicopter was used to locate and mark goats in alpine and partially forested areas throughout the Recreation Area. Single goats and individuals within groups were targeted. Marking was conducted by firing oil-based, Nelson "007" paint balls (The Nelson Paint Company, 48 Industrial Park Cres., Saulte Ste. Marie, Ont., P6B 5P2) from a pump-action, Rebel 90 paint-ball gun (Rebel 90 paint-ball gun based on Nelson paint gun design), from the helicopter. The paint-ball gun was powered by a 200 gm (7 oz.) CO_2 tank and firing velocity was set at approximately 140 m/sec. Goats were marked either by a direct hit with red or orange paint balls, or by brushing against nearby rocks that had been hit by paint balls. Each group was examined immediately after marking to determine the number of goats marked and the marking patterns on each animal.

Survey Technique

The Recreation Area was divided into 2 zones for surveying (Fig.1). Zone 1 was censused twice (July 22 and 24) and Zone 2 was censused once (July 23). Each zone was surveyed between 0630 and 1100 to minimize missing animals which moved below treeline during the heat of the day (Nichols 1980). All open and semi-open areas were searched. Surveys were conducted by Bell 206 helicopter with 3 observers, using the method described by van Drimmelen (1985). Locations of groups were plotted onto a 1:50 000 mapsheet and individual goats were classified as adult males, adult females, yearlings or kids. Classification was based on pelage and morphological characteristics, and presence or absence of a vulval patch (Hatler and Hazelwood 1985, van Drimmelen 1985, Smith 1988).

Population Estimation Using the Peterson Mark-recapture Estimate

The size of the mountain goat population in the Babine Mountains Recreation Area was estimated using the Chapman estimator of the Peterson mark-recapture estimate (Seber 1982):

$$N = \frac{(n+1)(M+1)}{(m+1)} - 1$$

where:

N = total number of goats in the population

n = number of goats counted during the survey

M = number of goats marked

m = number of marked goats counted during the survey

and an approximately unbiased estimate of the variance is:

$$Var(N) = \frac{(M+1)(n+1)(M-m)(n-m)}{(m+1)^2(m+2)}$$

A 95% confidence interval for the estimate was calculated as:

$$N \pm 1.96 \times (Var[N])^{0.5}$$

Assumptions associated with the Peterson mark-recapture estimate that must be satisfied by the marking and survey techniques for the population estimate to be valid are addressed in the discussion.

RESULTS

Marking

A total of 28 goats (26 adults, 2 yearlings) from 8 groups was marked in 2.3 hours of helicopter time, for a marking rate of 1 goat / 5 minutes of helicopter time (Table 1, Fig.1). Helicopter time included 'ferry' time between groups and 'ferry' time to and from the study area. Marks on individuals included single hits, multiple hits, and flanks brushed against rocks that were hit with paint balls (Fig.2). Accuracy was greatest when the helicopter was 20-40 m away from the goats, and when the helicopter was positioned directly beside and at the same level as the goats. Paint balls fired at goats above, below, in front, or behind the helicopter were deflected by 'prop wash'.

Survey

The weather during all 3 days of the survey was sunny or slightly overcast. Table 2 summarizes the number of goats counted during the surveys. Only 6 marked animals were observed in Zone 1 on July 22, out of a possible 13 that were marked in that zone. We believed that we missed seeing some marks on goats in larger groups due to inexperience of some observers with the survey procedure. Therefore, we resurveyed Zone 1 on July 24.

Data for Zone 1 from July 24, and for Zone 2 from July 23 were combined to estimate the total population size (Table 2). Using the unbiased estimator, the summer population size was estimated at 283 ± 64 (95% CL) and the adult and yearling population was estimated at 253 ± 53 (95% CL).

More goats were counted in Zone 1 on July 22 than on July 24 (Table 2). Data for Zone 1 from July 22 and for Zone 2 from July 23 were combined for a minimum population size of 236 goats. Zone 2 contained proportionally more males and yearlings and fewer females and kids than Zone 1, but, the ratio of kids:100 females was consistent for both zones and for both days of surveys in Zone 1, and averaged 34.5 kids:100 females (Table 3). The age/sex ratio of goats marked (7 adult males: 19 adult females: 2 yearlings) did not differ from the age/sex ratio of goats counted during the survey (51 adult males: 95 adult females: 16 yearlings) (X^2=0.86, $p<0.05$).

DISCUSSION

Marking Technique

Marking mountain goats with a paint-ball gun from a helicopter was an effective and cost-efficient method for marking goats for short-term purposes. As the shooter and pilot became more familiar with the behaviour of the paint balls in the 'prop wash', marking success and efficiency increased. Marking frequency of 0.2 goats/minute was lower than the marking frequency of 1.1 caribou/minute in

Table 1. Summary of goats marked with paint in the Babine Mountains Recreation Area, July 16, 1991.

Group No.[a]	No.goats in group	Sex	Location of mark
1	40-50	Female	[b]
		Female	[b]
		Female	[b]
		Female	Top front shoulder
		Female	Left rump
		Female	Left neck
2	40-50	Female	Left flank
		Female	Left shoulder
3	6	Male	Left shoulder/neck
		Male	Head
		Male	Head
		Male	Left shoulder and side
		Male	Head, head, left flank
4	10-15	Female	Right rump
		Female	Right side
		Female	Right side
		Female	Right side
		Female	Left side
		Female	Left side
5	8-10	Female	Top shoulders
		Female	Left neck
		Female	Left neck
		Male	Left neck
		Female	Left rump
6	9	Male	Left shoulder/upper leg
		Male	Right shoulder/upper leg
7	2	Female	Back, left front leg
8	1	Male	Right shoulder

[a] group numbers correspond to numbered locations in Fig. 1.
[b] location of marks on the first three goats was not recorded.

Table 2. Total number of goats counted during helicopter surveys in the Babine Mountains Recreation Area, July 22-24, 1991.

Zone	Date	Marked goats seen	Adult males	Adult females	Yrlgs	Kids	Total
1	22/07/91	6	14	80	8	28	130
2	23/07/91	9	36	42	14	14	106
1	24/07/91	10	15	53	2	19	89
2+1	23+24	19	51	95	16	33	195

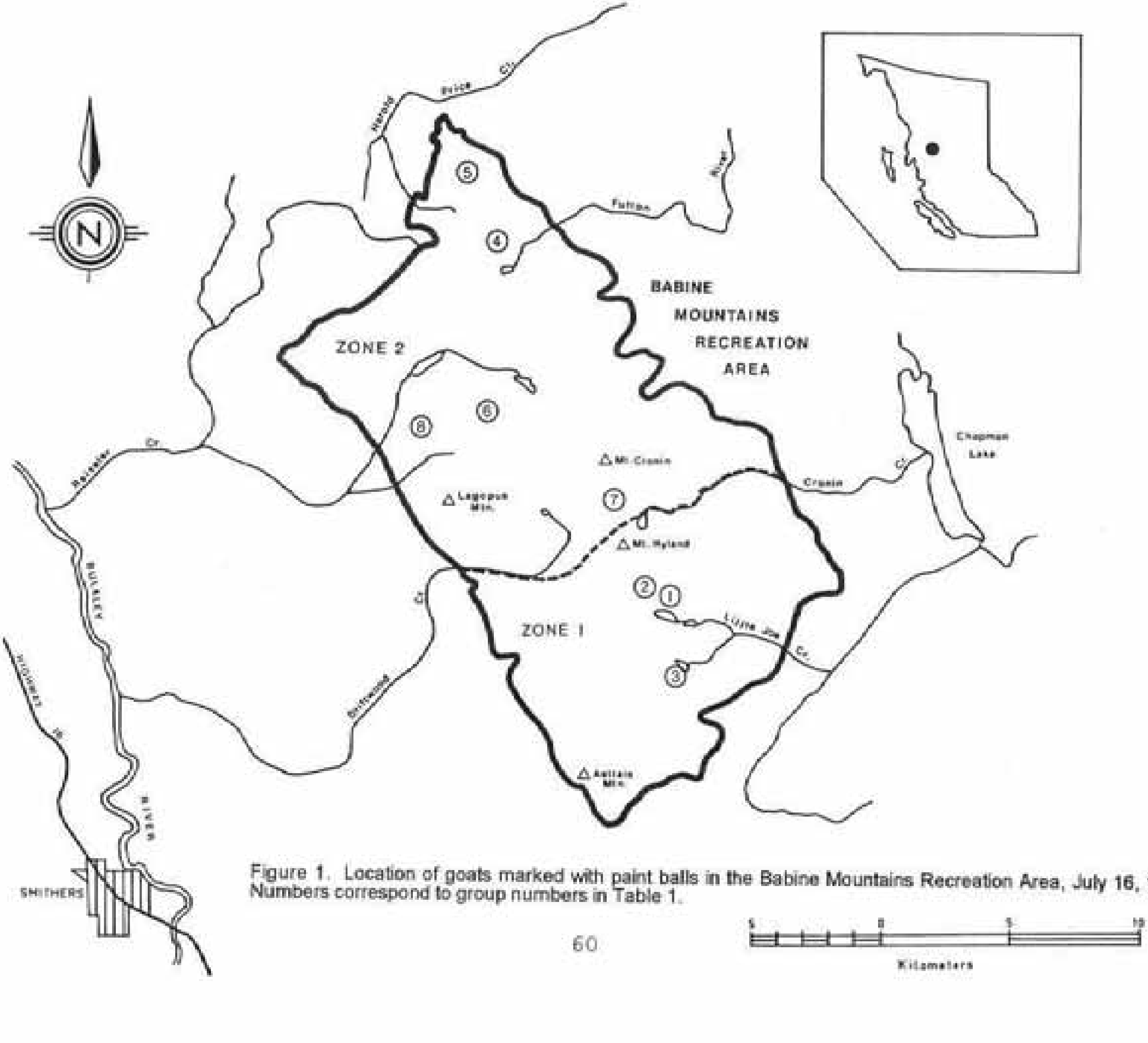

Figure 1. Location of goats marked with paint balls in the Babine Mountains Recreation Area, July 16, 1991. Numbers correspond to group numbers in Table 1.

Figure 2. Goats marked with paint balls, Babine Mountains Recreation Area, July 1991.

Table 3. Age/sex class percentages and ratios of goats counted during helicopter surveys in the Babine Mountains Recreation Area, July 22-24, 1991.

Zone	Date	% Adult males	% Adult females	% Yearlings	% Kids	Total	Kids: 100 females
1	22/07/91	10.8	61.5	6.2	21.5	130	35.0
2	23/07/91	34.0	39.6	13.2	13.2	106	33.3
1	24/07/91	16.8	59.6	2.3	21.3	89	35.9
1+2	22+23	21.2	51.7	9.3	17.8	236	34.4
2+1	23+24	26.2	48.7	8.2	16.9	195	34.7

Newfoundland using a paint spray apparatus (Mercer et al. 1989). However, the density of caribou (4.7 caribou/km^2) was greater and the size of the study area (20 km^2) was smaller than for the Babine Mountains goat population (0.9 goats/km^2, 324 km^2), which likely contributed to higher marking efficiency. Marking efficiency of the paint ball technique on the Babine Mountains goat population was comparable to the paint spray technique (0.15 caribou/minute) on caribou in Newfoundland when the density of unmarked caribou dropped to 1.0 caribou/km^2.

Red and orange paint marks were highly visible on both smooth and shaggy animals during surveys; however, both sides of each goat had to be observed since individuals may have had marks on either side. In large groups (>20 goats), both sides of individual goats were sometimes difficult to observe. Consequently, more time was spent looking for marks than would have been if all individuals had been marked on the same side. Future attempts to mark mountain goats with paint balls should focus on marking all individuals on the same side to increase survey efficiency.

Peterson Mark-recapture Estimate

The population estimate based on the Peterson mark-recapture equation must satisfy a number of assumptions in order for the estimate to be valid (Krebs 1989).

Assumption 1: The population is closed.

The population is closed if no natality, mortality, immigration or emigration occurs between marking and recapture. Because the Recreation Area is flanked by low elevation plateaus to the west, south and east, and is separated from the northern Babine Range by a forested valley, immigration and emigration during the week between marking and the survey likely did not occur. Also, since most kids are born by mid-June (Banfield 1974), natality was negligible. No kids less than 1 week of age were observed during the survey.

Although mortality was more difficult to assess, no evidence of recent goat mortality was observed during the intensive survey. Because the interval between marking and recapture was short, some evidence of mortality should have been observed had mortality occurred. Kid mortality during the marking and survey period for the present survey was likely negligible. No kid mortalities were reported for a sample of radio-collared kids in west central Alberta prior to August 19 (Smith et al. 1992), or for kids associated with radio-collared female goats in Montana prior to July 28 (Joslin 1986b).

Assumption 2: All animals have the same chance of being marked.

During the marking expedition, individual goats (males and females) and goats in groups were targeted throughout the Recreation Area in alpine and subalpine parkland habitat. Also, the age/sex ratio of marked goats did not differ from the age/sex ratio of goats counted during the survey, indicating that the marked sample represented the population.

Although kids were not marked, the population estimate derived from the yearling and adult population and factoring in the proportion of kids (283) was the same as the population estimate including kids.

Assumption 3: Marking individuals does not affect their catchability.

Marking individuals must not predispose them to being more or less detectable than unmarked animals. For example, in this case, because the goats were marked from a helicopter, the marked goats may have been more prone than unmarked goats to hiding when they heard the helicopter coming during the survey. To test for equal catchability, a minimum of 3 recapture or survey sessions is required (Krebs 1989). Because the study area was surveyed only once, we were unable to test this assumption. However, because the whole survey area was searched intensively, (i.e. a total count rather than a sample count), bias associated with not seeing marked animals was minimized.

Fewer goats were seen during the second survey of Zone 1 than during the first. Factors which may have contributed to the decrease in number of goats seen include avoidance or hiding from the helicopter due to exposure to the helicopter during the first survey, and weather conditions. If unmarked goats hid from the helicopter because they were exposed to it during the first survey, then marked goats would have likely avoided the helicopter even more. A smaller proportion of marked goats than unmarked goats observed during the second survey would have been expected. However, more marked goats were seen during the second survey. Because we attributed that increase to not seeing all marks during the first survey, we assumed that the maximum possible number of goats present in Zone 1 during the first survey was equivalent to the number of goats marked in that zone (13). No difference was detected between the ratio of marked goats (10/13) and the ratio of total goats (89/130) seen during the first and second surveys respectively (X^2=0.40, $p<0.05$), suggesting that the decrease in total goats seen was proportional to the decrease in marked goats seen, and likely did not affect the population estimate.

Weather conditions may have also affected goat distribution. The first survey of Zone 1 was conducted on a sunny day following several days of cloudy and rainy conditions. The second survey of Zone 1 was conducted on a sunny day following two sunny days. Fox (1977) observed that goats moved more immediately following rainy weather than during clear weather. For the Babine Mountains goat survey, goats may have been more visible while moving during the first survey of Zone 1 than during the second survey.

Assumption 4: No marks are lost between marking and recapture.

Because the paint used was oil-based, and because the interval between marking and recapture was short, it is reasonable to assume that all marks were retained. Also, losses due to mortality were unlikely (see Assumption 1).

Assumption 5: All marks encountered during the survey are recorded.

Due to the inexperience of some observers with the survey procedure, we believed that this assumption was violated during the first survey of Zone 1. Not all goats in large groups were observed from both sides so the area was resurveyed. All goats were observed from both sides in Zone 2 on, and during the resurvey of Zone 1. Marking goats on only one side would increase survey efficiency and reduce bias associated with not satisfying this assumption.

Overall, the marking and survey techniques used to estimate the Babine Mountains Recreation Area goat population were effective in satisfying the assumptions of mark-recapture estimates. The survey technique was weakest in satisfying equal catchability. However, because there did not appear to be any movement between the two zones in the Babine Mountains Recreation Area, equal catchability may be tested economically in future surveys by resurveying one of the zones 3 times.

Population Estimate

The Babine Mountains Recreation Area mountain goat population was estimated at 283 ± 64 (95% CL). During a survey in 1985, the population was estimated at 249 goats (van Drimmelen 1985); however, that estimate was not corrected for animals not seen during the survey. During the present survey, a total of 236 goats were counted on Day 1 and Day 2, without correcting for animals not seen. The 1985 estimate is comparable to the 1991 minimum population count and lies within the 95% confidence limits of the population estimate. The population appears to have remained stable between 1985 and 1991.

MANAGEMENT RECOMMENDATIONS

The marking and survey techniques used to estimate the mountain goat population in the Babine Mountains Recreation Area were cost effective and generally satisfied the assumptions associated with mark-recapture estimates. We feel this procedure could be used for determining reliable estimates of other mountain goat populations.

Survey efficiency and reliability could be increased by marking goats on only one side of the animal; testing for equal catchability by resurveying a portion of the survey area 3 times; or marking goats from different zones with different coloured paints to identify movements between zones.

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A STANDARDIZED TECHNIQUE FOR HELICOPTER SURVEYS OF BIGHORN SHEEP

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Abstract: Helicopter surveys are used commonly to provide population indices and to determine the distribution of bighorn sheep (*Ovis canadensis*) in Idaho. Surveys, however often differ in methodology, creating problems in comparisons and interpretation of data. We present a methodology that standardizes helicopter survey techniques and data collection procedures, and uses a sightability model to correct for visibility bias inherent in helicopter surveys for bighorns. Our technique provides estimates of total population and herd composition with known levels of precision. We present survey data for 4 populations of California bighorn sheep (*Ovis canadensis californiana*). The model calculated 90% CIs of ±18% for population number and parameter estimates.

Accurate and precise estimates of populations of ungulates have been elusive goals for wildlife biologists (Caughley 1974, 1977, LeResche and Rausch 1974, Pollack and Kendall 1987, Samuel et al. 1987) and specifically for mountain sheep (Bodie et al. 1990, McDonald et al. 1990, , Neal et al. 1994). Highly variable population trend and herd composition data collected during mountain sheep aerial surveys can create difficulty in assessing population performance (Bleich et al. 1990, Bodie et al. 1995, Neal et al. 1994).

In the past, Idaho Department of Fish and Game (IDFG) wildlife managers and biologists conducted independent aerial trend surveys with little coordination between individuals. Population trend survey methods and data collection techniques were based on the survey supervisor's past experience in conducting aerial surveys for other large ungulates, primarily mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*). The literature provided little assistance in designing bighorn trend surveys.

IDFG and U. S. Bureau of Land Management (BLM) biologists and managers were concerned that aerial trend surveys of California bighorn sheep were not providing sufficient information to intensively manage a sensitive and limited wildlife resource. Increased demand for bighorn harvest and livestock grazing opportunities, wilderness designation for portions of the California bighorn range, a proposed U. S. Air Force tactical electronic bombing range adjacent to a major California bighorn range, and a subsonic and supersonic Military Operating Area over most of the California bighorn habitat in Idaho created a need for more accurate population estimates.

The IDFG and BLM funded a research project, Federal Aid in Wildlife Restoration, Project W-160-R-19, to determine the variables affecting visibility bias during California bighorn sheep helicopter surveys (Bodie et al. 1995). Our objective was to use the results of these and other studies to develop a standardized method for bighorn surveys that would provide cost efficient, reliable estimates of population numbers and performance, and detect a change in population of ± 20%.

METHODS

We conducted a literature review of studies of population estimation techniques and evaluated these for relevancy to Idaho conditions and the needs of our California bighorn management program. A method was selected and implemented in 1992 for California bighorn populations in Idaho. The selected method was then used to estimate population numbers and herd composition parameters of 4 California bighorn populations in southwestern Idaho.

Standardized Survey Methods

Surveys were flown in June since average group sizes were large, most lambing was completed, and ewes and lambs had already formed nursery groups reducing the potential to disrupt lambing activities (Bodie et al. 1995). Rams used open flats and slopes at the upper edge of canyons where green-up was occurring and sightability was high. Ewes and lambs ran less, were in or near escape cover, and the lambs were out of the lying-in-seclusion phase and moving with the ewes. Sightability in the escape cover habitats was low and since ewes and lambs ran less, avoidance of the survey was minimized resulting in relatively precise estimates (Bodie et al. 1995).

Most bighorn habitats in Idaho are characterized by steep, rugged terrain, with limited human access. These factors preclude the use of ground or fixed-wing aircraft surveys. Helicopter survey was selected because it provides a time and cost- efficient survey tool, while allowing a more intensive observation of the survey area than possible during fixed-wing surveys (Bleich et al. 1990).

Sample Design

The survey area was divided into sampling subunits (6 to 12 km^2). Results from previous surveys provided information on how sheep responded to the helicopter. This information was used to design survey routes that moved sheep into habitats with higher visibility. Bighorns react to helicopter disturbance by moving large distances during and after helicopter surveys (Bleich et al. 1990, Bodie et al. 1995). Large movements during surveys and our inability to predict subunit densities violate two of the assumptions of random or stratified random sampling (Bodie et al. 1995) and suggest that these sampling designs are not suitable for bighorn surveys. Our procedure was, therefore, to survey all sampling subunits. The helicopter crew was instructed to include marginal areas with widely scattered groups of sheep since the population estimate was only valid for the area surveyed.

Survey Procedures

Flight paths were designed to consider the reaction of sheep to helicopter caused disturbance. In some cases bighorns could be "pushed" to the edge of bighorn habitat where observability was higher.

A Bell Jet Ranger III helicopter with two trained and experienced observers was flown at 35 to 45 km/hr at 30 to 60 m agl on 100 m vertically separated contours, systematically over the entire survey area. The doors nearest the observers were removed to increase visibility. A survey segment was started at drainage bottom and progressed up slope until a plateau or ridge top was reached. Survey segments were small, <1 km in length. Larger segments allowed these highly mobile animals to move greater distances creating difficulty in determining if a group had been counted. Survey segments used borders that were readily identified from the canyon bottoms and from the plateau. Plateaus were flown at 200 m intervals to a minimum of 1,000 m from the canyon rims. Survey flights were not conducted when wind speed exceeded 25 km/hr or rain decreased visibility.

Data were recorded on a standard survey form using the instructions given in Appendix A and the locations mapped. The latitude and longitude were recorded from a ship-board Global Positioning Service (GPS) receiver.

The bighorn classification system described by Geist (1971) was modified to reflect differences in horn growth patterns of local bighorn populations, difficulties in identification of sheep by the helicopter crew, harvest regulations for rams, and because the June surveys occur during the middle of the yearly growth period. Sheep were classified as ewes, lambs, legal, and sub-legal rams.

Sightability Model

Two techniques have been described to correct for visibility bias encountered during helicopter surveys of bighorn sheep, mark-recapture (Neal et al. 1994) and sightability correction (Bodie et al. 1995). We selected the sightability correction method to avoid the expense of marking animals and the expense and disturbance associated with multiple helicopter surveys. The computer program AERIAL SURVEY (Unsworth et al. 1991) modified for bighorn sightability (Bodie et al. 1995) was used to estimate population parameters (Steinhorst and Samuel 1989) for all survey areas.

RESULTS AND DISCUSSION

Population surveys were conducted during June 1992 and June 1993 for 4 California bighorn populations in southwestern Idaho (Table 1.). The sightability model reduced the ram:ewe ratio and increased the lamb:ewe ratio estimate for all surveys, because rams, and ewes without lambs, tended to use habitats of higher visibility than ewes with lambs (Bodie et al. 1995). During 1993, lamb survival was about 50% of that observed in 1992. The higher percentage of ewes without lambs observed in 1993 resulted in lower observed ram:ewe ratios for the Little Jacks Creek and Owyhee River populations, since ewes without lambs are more likely to be in habitats with high visibility. Severe conditions during the 1992-93 winter (snow depths >140% of normal) were probably responsible for the decreased lamb survival observed in 1993. The number of sheep observed during 1993 increased by 29% for the Little Jacks population and by 6% for the Owyhee population over 1992 data. The model estimated that the Little Jacks Creek population was not different

Table 1. A comparison of observed and estimated bighorn sheep population parameters from helicopter sightability surveys of 4 populations in southwestern Idaho, 90% CI in parenthesis, 1992-93.

		Observed [a]			Estimated [a]			
Survey location	Year	Rams per 100 ewes	Lambs per 100 ewes	Total	Rams per 100 ewes	Lambs per 100 ewes	Total	
Little Jacks Creek	1992	87.9A	52.0A	194	69.4A	55.8A	308A	(±51)
	1993	62.1B	22.9B	251	57.1A	23.6B	341A	(±63)
Owyhee River	1992	50.9A	44.1A	628	45.4A	46.7A	1041A	(±205)
	1993	44.8A	19.9B	669	40.5A	21.5B	858B	(±141)
Bruneau/Jarbidge	1993	107.8	15.7	114	91.9	16.7	165	(±37)
Big Jacks Creek	1993	54.3	41.3	90	53.1	41.9	114	(±33)

[a] Estimates for populations within columns followed by different letters are different (Bonferroni method; z < 0.033). Ratios by populations within columns followed by different letters are different (Tukey type test for multiple proportions; G < 0.05, Zar 1984).

between years (z > 0.033) but the Owyhee population was (z < 0.033), (Table. 1).

A typical evaluation of the differences between 1992 and 1993 survey data (not corrected for visibility bias) could include the following. The severe winter probably caused some additional mortality for rams in the Little Jacks Creek population and possibly, to a lesser extent, in the Owyhee population. Lamb survival decreased in both units. Total ram numbers and total animals observed increased between 1992 and 1993. These data give conflicting information to the manager trying to set harvest levels. However, the sightability model estimates for the same comparisons indicate that ram:ewe ratios and estimates of ram numbers were not different between years for both populations, and lamb:ewe ratios decreased between years. The Little Jacks Creek population was not different while the Owyhee population decreased between 1992 and 1993.

MANAGEMENT AND RESEARCH IMPLICATIONS

Standardized survey methods that correct for visibility bias provide the IDFG with estimates of California bighorn numbers and population parameters with known levels of precision. The lack of sightability estimates for bighorns in timbered habitats precludes the use of the model to correct Rocky Mountain bighorn (*O. c. canadensis*) survey data for visibility bias. A better understanding of bighorn response to helicopter disturbance, factors affecting sightability, and importance of standardizing survey techniques can improve data gathered from trend surveys of Rocky Mountain bighorn populations.

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STATUS AND HISTORY OF MOUNTAIN GOATS IN OREGON

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Abstract: The status and history of mountain goats (*Oreamnos americanus*) in Oregon is reviewed. Recent archeological evidence suggests goats occupied Hells Canyon prior to the influence of European settlement. Mountain goats were released in the Wallowa Mountains of northeast Oregon in 1950. The population status, influence of hunting, lack of genetic diversity, and isolation of the Wallowa Mountain goat herd is discussed. Transplants to the Elkhorn Mountains of northeast Oregon and the Columbia River Gorge are reported.

Indigenous mountain goat distribution has been described as rugged mountainous areas of western North America from southeastern Alaska to southcentral Washington, and from western Alberta as far south as central Idaho (Johnson 1977, Guenzel 1980, Wigal and Coggins 1982). Physical evidence has been lacking to establish the historical occurrence of goats in Oregon.

Mountain goats were not present in Oregon at the turn of the twentieth century (Bailey 1936); hence, goats have traditionally been considered an exotic species. In 1950, six goats were released in the Wallowa Mountains, and since that date subsequent transplants have occurred in the Wallowas, Elkhorn Mountains, and Columbia Gorge. This paper provides information on the historical occurrence of Rocky Mountain goats and a review of the current status of goat populations in Oregon.

HISTORIC EVIDENCE

Early literature reports mountain goat as an indigenous species in Oregon. Lewis and Clark describe the skins of mountain goat possessed by Indians along the Columbia River, and describe goats occurring "on the chain of mountains forming the commencement of the woody country on the coast, and passing the Columbia between the falls and the rapids" (Hosmer 1924: 180). Grant (1905) reported the mountain goat ranging as far south as Mount Jefferson, Oregon, based on the records he was able to obtain. However, Grant does not provide sources for his records. Bailey (1936) cites Richardson (1829), Townsend (1839), Suckley and Gibbs (1860), Grinnell and Fannin (1890), Hornaday (1906), and Miller (1924) reporting mountain goat as a species native to Oregon, but disagrees with these reports. Bailey questioned whether goats were ever native to Oregon since there were no authentic records of their occurrence in recent years. He admits that it is not improbable that in earlier times, goats may have occupied Mount Hood and perhaps other peaks in the Oregon cascades, as well as the Wallowa Mountains in northeast Oregon, and the Seven Devils in Idaho. However, he suggests further evidence should be sought. Hall and Kelson (1959) describe goat distribution in North America, and include the north portion of the cascade range in Oregon.

Diary entries by Henry H. Spalding describe a meeting with the Nez Perce Indians near Wallowa Lake, Oregon, in July 1839; "Joseph proposes a sport with goats" and "goes to a lick the goats frequent, to start them out," but does not find any (Drury 1958: 271). Horner (unpublished manuscript, Origin of Wallowa County Place Names, p.120, Wallowa Library) describes a basin east of Joseph, Oregon, "named for a bunch of wild mountain goats that ranged there in the winter of the 1890s. Fred Herson killed the guard goat--they always have a guard on lookout. Their hair is different from that of the mountain sheep, also their horns grow up and back, different from the sheep." Both of these accounts have been questioned, since neither provides sufficient information differentiating between goats, bighorn sheep, or pronghorn.

These reports of mountain goats occurring in Oregon are based primarily on anecdotal accounts and have left managers with concerns as to their authenticity. However, archaeological evidence from the Bernard Creek Rock Shelter, along the Idaho side of Hells Canyon, indicates the presence of mountain goat remains in two excavation levels at that site (Randolph and Dahlstrom 1977). The goat remains (bones) were estimated to be 300 - 1000 years old (Reagan and Womack 1981). Since the goat remains were fragmented, it suggests their use as food rather than raw material for tools or religious objects (Reagan and Womack 1981). Based on this evidence, along with the current knowledge of prehistoric hunting and gathering activities, Reagan and Womack concluded goats were present in Hells canyon 300-1000 years ago. In a later archaeological investigation on Camp Creek, Oregon side of Hells Canyon, goat remains were identified and radiocarbon dated from 500-1500 years before present (Leonhardy and Thompson 1991). Corless (1990) reported Weiser Indians hunting mountain goats in the Seven Devils Mountains, which coincides with these findings.

It has been argued that goats may have occurred in the Seven Devils Mountains on the Idaho side of Hells Canyon, but that the Snake River was a barrier to the goats; therefore, they were never indigenous on the Oregon side of Hells Canyon. This same argument has been proposed along the Columbia River separating the Washington and Oregon Cascades. We refute this argument. The Snake River would commonly freeze-over during severe winters, prior to dams, and would have allowed goats easy access to either side of the Canyon. In addition, goats occur on adjacent canyon walls of large river corridors such as the Fraser in British Columbia (Macgregor 1977), and have been documented swimming across Kenai Lake, Alaska (Smith and Nichols, 1984). This suggests that river corridors such as the Snake and probably the Columbia would not have been barriers to emigrating goats.

We conclude that early anecdotal reports and references, coupled with recent archaeological findings, demonstrate that mountain goats were indigenous to the northeast corner of Oregon and most likely portions of the Oregon Cascades. Goats probably disappeared from Oregon during or prior to European settlement in the early 1800s. The northeast corner of Oregon was isolated from European settlement by rugged terrain until the 1870s; however, European influence arrived much earlier, with Nez Perce Indians acquiring horses in the early 1700s. Improved mobility and firearms greatly changed local Indian culture which influenced tribal hunting impacts on native wildlife.

STATUS OF TRANSPLANTS

Wallowa Mountains

The Wallowa Mountains encompass an area of approximately 575 km^2 and are situated in the very northeast corner of Oregon. The area is characterized by U-shaped glaciated valleys, alpine basins, rugged precipitous terrain, and sharp ridgetops. Elevation ranges from 1400-3000m. Dense timber stands occur below 2287m with Douglas fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), and western larch (*Larix occidentalis*) the most abundant tree species. Scattered timber stands occur above 2287m with subalpine fir (*Abies lasiocarpa*) and white-bark pine (*Pinus albicaulis*) predominating. Forbs and grasses are the most abundant plant forms on high elevation ridge tops.

The Wallowa Mountain goat herd has originated from 4 separate releases (Table 1). One adult female died the day following the 1950 release. Of the 33 goats released in the 1980s, a

Table 1. Mountain goat transplants to the Wallowa Mountains of Oregon.

Release location	Year	Number released	Male	Female	Origin of stock
Joseph Mt.	1950	5	3	2	Chopaka Mt., WA
Hurricane	1985	8	2	6	Olympic N.P., WA
Hurricane	1986	8	3	5	Misty Fiord, AK
Hurricane	1989	17	8	9	Olympic N.P., WA
Total		38	16	22	

minimum of 6 individuals, 1 male and 5 females, are known to have died within 1 year following the releases.

Survey Techniques

From 1962 through 1982, goats were counted and classified annually from fixed-wing aircraft during mid to late summer. Ground surveys occasionally were incorporated with aerial surveys from 1983-1993. Ground surveys were conducted in areas of high goat use and helped provide a more thorough count in the area surveyed; however, ground surveys are more time consuming and have not been conducted with equal effort from year to year. Tracking of radio-collared individuals, from 1980s transplants, helped to locate animals during surveys and provide information on movements.

Population Status

The Wallowa Mountain goat population grew from the original transplant of five animals to a minimum population of 29 animals by 1966 (Table 2). The population declined in the late 1960s and remained static through the 1980s, with aerial counts ranging from a low of 10 to a high of 32 animals. The estimated population never exceeded 45 animals during those years. Surveys from 1990-1993 indicated an increase with counts ranging from 25 to 37 goats. The current population estimate is 55 animals.

Kid production was highest in 1966 with an adjusted kid ratio of 61 kids per 100 adults (yearlings included with adults) (Table 2). Production decreased thereafter and remained static at low levels through the 1980s. From 1990-1993 kid production improved and remained stable with a mean kid ratio of 33 per 100 adults.

Table 2. Late summer mountain goat classification survey data for the Wallowa Mountains of Oregon.

Year	Total count	Adults[a]	Kids	Adjusted kids/100 adults
1962	12	8	4	50
1963	--	--	--	--
1964	26	18	8	44
1965	--	--	--	--
1966	29	18	11	61
1967	21	17	4	24
1968	11	9	2	22
1969	10	8	2	25
1970	17	12	5	42
1971	22	17	5	29
1972	18	17	1	6
1973	18	16	2	13
1974	15	13	2	15
1975	20	17	3	18
1976	19	17	2	12
1977	16	11	5	45
1978	22	18	4	22
1979	24	20	4	20
1980	31	23	8	33
1981	19	14	5	36
1982	15	13	2	15
1983	12	11	1	9
1984	10	8	2	25
1985	14	12	2	17
1986	--	--	--	--
1987	26	20	6	14
1988	8	8	0	0
1989	9	8	1	13
1990	31	23	8	35
1991	28	21	7	33
1992	25	19	6	32
1993	37	28	9	32

[a] Includes subadults.

DISCUSSION

Hunting of mountain goats was initiated in 1965 and continued annually through 1968. A total of 23 tags were issued and 20 animals, including 13 males and 7 females, were harvested (Table 3). During the corresponding time period, the number of goats observed on aerial surveys decreased to a low of 10 animals. We believe that hunter harvest, particularly of adult females, was a major factor in the initial decline of this population. Similar relationships between hunter harvest and goat population declines have been reported

Table 3. Hunter harvest of mountain goats in the Wallowa Mountains, Oregon, 1965-68.

Year	Tags issued	Males	Females	Total
1965	5	4	1	5
1966	5	3	2	5
1967	5	3	2	5
1968	8	3	2	5
Total	23	13	7	20

(Macgregor 1977, Kuck 1977, Foster 1977, Bone 1978).

Although legal goat hunting has not been allowed since 1968, the population did not increase significantly until recently. There are various factors that may account for the lack of increase. Predation, avalanches, and accidents are mortality factors which have been observed in this population. However, we do not believe them to be major factors limiting population growth.

Low kid production or survival in the Wallowa Mountains may be directly related to a lack of suitable winter range resulting in a winter nutritional deficiency (Vaughan 1975). We believe inbreeding may have been a major factor suppressing production. The effects of inbreeding in small populations have been discussed by Farnsworth (1978), Pettus (1982), and Nash (1982). In 15 of 16 species of captive wild ungulates, inbred young were significantly less likely to survive than non inbred young (Ralls et al. 1979). Because the Wallowa goat population originated from a transplant of five individuals, of which only two were females, and outbreeding has not been possible due to the isolation of these animals from any neighboring goat herds, we believe that a lack of genetic diversity through inbreeding may have been a major factor suppressing kid survival. In 1985, 1986, and 1989 supplemental goat releases provided genetic diversity to the Wallowa Mountains population. Individuals from the supplemental transplants have been observed utilizing the established goat ranges, as well as ranges previously unoccupied by goats. We believe the improvement in kid production and survival during the past four years was directly related to the supplemental releases. Survey information suggests that these releases provided the genetic diversity, along with the pioneering of new habitats, necessary to improve population production.

ELKHORN MOUNTAINS

The Elkhorn Mountains, approximately 126 km^2, lie just west of Baker City, Oregon. Elevations range from 1400-2770m. The area is characterized by glaciated valleys and rugged alpine basins similar to the Wallowa Mountains.

From 1983-1986 a total of 21 goats were released in the Elkhorn Mountains (Table 4). Tracking of radio collared individuals provided information on movements and establishment of herd ranges post release. In 1992, aerial surveys were initiated with fixed-wing aircraft to count and classify goats during late summer.

Total number of goats observed was lower in 1993 than in 1992 (Table 5); however, this was thought to be a result of observation error and not an actual decrease in population size. Kid production has been good (Table 5), and the Elkhorn Mountains goat population is believed to be growing.

COLUMBIA RIVER GORGE

Mountain goat habitat in the Columbia Gorge encompasses the northern extension of the Cascade Mountains in Oregon and lies within the Columbia Wilderness, Bull Run Watershed, and the Mount Hood Wilderness. Elevations range from 670- 3000m. Lower elevation ranges are characterized by north facing vertical rock outcrops surrounded by stands of Douglas fir and mountain hemlock (Tsuga mertensiana). Upper elevations consist of primarily alpine basins near the foothills of Mount Hood.

Since 1969, 15 goats have been released in the Columbia Gorge (Table 6). Annual surveys specific to this goat herd have never been established. Miscellaneous observations of goats occurred from 1973-1990 and ranged from 1 to 4 individuals observed. Observations of 2-4 goats were reported occasionally from 1980-1985. However, since that time, observations have declined, with no goats reported since 1990.

Small transplant size, scattering of individual goats, and paucity of male goats have been major concerns and possible explanations for the failure to establish goats in the Columbia Gorge.

Table 4. Mountain goat transplants to the Elkhorn Mountains of Oregon.

Release location	Year	Number released	Male	Female	Origin of stock
Pine Cr.	1983	6	3	3	NF Clearwater, ID
Pine Cr.	1985	8	4	4	Olympic N.P., WA
Pine Cr.	1986	7	2	5	Misty Fiord, AK
Total		21	9	12	

Table 5. Late summer mountain goat classification survey data for the Elkhorn Mountains of Oregon.

Year	Total count	Adults*	Kids	Kids/100 adults
1992	29	19	10	53
1993	23	14	9	64

* Includes subadults.

Table 6. Mountain goat transplants to Tanner Butte in the Columbia River Gorge of Oregon.

Year	Number released	Male	Female	Origin of stock
1969-71	8	2	6	Olympic N.P., WA
1975	6	2	4	Olympic N.P., WA
1976	1	1	-	Olympic N.P., WA
Total	15	5	10	

SUMMARY

Archaeological findings presented in this manuscript demonstrate that mountain goats were indigenous to Hells Canyon prior to European settlement. Faunal remains now place goats within 48 km^2 of the existing Wallowa Mountains goat herd. We believe that goats also occurred in the Wallowa Mountains and probably other ranges in northeast Oregon, since rugged canyon corridors link the Wallowas to Hells Canyon. Wildlife managers typically have described the distribution of goats based on occurrence at the time of European exploration or settlement. Efforts to document the historical range of goats should continue through the identification of faunal remains recovered in archaeological excavations of human encampments and wood rat middens. We encourage wildlife managers to utilize archaeological information in conjunction with other sources of physical evidence to more accurately describe historical distribution of native wildlife. Restoration of mountain goats to native ranges should be continued, especially where priorities are to manage for ecological diversity.

The Wallowa Mountains goat population declined during the 1960s as a result of heavy hunter harvest. Legal hunter harvest was not allowed thereafter; however, the population level remained static with low kid production through the 1980s. We believe the lack of genetic diversity was a major factor affecting kid production and growth of this population. Recent supplemental goat transplants appear to have improved annual kid production, and the Wallowa Mountains goat herd currently is increasing.

The Elkhorn Mountains goat herd appears to be established. This goat herd continued to increase since the initial transplant in 1983 and has demonstrated good kid production in recent years.

Attempts to establish goats in the Columbia Gorge have not been successful. Currently there are no goats known to be alive in this area. Failure to establish goats in the Gorge may be due to small transplant size, lack of male goats, and scattering of transplanted individuals.

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REVIEW OF THE HISTORICAL LITERATURE REGARDING THE DISTRIBUTION OF THE ROCKY MOUNTAIN GOAT (*Oreamnos americanus*)

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Abstract: The presently accepted southernmost range of non-introduced Rocky Mountain goats is the Sawtooth Range of Idaho (43° N, near 114° W). A significant number of credible historical accounts written during the 1800s places the Rocky Mountain goat south of 40° N Latitude in the Colorado Rocky Mountains. The outline of faunal investigations of the U.S. Department of Interior provided the method used to conduct the literature review. Criteria used to screen fictitious and unhelpful materials from credible sources is discussed. This paper reviews historical documents and explains how important information regarding the Rocky Mountain goat has been lost. Brief side notes on Western American history provide a useful background.

A lack of careful and scientific study of the Rocky Mountain goat prior to 1900 opens a question regarding its original range. Much of the confusion surrounding the issue of distribution may be attributed to terminology errors used when referring to mountain goats, bighorn sheep (*Ovis canadensis*), and pronghorns (*Antilocapra americana*). Lewis and Clark, and members of their expedition party, called the Rocky Mountain goat a "mountain sheep" and used the same term when referring to bighorn sheep (DeVoto 1953). They originally called pronghorns 'goats' or 'buck goats' prior to discovering the bighorn and the mountain goat.

The terminology error became a reproduction error in many Natural History books. In Stewart (1833), *Oreamnos americanus* is called a mountain sheep. While the accompanying illustration depicts a mountain goat, the text is almost exactly the same as the text printed on the next page for *Ovis canadensis*. Meanwhile, the name for *Ovis canadensis* is given as American argali (and is accompanied by an illustration of a bighorn sheep). The book does not describe the distribution of these animals. Such errors contributed to public and scientific confusion regarding the distinction between these two species.

Mountain men apparently saw "white goats" in what are now called the Colorado Rocky Mountains in the 1820s and 1830s. Many of them probably travelled above the tree line on occasion and may have seen mountain goats, but their general lack of literacy and familiarity with descriptive zoological methods prevented them from conveying this information in a form useful to modern research.

Reports of Rocky Mountain goats show up in the literature printed prior to and during the era of the Colorado gold rush which began in 1858. Mining camps were hastily erected in the mountains before roads were built. The few toll roads that had been built in the 1860s were so expensive and poor that the price of food was extremely high and there were frequent shortages. Many of the prospectors turned to market hunting, killing as much game as fast as they could to earn a fortune from hungry miners (Ubbelonde et al. 1988). Like the prairie (*Bison bison bison*) and mountain bison (*Bison bison athabascae*), all traces of Rocky Mountain goats in Colorado could well have been eliminated by market hunting.

Angora goats (*Capra* spp.) had been imported to Colorado as of 1872 (Baille-Grohman 1900). These animals were covered with long white hair and had horns extending horizontally from the head in a T-shaped pattern. Some modern scholars insist that these domestic goats are the cause of all "white goat" sightings in nineteenth century Colorado. However, Angora goats and Rocky Mountain goats are distinguishable not only by their appearance, but by their behavioral characteristics. This literature review cites only documents that clearly-illustrate, and/or describe the features, natural history, or behaviors of *O. americanus*.

The habitat of the Rocky Mountain goat is an environment that makes the chance finding of century old specimens highly unlikely. The alpine zone is blanketed with snow in winter and repeatedly blasted with dry winds year round. A carcass left exposed to the elements quickly disintegrates leaving no trace of the animal that died. The geographic features of the land are constantly in motion, grinding up any subsurface remains with ground movement resulting from freeze and thaw cycles. Glaciers grind up any trapped animal and plant remains into tiny bits of debris. Only carcasses left in immobile pockets of glacier ice or caves might remain intact and none of these have been found to date in Colorado. However, Pleistocene fossil evidence of Rocky Mountain goats has been located within a few miles of the Colorado state line in Wyoming.

The objectives of our project are: to question the historical distribution of the Rocky Mountain goat and to report all available documentation listing *O. americanus* occurring in Colorado.

We thank Martin T. Wirth, Terry Fridh, Arch Andrews, and the International Order of Rocky Mountain Goats for their help during this study. Funding for this project was generated by the International Order of Rocky Mountain Goats and supported by the Colorado Division of Wildlife requisition number PBA-3-0450, Denver, Colorado.

METHOD OF SCREENING LITERATURE

This research recognizes the misidentification errors and cites credible historical sightings contingent upon the original author's demonstrated ability to distinguish between the bighorn sheep, pronghorn, and the mountain goat. These distinctions were made based on the narration of the behavior and habits of the animal and by the physical description of live or killed specimens. Many fanciful and fictitious accounts were discovered during the course of the review. Such accounts were excluded because of incorrect descriptions of geography, habitat, fauna, history, or climate. No part of any account which could reasonably be judged fictitious was used in the review, even if by coincidence some part of it would agree with known truths. The precedent for this survey can be found in the outline of faunal investigations of the U.S. Department of Interior (Wright et al. 1932).

CHRONOLOGY OF FINDINGS

Fossil Remains

If Rocky Mountain goats lived in Colorado during the 1800s, they may have resulted from relict populations from the last ice age. Fossil evidence has been located in the Bell and Horned Owl Caves located in Albany County, 32 km NE of Laramie, Wyoming (41°34'N, 105°31'W) [the Colorado-Wyoming state line is at 41°00' N] and in Little Box Elder Cave in Converse County, 30 km west of Douglas (42°40'N, 105°52'W)(Guilday et al. 1967, Anderson 1974). These specimens date to the late Wisconsinian period 30,000 years ago. The remains of *O. americanus* have been found along with other animals of alpine affinity (Kurtén & Anderson 1980).

Early Explorations

The expeditions of Pike in 1806-7 and Long in 1820 failed to document any sightings of Rocky Mountain goats in Colorado (Coues 1895, James 1966). Long did not travel as extensively as Pike and confined his explorations to the Front Range between present day Denver and Colorado Springs.

Mountain men of the 1820s and 1830s later claimed to have seen animals fitting the description of the Rocky mountain goat; however, these accounts were later discredited in the literature by aristocratic sporthunters who were disappointed in their quests to kill the animal in Colorado. Burrington visited local Native Americans in the Cañon City area between 1838-1842 and noticed that they possessed samples of "a shiny long black horn" (Messiter 1878). After negotiating, he got them to agree to take him on a hunt for the animal which provided the horns. Burrington hunted bighorns, prong-horns, and bison and knew that the horns did not come from these species (Messiter 1878).

A report, compiled from the notes of Johnson and Abert of the U.S. Army Hunting Party in the Southern Tetons (Cooke 1847-1848) describes the killing of a mountain goat in Wyoming. The location of the kill was south of our presently accepted historical distribution.

The first mountain goat specimens given to the Museum of the Royal College of Surgeons of England was inventoried as the head and skin of a female and her kid that had been "shot south of the 40th parallel" in 1849 (Garson 1871).

U.S. Army Hunting parties continued to explore the Colorado Rocky Mountain region in the 1850s. Their purpose was to survey game availability as food along proposed railroad routes and for provisioning troops on future expeditions. A party scouting the region around the Gunnison River in

1853 killed several mountain goats (Old Army Section document #21311).

The Topographical Corps (1857), a 13 volume quarto set, contains the correspondence and field journals of various railroad exploring parties of 1853-55. Volumes 7, 9, & 10 are devoted exclusively to scientific reports on botany and zoology. These volumes are considered to be among the most important American scientific productions of the nineteenth century. Volume 5 reports: "42 white goats killed for meat." This occured north of Meade and Wasatch canyon of southern Idaho.

Market Hunting During the Gold Rush Starting in 1858

The Colorado Rocky Mountain ecosystem could sustain a permanent native population estimated at around 4,000 to 10,000 Native Americans (Ubbelohde et al. 1988). The Gold Rush brought over twice that many newcomers each year after 1858. As of 1859, as many as 50,000 gold miners had arrived in and along the front range and as many as 25,000 may have stayed on after the first grueling weeks and months of prospecting (Ubbelohde et al. 1988). This influx continued through the 1860s despite the Civil War starting in 1861. In the beginning, roads were non-existent, leading to chronic food shortages and prices that were ten times higher than in Denver. Many of the prospectors abandoned their claims to hunt and provide meat for the mining camps and towns, an occupation that often proved more lucrative than digging for gold.

After panning out gold laden streams, mining operations turned to more ecologically destructive methods such as placer mining which polluted numerous streams with mercury, and smelting which denuded entire mountain valleys of trees. These environmental changes would have helped deplete game animals in the lower valleys and driven market hunters to higher elevations.

Sportsman's Literature in the Gold and Silver Years

The earliest published sporthunting book to claim that Rocky Mountain goats reside in Colorado is the Encyclopaedia of Sport (Pike 1872). In Cartwright (1875, Chapter 5: The Rocky Mountain Goat), the distributional range of the Rocky mountain goat is given as 40 to 60 degrees north latitude. This agrees with Hallock (1879), who wrote "the White Goat is confined to the loftiest peaks of the Rocky Mountains; it is not known south of Colorado, and is probably rare south of Washington Territory, but is found to the northward as far as Alaska."

Theodore Roosevelt (1888) wrote that Rocky Mountain goats were found "on the highest most inaccessible mountain peaks down even to Arizona and New Mexico; but being fitted for cold climates, they are extremely scarce everywhere south of Montana and northern Idaho and the great majority even of the most experienced hunters have hardly so much as heard of their existence." Cooper (1980), is less specific regarding the range of the mountain goat stating that "the Rocky Mountain Goat has been reported as far south as 36 degrees north latitude". Grinnell (1897) likewise asserted that the mountain goat could be found "on a peak or two in Colorado".

The United States Cartridge Company of Lowell, Massachusetts sent out letters to governors of the various states and territories requesting information on game availability in their region. According to this information published in their book (1898), the governors "referred the matter to the game commissioners." Cited in the chapter for Colorado, are references from Gordan Land, the Colorado State Fish Commissioner. In regard to mountain goats, the book states: "there are some Rocky Mountain goats in the state, but they are not abundant."

Huntington (1904), is not as assertive in his claim of mountain goats living in Colorado. He approaches the subject of mountain goat distribution by stating that: "other writers" claim the mountian goat can be found in Colorado.

By contrast, 68 years later, Armstrong (1972) cited from Coues and Yarrow (1875): "in an account of the mountain goat, reported 'one individual seen in Colorado by Lt. Marshall's party.' Trippe (1874) noted the mountain goat (as *Aplocerus montanus*) among the mammals of Clear Creek and Gilpin counties." Armstrong goes on to assert that "there is no evidence to indicate that the mountain goat has occurred in Colorado in recent times prior to its introduction by man. Perhaps early reports represent sightings of bighorn ewes."

The Session Laws of 1887 and 1889

Recognizing a steady reduction in the availability of game, the Colorado state legislature passed two sets of session laws that established hunting seasons and banned the killing of bison for 10 years, bighorn sheep for 8 years, and Rocky mountain goats for 10 years (General Assembly Sesson Laws 1887 and 1889). The 1889 law made it easier to prosecute poachers in the district in which they were caught, and added possession and transportation of protected animals' remains to the list of offenses.

William T. Hornaday

Hornaday (1914), remembered purchasing 150 mountain goat hides in Denver, Colorado for fifty cents each around 1887. He was pleased to note that the seller probably lost money in the transaction. It is not clear where Hornaday believes the southern-most distribution of Rocky Mountain goat lays. His map "Distribution Of The White Mountain Goat" subtitle: "the black dots represent actual occurrences", shows several dots locating goat populations along the Rocky and Canadian Pacific coast mountain chains. A single population dot has been placed in the Teton Mountains near Jackson Hole, Wyoming. The map ends at the southern boundary of Wyoming.

Edwin Carter and the Denver Museum of Natural History

In 1868, Edwin Carter and William Wilkinson set up a museum of Colorado fauna in Breckenridge. Carter bought out Wilkinson's share of the museum in 1896. The collection consisted of a large number of wild animals: "100 elk heads [*Cervus elaphus*] and 1 elk, 8 bison (of which 2 were the mountain subspecies), 55 deer heads [*Odocoileus* spp.], 161 ptarmigans [*Lagopus leucurus*], 3 wolverines [*Gulo gulo*], 4 grizzly bears [*Ursus arctos*], etc." (Fiester 1973). Prior to this project, it was believed that Edwin Carter had no mountain goats in his collection. Recently obtained information now challenges this belief. In the past few years the Summit County Historical Society has been restoring the Edwin Carter Museum and one of their projects was the restoration of a collection of glass plates photographed in the late 1800s. From this collection, a photograph was discovered showing a full body mount of a Rocky Mountain goat standing in the north room of the Museum. Another photograph contains the unfocused image of a Rocky Mountain goat head mounted to the wall behind Edwin Carter displaying a wolf (*Canis lupus*) in the foreground. While the wolf photograph merely suggests the presence of a mountain goat specimen in the background, the other photo confirms that at least one entire Rocky mountain goat was displayed in Edwin Carter's museum of "Colorado fauna".

Other references to Rocky Mountain goats include the Probate Record (Summit County Court House- No. 18) where several goat skulls and horns were listed and appraised. The values given to the items in the appraisal were greater than that given to the complete remains of bighorn sheep suggesting that the goat items were relatively rare and certainly not of domestic goats.

After Carter's death in February 1900, his collection was acquired for the museum in Denver, taken from Breckenridge, and stored in the state capitol. Many of the specimens were never displayed in the Colorado Museum of Natural History because they had deteriorated. This is because of Carter's primitive methods of taxidermy and the stuffing of larger mammals with straw. Meanwhile, the first employees of the Colorado Museum of Natural History, a father and son team of taxidermists named Rudolf and Victor Borcherdt, quickly sought replacements for the mountain goat specimens. This is described in an article in the Denver Times (October 14, 1900) where several members of the Colorado Museum and Library Association put together a hunting expedition to search Idaho for mountain goats to complete the collection. The article states that: "in Colorado, they [mountain goats] had become quite extinct."

The mountain goats were displayed in the collection of mammals indigenous to Colorado until 1908. After that, a variety of exhibits were intermixed with the Colorado fauna collection and it was not until 1920 and after several turnovers in staff that the museum put together another exhibit hall dedicated solely to Colorado fauna (Colorado Museum of Natural History Annual Report to the Trustees 1912-1920). Meanwhile, the 1913-1914 Biological Surveys failed to find any Rocky Mountain goats in Colorado (Colorado Museum of Natural History Annual Report to the Trustees 1914). The museum staff had records indicating that the mountain goats in their collection were acquired in Idaho. As such they judged the mountain goats to be "obviously doubtful forms" and had them moved to the Standley Wing which was set up to display animals that were not indigenous to Colorado. Thus, the Rocky Mountain goat was informally and unknowingly declassified as a species indigenous to Colorado. None would be seen in the Colorado Rocky Mountains until their successful reintroduction in 1948 (Irby and Chappell.

DISCUSSION

This paper identifies numerous historical sources placing the Rocky Mountain goat in Colorado previous to and during the Gold Rush years. The destructive environmental changes of the late nineteenth century led to habitat loss and overhunting of many game species. The mountain bison is known to have suffered extinction in Colorado during this period. It is highly probable that the Rocky Mountain goat became extinct in Colorado as well. This paper is an attempt to make a comprehensive survey of historical documentation that focuses on the distribution of the mountain goat with emphasis on its presence in Colorado.

Although archeological evidence is felt to be a more decisive way of ascertaining the mountain goat's existence in Colorado prior to 1900, historical documentation cannot be ignored as a valid source of information in determining animal distributions. The historical materials reviewed here suggest that the Rocky Mountain goat may have lived south of the 40°N Latitude in the Colorado Rocky Mountains.

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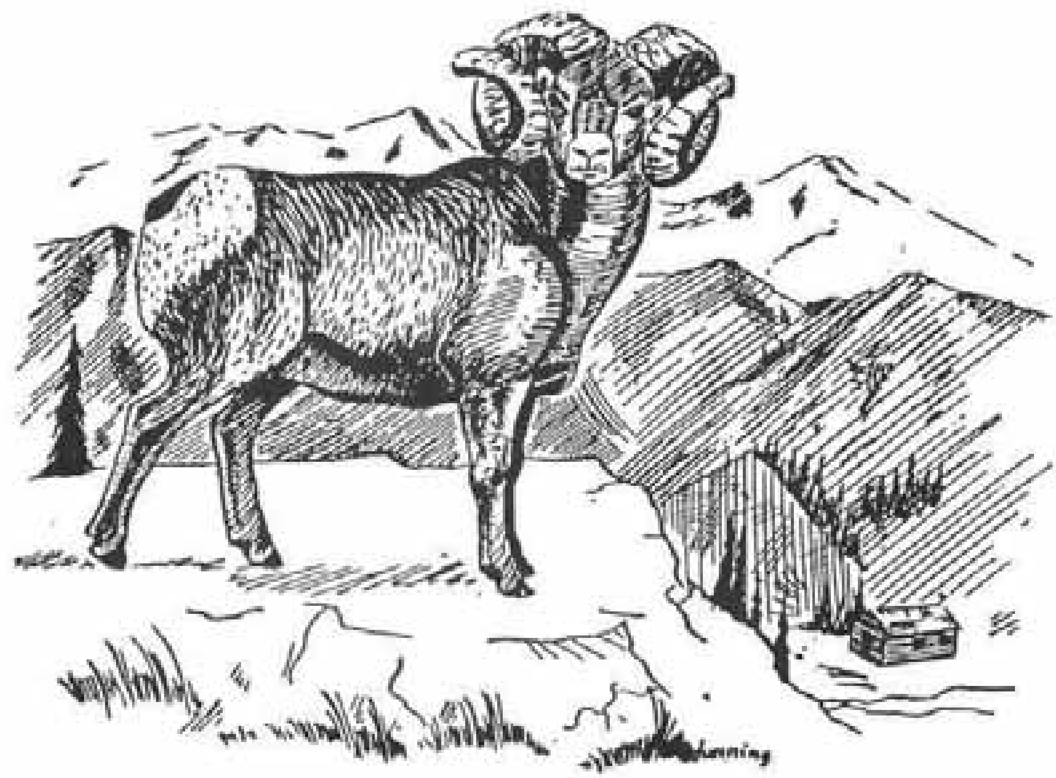

Bienn. Symp. North. Wild Sheep
and Goat Counc. 9:81-91.

EFFECTS OF HORN SIZE AND HUNTER SUCCESS ON SATISFACTION WITH BROOKS RANGE SHEEP HUNTS

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Abstract: For many years, the Alaska Department of Fish and Game's goal for sheep (*Ovis dalli*) hunting in the Brooks Range was to provide for taking rams under aesthetically pleasing conditions, including opportunities to be selective about which rams to take. Seven-eighths-curl remained the minimum legal horn size after most of the rest of Alaska had gone to full-curl management. To determine whether hunters were satisfied with their Brooks Range experience, we sent questionnaires to 750 people who hunted from 1990 to 1992; 444 (62%) were filled out and returned. Fifty-four percent of the respondents were successful in taking a legal ram, and only 14% did not see a legal ram. Fifty-eight percent of all hunters saw legal rams they did not stalk, and 34% stalked rams they did not shoot. Hunters were evenly divided in their response to statements that any legal ram is a trophy or that only large, old rams >full-curl are true trophies; however, they generally agreed that full-curl rams are trophies. When asked to define "trophy" in their own words, 61% described rams that would be full-curl or larger while 25% specified any legal ram. Twenty-four percent added that the quality of the hunt should determine the value of the horns as a trophy. Successful hunters were more satisfied with their overall hunting experience than unsuccessful hunters, but successful hunters generally were satisfied with their rams as trophies regardless of horn size or how they defined a trophy.

By the early 1990s, general hunting regulations for Dall sheep in most of the interior and southcentral Alaska allowed the taking of full-curl rams only, with the legal definition of full-curl also including any rams over 8 years old or with both horns broomed. A less restrictive bag limit of 7/8-curl prevailed in the Brooks Range in northern Alaska, where the sheep management goal was to provide opportunities for taking rams under aesthetically pleasing conditions. Absence of crowding and the opportunity to be selective in choosing which ram to shoot were generally understood to be the primary components of hunting under "aesthetically pleasing conditions." Remoteness of the Brooks Range, abundant sheep populations, and generally low hunting pressure led the Alaska Department of Fish and Game (ADFG) to believe we were achieving our sheep management goal in spite of the less restrictive regulations. However, numbers of hunters using the Brooks Range increased steadily during most of the 1980s and, by 1992, sheep numbers were declining after a series of harsh winters. Hunters and managers became concerned that competition for reduced numbers of rams, along with a 7/8-curl bag limit, would soon compromise the Brooks Range hunting experience.

After 1989, management plans for the Brooks Range included an objective to maintain a harvest with a mean horn length exceeding 34 inches and a mean age exceeding 8 years (Nowlin and Heimer 1989, Golden 1990, Stephenson 1993). We were achieving this objective through 1991, but beginning to fall slightly short in some areas by 1992 (Goodwin 1993). However, we had little or no information on whether sheep hunters were selective in choosing which rams to shoot and, if so, what criteria they used for selection. Therefore, we decided to survey Brooks Range hunters to determine how ram horn size influenced their overall hunting experience and to solicit ideas for what we could do to provide continued or improved hunter satisfaction.

METHODS

In late 1992, we sent questionnaires to all people who reported hunting sheep in the northern and eastern Brooks Range during 1990 and 1991. A random sample of hunters from 1992 was added to raise the total number of contacts to 750. Hunter names were screened so that no one was sent >1 questionnaire, and hunters were instructed to base their responses on their most recent Brooks Range hunt only. Questionnaires were sent to the address the hunter used when obtaining a Dall Sheep Hunter Report Card, which was required of all resident and nonresident sport hunters. We made no attempt to find hunters who had moved to new addresses, and no follow-up or reminder letters were sent. The survey asked questions about a number of aesthetic values, but only responses related to horn size and its effects on hunter satisfaction will be provided in this report.

RESULTS

Thirty-five questionnaires were not deliverable. Hunters returned 444 of the remaining questionnaires, a response rate of 62%. However, 1 respondent refused to answer any questions and 4 more had not hunted in the Brooks Range, yielding 439 questionnaires with usable data. Sample sizes for specific responses or analyses varied because some respondents did not answer all questions.

Fifty-four percent of the respondents (n = 420) were successful in taking a 7/8-curl or larger ram, compared to 37% of Dall sheep hunters statewide during the same time period (n = 10,087; D. Harkness, ADFG, unpubl.). Eighty-six percent of all hunters (n = 439) and 70% of the unsuccessful hunters (n = 193) saw at least 1 legal ram during their Brooks Range hunt. Unsuccessful hunters reported seeing a mean of 3.5 legal rams each, while successful hunters (n = 227) saw a mean of 7.3 each (Fig. 1). Fifty percent of the unsuccessful hunters (n = 196) passed up a mean of 4.4 legal rams each (i.e., decided not to stalk them), compared to 64% of the successful hunters (n = 231) passing up a mean of 5.7 rams each. Successful and unsuccessful hunters differed little in their reasons for passing up rams (Table 1). Thirty-eight percent of the unsuccessful hunters stalked rams they did not shoot ($\bar{x}$ = 2.2 per hunter), compared to 30% of the successful hunters ($\bar{x}$ = 1.7 per hunter).

Hunters were fairly evenly divided in their responses to statements that any legal ram is a trophy or that only exceptionally large, old rams are true trophies (Table 2). Hunters generally agreed with a statement that trophy rams are $\geq$full-curl, and this was particularly true for unsuccessful hunters. When asked to define "trophy" in their own words, both successful and unsuccessful hunters gave similar responses (Table 3). After adjusting for double responses from some individuals, 61% of all hunters defined trophies as full-curl or larger rams (assuming that rams with 36-inch horns have reached full-curl). Successful hunters enjoyed their overall hunting experience more than unsuccessful hunters (Fig. 2). Successful hunters were generally satisfied with their rams as trophies (Fig. 3), even though horn length and age of rams varied greatly (Fig. 4). Mean horn length for all rams shot by hunters in this survey was 35.1 inches and mean age was 8.43 years. Horn length had to be <33 inches before hunters began to be less satisfied with their rams as trophies or >37 inches before they began to show increased satisfaction (Table 4).

Mean ram horn lengths and ages were essentially the same regardless of how hunters defined a trophy (Table 5). Most hunters who defined trophies as exceeding specific minimum horn lengths actually shot rams with smaller horns; most were still satisfied with their trophies, although a few were not (Table 6).

Hunters using highway vehicles for access reported only 32% success (n = 75), and 27% did not see a legal ram. Hunters using aircraft had a success rate of 60% (n = 341), and only 9% did not see a legal ram. Successful hunters were more satisfied than unsuccessful hunters regardless of the type of transportation used. Unsuccessful hunters using highway vehicles or charter aircraft reported the lowest satisfaction ratings (Table 7).

Unsuccessful hunters reported more years of prior sheep hunting experience than successful hunters in all categories except for hunting sheep outside Alaska (Table 8).

DISCUSSION

Several factors may explain why successful hunters tended to be satisfied with their rams regardless of horn length or age. Hunters often described trophy value in terms of horn curl, and some full-curl or >full-curl rams had horns well below the mean horn lengths in this sample. Also, relatively short but heavily broomed horns meet the legal definition of full-curl and are very appealing to some hunters. Finally, almost 1 quarter of all hunters responded that a trophy is undefinable (or at least unquantifiable) because the quality of the hunt should determine the value of the horns as a reminder of the hunting experience, rather than the size of the horns determining the value of the hunt.

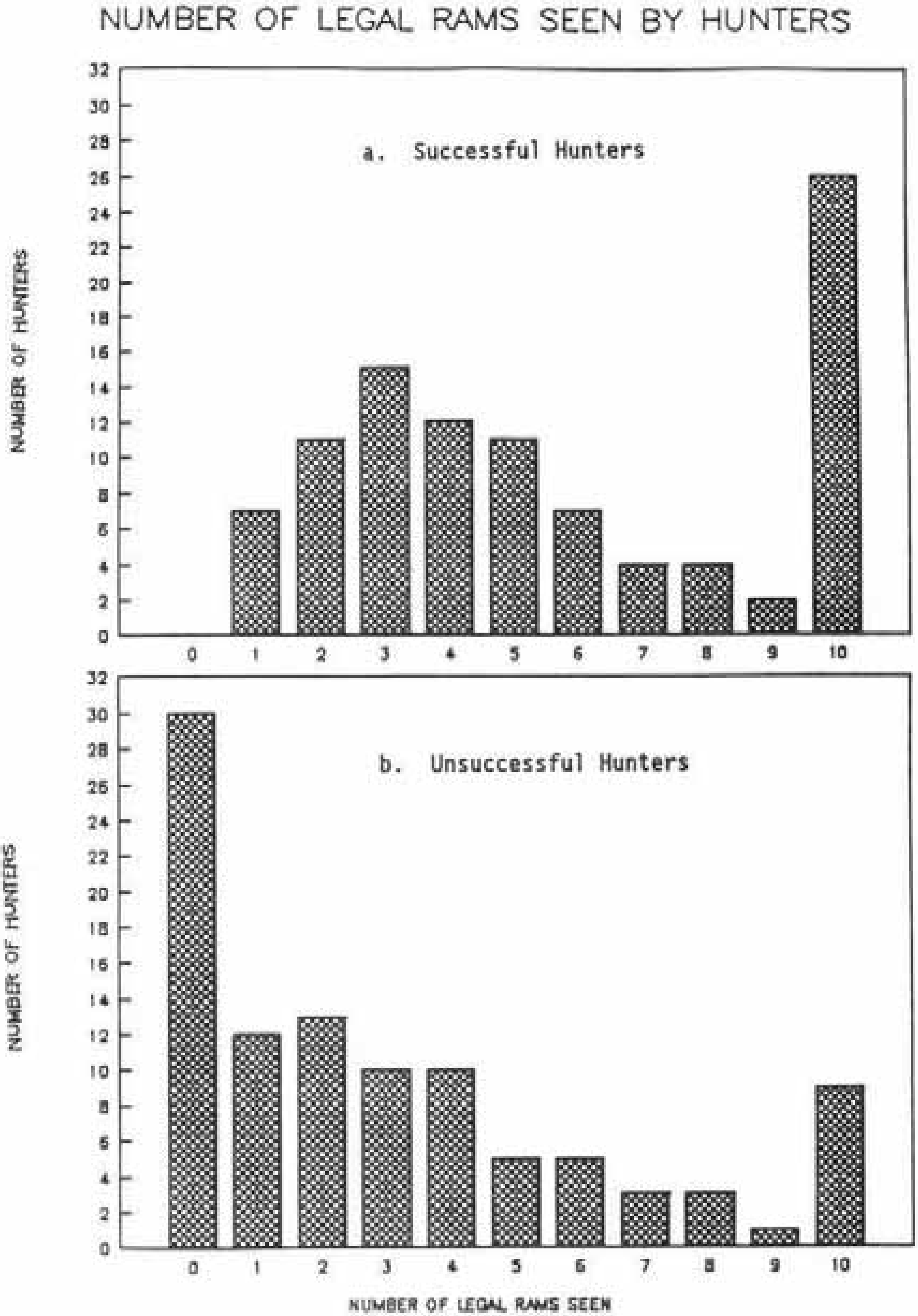

Fig. 1. Number of legal rams seen by successful and unsuccessful sheep hunters in the Brooks Range, 1990-1992.

Table 1. Reasons given by hunters for passing up legal rams in the Brooks Range, 1990-1992.

	Successful hunters (n = 153)	Unsuccessful hunters (n = 103)
Not as big as desired.	61[a]	57
Not right kind of trophy.	15	17
Too early in the hunt.	31	21
Too far away.	24	18
Inaccessible.	20	24
Being stalked by someone else	5	7
Other	16	19

[a]Percent of hunters. Totals add up to >100% because some hunters listed >1 reason.

Table 2. Responses of Brooks Range sheep hunters to statements on what defines a trophy ram.

	Strongly agree (%)	Moderately agree (%)	Moderately disagree (%)	Strongly disagree (%)	No opinion (%)
A. Any legal ram is a trophy.					
Successful (223)[a]	19	35	27	19	1
Unsuccessful (185)	18	33	28	19	2
All hunters (408)	18	34	27	19	1
B. Not all full curls are trophies; only rams near the end of their natural lifespans are true trophies.					
Successful (222)	18	29	29	20	4
Unsuccessful (179)	25	28	26	17	4
All hunters (402)	21	29	27	19	4
C. Only full-curl rams are true trophies.					
Successful (225)	27	32	29	11	2
Unsuccessful (185)	25	41	21	11	3
All hunters (410)	26	36	25	11	2

[a] (Sample size)

Table 3. Definitions of "trophy ram" proposed by Brooks Range sheep hunters.

	Successful hunters (%; n = 213)	Unsuccessful hunters (%; n = 155)	All hunters (%; n = 373)
>Full-curl[a]	31	30	31
Any legal ram	27	24	25
Undefinable[b]	25	23	24
Full-curl	22	21	21
Broomed	4	14	9
>40 inches	8	12	9
>38 inches	4	6	5
>36 inches	6	3	5
Unbroomed	7	3	5
Other	4	5	4

[a] A ram that would be larger and/or older than a typical full-curl sheep.
[b] The hunting experience determines the value of the trophy, rather than vice versa.

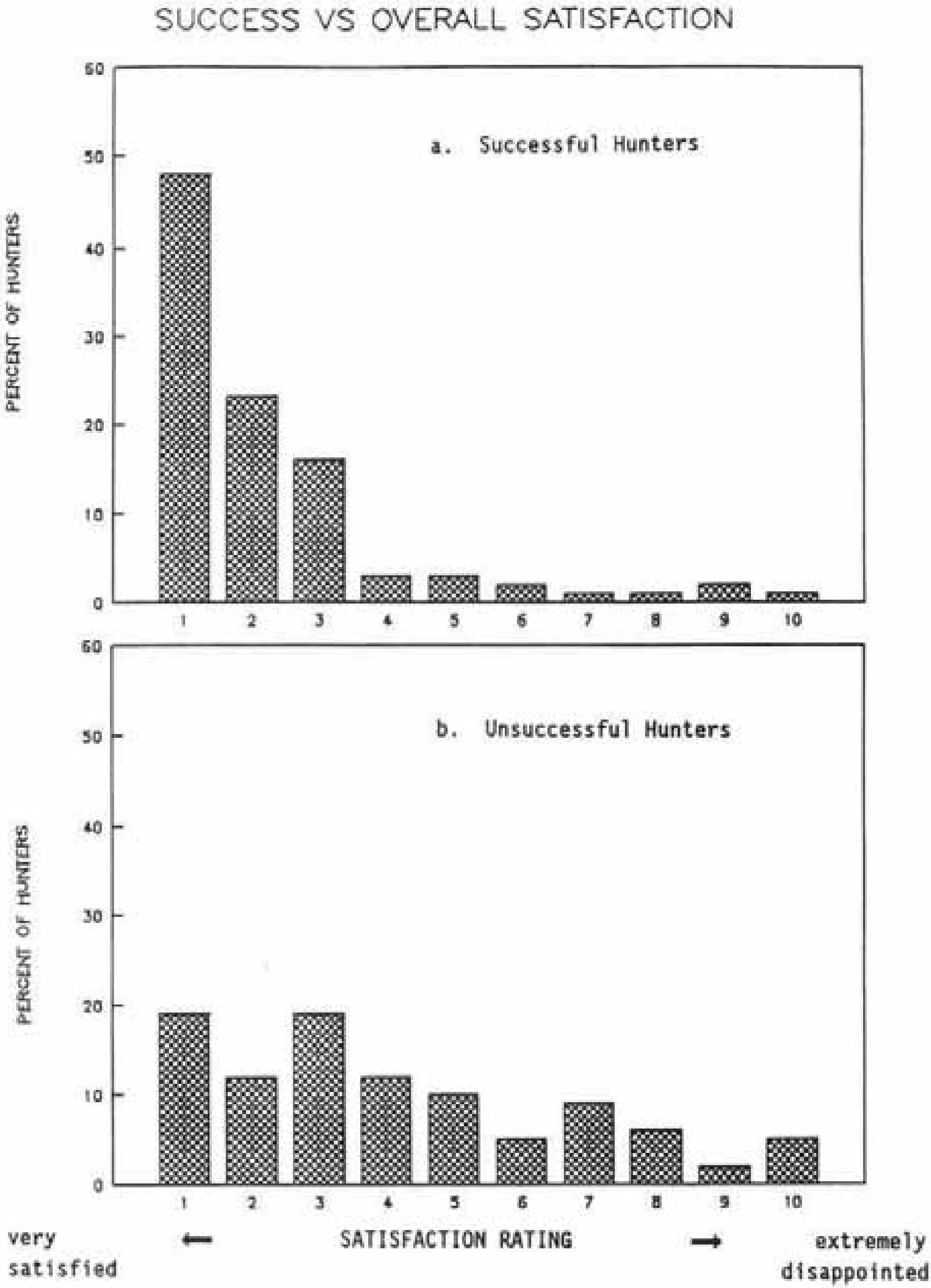

Fig. 2. Satisfaction with the overall hunting experience for successful and unsuccessful sheep hunters in the Brooks Range, 1990-1992.

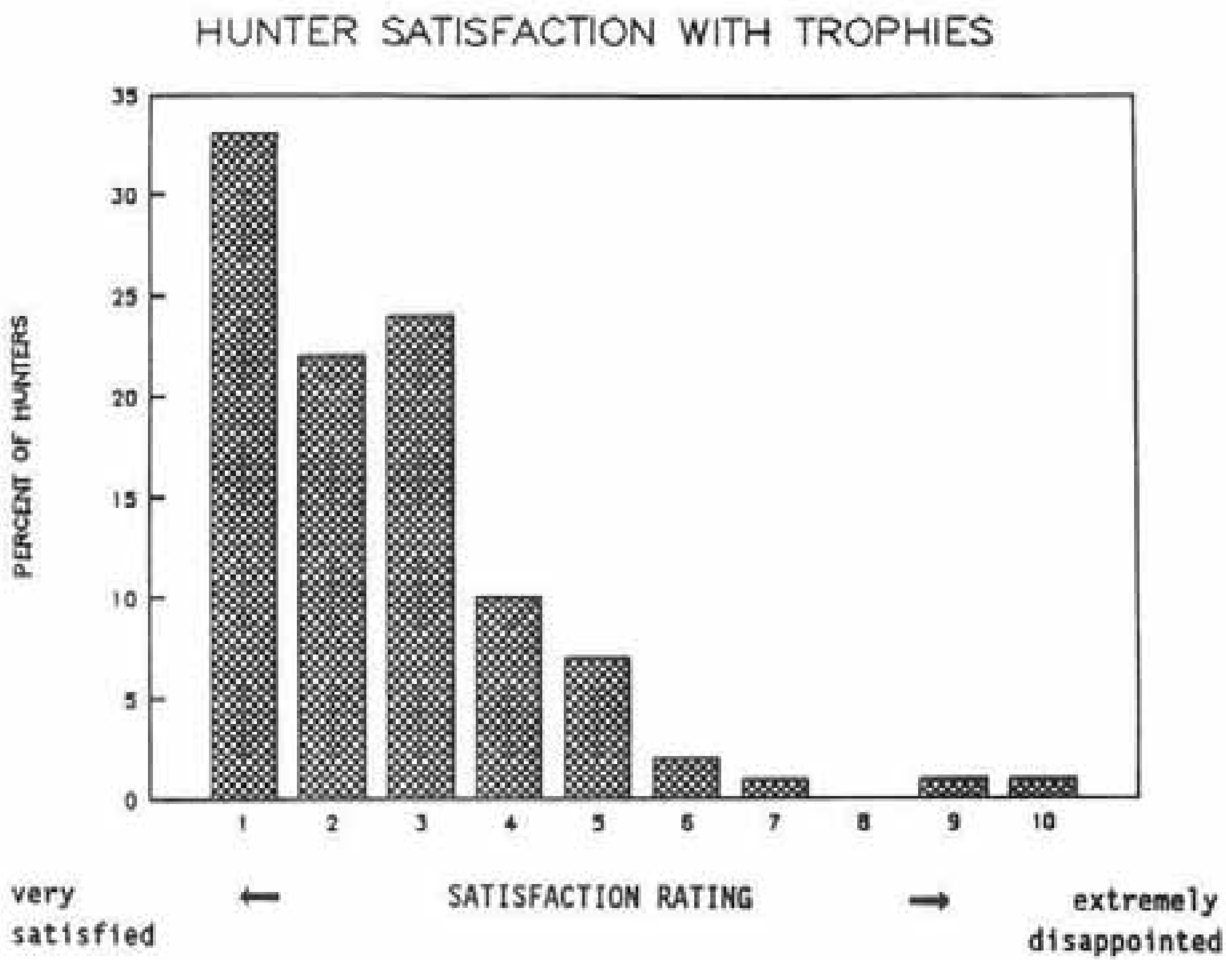

Fig. 3. Satisfaction with trophy value of rams taken by Brooks Range sheep hunters, 1990-1992.

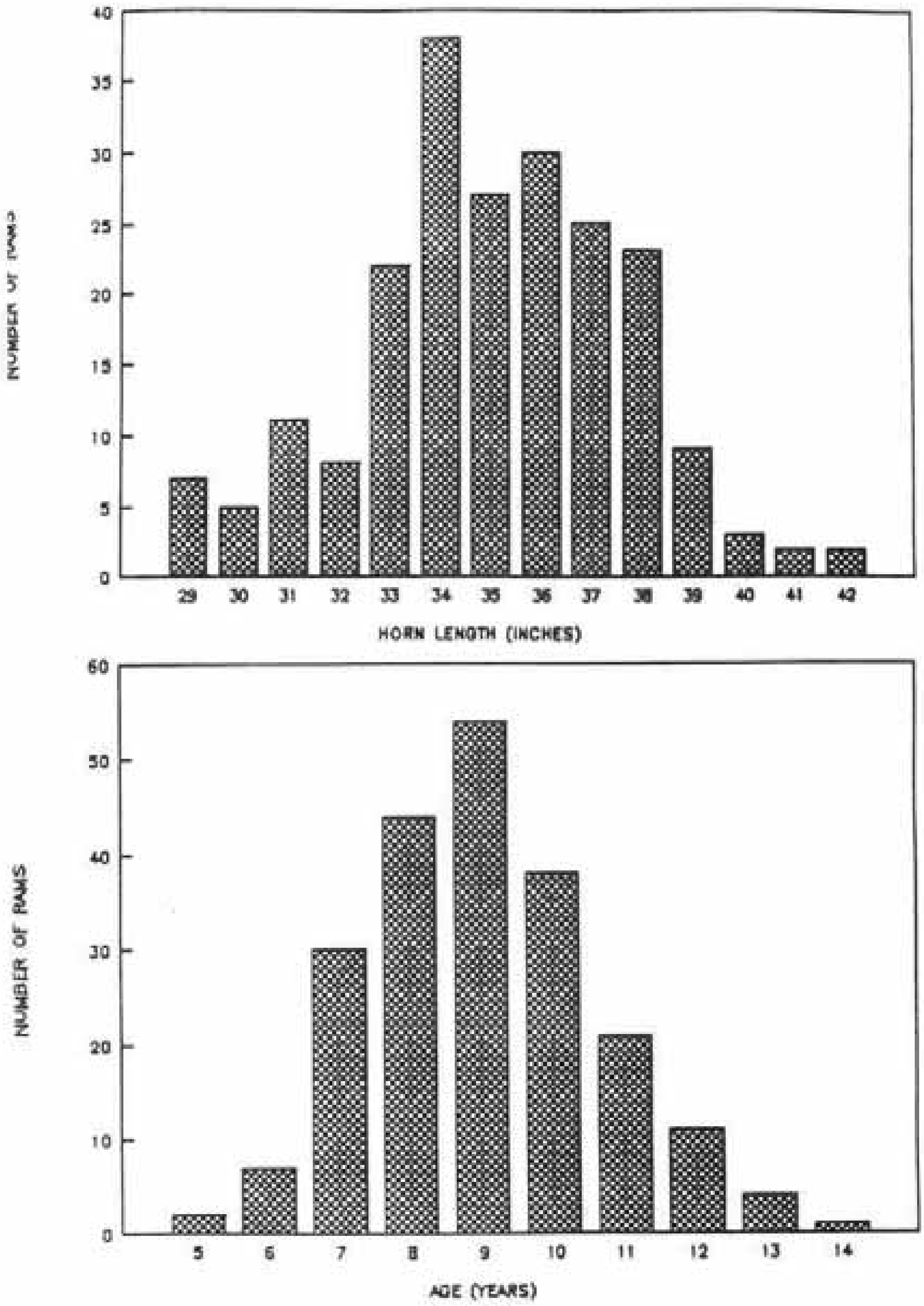

Fig. 4. Length of horns and ages of rams taken by Brooks Range sheep hunters, 1990-1992.

Table 4. Effects of horn length on Brooks Range sheep hunters' satisfaction with trophy value of their rams.

	Satisfaction rating	Horn length (inches)											
		<30"	<31"	<32"	<33"	<34"	<35"	≥35"	>36"	>37"	>38"	>39"	>40"
Very satisfied	1	14[a]	31	26	29	35	35	34	37	41	46	63	83
	2	57	31	26	23	19	17	22	26	25	24	19	17
	3	14	23	22	23	19	20	26	24	21	14	6	0
	4	0	15	4	3	6	10	10	11	10	14	13	0
	5	14	0	9	6	10	10	6	2	2	3	0	0
	6	0	0	9	0	8	6	0	0	0	0	0	0
	7	0	0	0	1	2	1	1	1	2	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0
Extremely disappointed	9	0	0	1	0	2	1	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	0
	n	7	13	23	31	52	89	117	89	61	37	16	6

[a] Percent of rams assigned by hunters to each satisfaction rating.

Table 5. Brooks Range sheep hunter definitions of trophy ram relative to mean horn length and age of rams they shot.

Definition	n	Mean horn length (inches)	Mean age (years)
Any legal ram	45[a]	34.90	8.43
Full-curl	41	34.56	8.46
>Full-curl[b]	64	34.88	8.55
>36 in.	36	34.46	8.39
>38 in.	24	35.00	8.29
>40 in.	16	35.42	8.81
Undefinable[c]	52	34.61	8.71

[a] Number of hunters. Some hunters listed >1 definition.

[b] A ram that would be larger and/or older than a typical full-curl sheep.

[c] Hunting experience determines value of the trophy, rather than vice versa.

Table 6. Horn lengths (inches) and satisfaction ratings of rams shot by Brooks Range sheep hunters who defined trophy horns as >36 inches, >38 inches, or >40 inches.

>36"		>38"		>40"	
Length	Rating[a]	Length	Rating	Length	Rating
31	9	30	3	32	1
31.5	6	34	3	33	4
32	7	34	4	33	7
33	4	35	3	34	1
34	4	35	4	34	1
34.5	1	37	2	34	4
35	1	37	3	34	4
35	1	38	1	34	5
36	3			34	5
36	4			35	5
36.5	3			36	4
39	1			37	3
				37.3	4
				39	3
				40	1
				40.5	2

[a] 1 = very satisfied to 10 = extremely disappointed.

Table 7. Effect of transportation method on overall hunt satisfaction of Brooks Range sheep hunters, 1990-1992.

	Successful hunters		Unsuccessful hunters	
	Mean satisfaction rating	n	Mean satisfaction rating	n
Aircraft				
Private	1.93[a]	54	3.63	59
Guides	2.19	53	3.12	8
Charter	2.41	100	4.34	70
Highway Vehicle	2.18	22	4.74	46

[a] 1 = very satisfied to 10 = extremely disappointed.

Table 8. Years of prior sheep hunting experience for successful and unsuccessful hunters Brooks Range sheep hunters, 1990-1992.

	Successful hunters		Unsuccessful hunters	
	years	n	years	n
Same area	0.84	203	1.38	177
Elsewhere in the Brooks Range	0.51	195	1.10	156
Elsewhere in Alaska	2.54	201	3.45	170
Outside Alaska	0.83	192	0.40	144

This may explain how some hunters were very satisfied with even the smallest legal rams.

Nevertheless, hunters did generally agree with full-curl-only management, and satisfaction with the trophy value of rams increased somewhat at moderately greater horn lengths (i.e., greater than about 37 inches). A few hunters apparently had such strict personal standards for trophy quality that they registered dissatisfaction with some of the largest rams in the sample.

Success in taking a ram appeared to be the most important factor influencing overall hunt satisfaction. For example, hunters using highway vehicles or charter aircraft often complained of overcrowding and competition. Taking a ram tended to override these negative factors, however, and successful road hunters still reported high satisfaction. Nevertheless, unsuccessful road and charter aircraft hunters reported the lowest overall hunt satisfaction ratings, suggesting that unfavorable experiences such as crowding did adversely affect hunter satisfaction when coupled with lack of success.

Successful hunters saw more legal rams and elected to pass up more legal rams, but made fewer stalks than did unsuccessful hunters. This could indicate that successful hunters tended to choose areas with more legal rams, or that they were more experienced and skillful. Unsuccessful hunters actually reported more years of sheep hunting experience, but nonresident sheep hunters in Alaska (with a few exceptions) must hire the services of professional guide/outfitters. Thus inexperienced, but successful, hunters may have benefitted from the experience of their guides. Another confusing factor may be that resident sheep hunters using the Dalton Highway had previous experience either there or in other road accessible areas which are not necessarily the best places to hone one's sheep hunting skills. Finally, some unsuccessful hunters may have been very skilled and experienced, yet terminated stalks voluntarily because they were more discriminating and, at close range, elected not to take legal rams that were smaller than desired.

MANAGEMENT IMPLICATIONS

The key to hunter satisfaction seems to be maintaining a high rate of success. Hunters may be most satisfied with large rams but they remain very satisfied with virtually any legal ram they take. Beginning with the 1993 hunting season, minimum horn size for the Brooks Range was increased to full-curl. Under the previous 7/8-curl regulation, most hunters saw more than 1 legal ram and were able to be selective in choosing which rams to stalk and shoot. Eighty-two percent of the rams shot were $\geq$8 years old and would still be legal under the new regulations. At least a few of the younger rams could also have been legal based on horn curl. This fits well with experience elsewhere in Alaska where increasing the horn size standard has had only a minor or short-term effect on harvest success. At the very least, the harvest should remain comparable with only slightly increased hunter effort.

Currently, factors other than horn-curl regulations are having a much greater short-term effect on Brooks Range sheep harvests. In conjunction with a series of severe winters, sheep populations in some areas may have fallen as much as 50% over the past few years (F. J. Mauer, U.S. Fish and Wildl. Serv., unpubl. data), and harvest also has dropped nearly 50% (ADFG unpubl. files). However, word of reduced sheep numbers must have spread rapidly among sheep hunters. By 1992, fewer hunters were going afield, and thus the success rate fell proportionately less than the absolute drop in the harvest.

The ultimate benefits of full-curl management, in terms of hunter satisfaction, may be subtle. Those hunters who seek really large rams will have a better chance of fulfilling their desire when the minimum standard is set higher, and fewer rams are taken while still small. Hunters who are presently satisfied with any ram they can take should be even more satisfied if they happen to take larger rams under the new regulations.

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THE SUCCESS OF MOUNTAIN GOAT MANAGEMENT ON THE KENAI PENINSULA IN ALASKA

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Abstract: Innovative management strategies are sometimes necessary when budgets and manpower are limited and the demand for a resource is high. Mountain goat (*Oreamnos americanus*) management on the Kenai Peninsula in Alaska has evolved under these limitations from a liberal general season to a quota-based dual permit system. We utilized a limited drawing permit hunt based on a predetermined harvest quota followed by an unlimited registration permit hunt. Drawing permit hunters were allowed 52 days (10 August-30 September) and registration permit hunters were allowed a maximum season length of 47 days (15 October- 30 November). Twenty-nine survey areas were open to hunting in 1994 from a total of 35 areas. Each hunt area was surveyed on 1-5 year intervals and harvest quotas have increased from 5% to 7% of the number of goats observed. Individual hunt areas reopened for a registration hunt if the quota had not been harvested during the drawing permit season and the risk of overharvest was considered low. Hunt areas were closed as harvest objectives were met. We evaluated this system based on three major criteria: mountain goat population status, hunter opportunity, and control of harvest levels. This harvest-tracking strategy allowed for gradual increases in population size, maintained productivity, and controlled harvest where access is variable while maximizing hunter opportunity and maintaining a sustained and distributed harvest of goats.

Mountain goats occur along the entire length of the Kenai Mountains in Alaska (Fig. 1) which represents the western-most natural extension of the species' continental range. Goat populations are most abundant in the coastal mountains and least abundant along the drier western slopes and interior portions of the Kenai mountain range, where they coexist with Dall sheep (*Ovis dalli*).

Goats within Kenai Fjords National Park (KFNP) were unavailable to hunting after the park was established in 1980. In addition to the 2,268 km^2 KFNP, most goat habitat on the Kenai Peninsula lies within the Kenai National Wildlife Refuge (7,839 km^2), Chugach National Forest (ca. 5120 km^2), or Kachemak Bay State Park system (1,500 km^2), and remains virtually unaffected by human development.

The most significant factor affecting goat populations on the Kenai (Hjeljord, 1973) and near Ketchikan (Smith 1984) was believed to be winter weather. Severe winters have pronounced effects on natality rates and mortality of older aged animals and juveniles (Smith 1986). Coupled with hunter harvest on prime aged animals, goat populations could decline. Since hunter harvest is primarily additive (Hebert and Turnbull 1977, Kuck 1977, Smith 1986), restrictions on or elimination of human caused mortality is necessary following back to back or multiple severe winters. Surveys following suspected severe winters would help managers identify population declines and make difficult decisions regarding permit reductions or season closures.

The Kenai Peninsula has been a popular mountain goat hunting area since statehood because of its proximity to Anchorage and relatively accessibe goat populations. By the late 1970s, Alaska Department of Fish and Game (ADF&G) wildlife managers recognized that moderate to severe winters, combined with liberal seasons and bag limits of up to 2 goats, resulted in local population declines. For example, the number of goats surveyed in area 342 declined from 84 in 1968 to 22 by 1980. Consequently, a registration permit hunt system was implemented in 1978 to reduce harvest and distribute hunting pressure. In 1980, drawing permits were issued by lottery followed by unlimited registration permits for areas where harvestable quotas remained. In addition, subsistence permits were allowed in designated

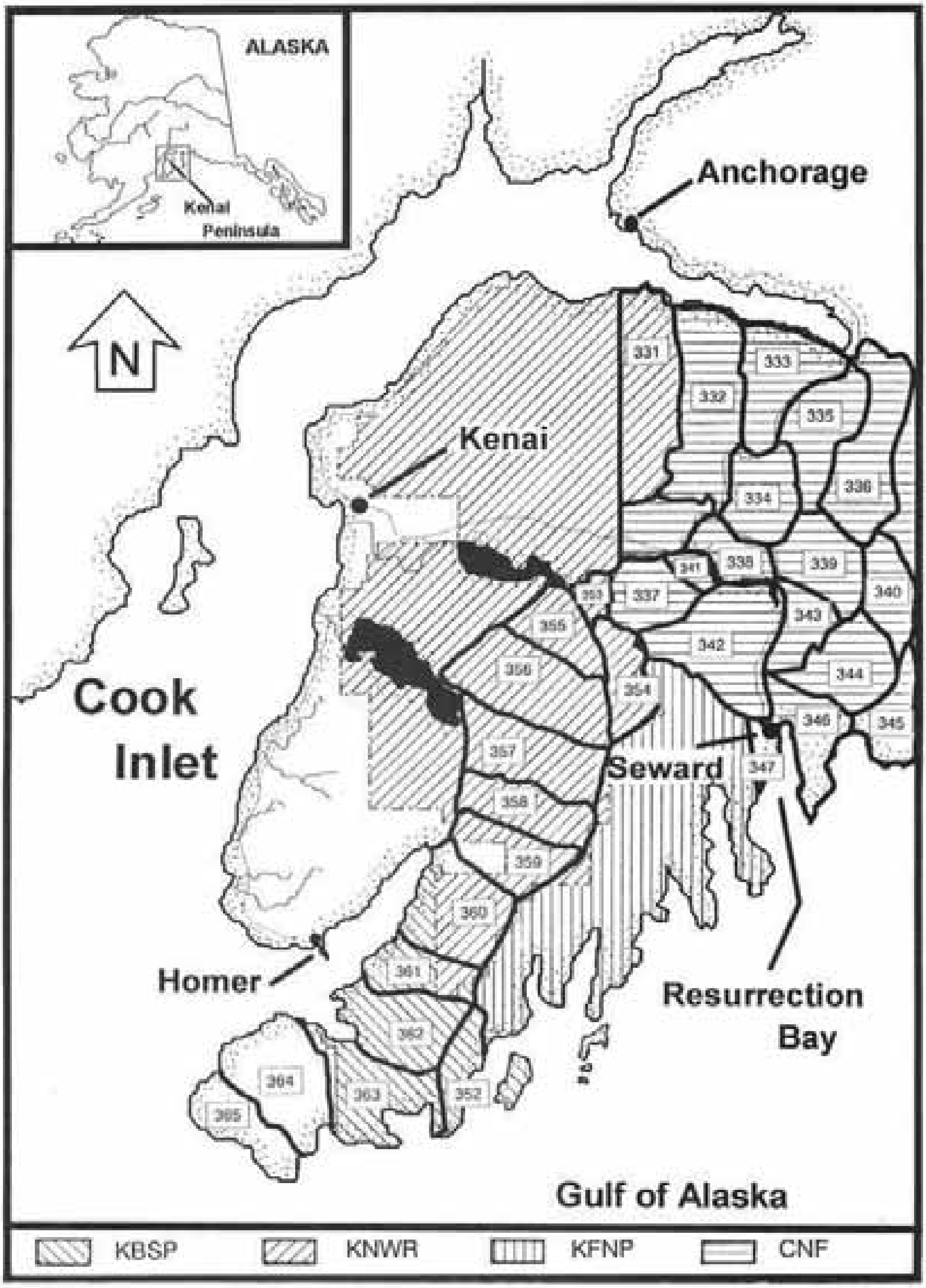

Figure 1. Kenai Peninsula and the associated mountain goat hunt areas. Most habitat lies within Kachemak Bay State Park (KBSP), Kenai National Wildlife Refuge (KNWR), Kenai Fjords National Park (KFNP) and Chugach National Forest (CNF) as indicated by cross hatching.

subsistence use areas only.

ADF&G management objective is to maintain a population of 4,000 to 4,500 mountain goats on the Kenai with a harvest of predominantly (66% minimum) males. The Department utilizes a harvest-tracking system (Caughley 1977) based on survey results of individual hunt areas.

We would like to thank L. Nichols and Dr. C. Schwartz for their review of the manuscript, all the pilots and observers (two of whom never came home) who spent hundreds of hours surveying goats and collecting data on the Kenai , and the various ADF&G staff who assisted in developing our current management system.

STUDY AREA AND METHODS

The Kenai Peninsula (21,831 km²) is located south of Anchorage, Alaska (Fig. 1) between 59° and 61° N. latitude and 149° and 152° W. longitude. Cook Inlet bounds the Kenai on the West, the Gulf of Alaska on the south, and Prince William Sound on the east. The Kenai Mountains and the associated mountain goat range lie on the eastern side of the Peninsula.

Climate on the Kenai varies from coastal maritime along the Gulf of Alaska to drier interior portions of the peninsula. Snowfall data available from the USDA Soil Conservation Service (1994) indicate that snow pack levels peak in late April or early May. Mean snow depth in 1961-1990 in selected sites near goat habitat ranged from 76.2 cm (30 in) at Summit Creek to 248.9 cm (98 in) at Nuka Glacier and Turnagan Pass. Annual variations in snowpack were caused by maritime influence, surrounding topographic features (Paez 1991), and prevailing storm direction.

The Kenai Peninsula mountain goat range is divided into 35 survey areas, which correspond to individual hunt areas. Twenty-nine areas were open to mountain goat hunting in 1994 . Of the 6 areas not opened, 4 were located within KFNP and the other 2 contained small herds (less than 20 goats).

Since the early 1970s, the department has monitored goat populations using aerial survey techniques described by Lentfer (1955). Surveys were flown using a Piper PA-18 Super Cub with an observer during early morning and evening in July and August (prior to hunting season). Surveys generally were flown along drainage contours beginning at the subalpine zone progressing upward into the alpine zone by 150-200 m increments. We counted and classified goats as either kids (< 4 months) or adults and recorded data on standardized forms. Harvest quotas were calculated based on the number of observable goats in each hunt area.

Three goat population trend areas, each consisting of 2 or 3 contiguous count areas, were established in separate geographic regions of the Kenai (Del Frate 1992a). These areas became the primary sampling units for monitoring trends in goat production and abundance for the regions they represented. Insufficient annual budgets restricted us from surveying all areas annually. Trend areas and other high priority areas were surveyed every 1-3 years, while low priority areas were surveyed at least every 5 years.

The Kenai Peninsula mountain goat population size was estimated by summing the most recent aerial survey results for all count areas and correcting for sightability. In doing so there was an unavoidable lag in the magnitude and direction of increase or decline of estimated population size. Additionally, since 1980 we assumed the population was increasing in all areas. The composite estimate was expressed as a range by assuming that 70% to 90% of the goats present during aerial surveys were observed (Nichols 1980a). Recent accurate estimates of mountain goats in KNFP were not available but were assumed between 800-1,000 animals.

Drawing permits were allocated based on the number of goats observed, degree of accessibility, and historical success rates for individual hunt areas. ADF&G is authorized through the Board of Game to issue up to 500 permits. Currently, 29 hunt areas are open and the number of permits differs from 2-40 per individual hunt area. The drawing permit season opened 10 August and closed 30 September. Hunters were required to report to a local department office within 10 days of harvesting a goat with the horns for aging and verification of sex. Unsuccessful hunters were required to report within 15 days of the end of the season by returning the harvest report portion of their permit.

Since success rates differed annually and because we suspected that additional drawing permits could result in overharvest in some areas, we included a registration permit system in 1982 for 7 days and quantities were unlimited. Only selected areas were opened (where harvest quotas were not met and chances for overharvest were minimal). Hunters were required to apply in person at an ADF&G office. Successful hunters were required to present the horns within 5 days for measuring and aging. A short 5-day reporting period was necessary to facilitate in-season management.

The registration hunting season opened 15 October and closed 30 November unless areas were closed by Emergency Order (EO). In recent years most areas were closed by EO because individual area quotas were filled within 1-2 weeks of the registration season. Emergency orders issued locally allowed for closure of an area in one or two days, thus, reducing the risk of overharvest. Hunters who had not yet gone afield were advised of the EO closure by phone.

In Alaska, special provisions provide a priority for subsistence uses of wildlife. Where resources were not plentiful enough to provide for the subsistence needs for all residents (Tier I), resources were allocated to qualified individuals through lottery (Tier II). Hunter qualifications were based on need, proximity to the resource, history of use, and sources of alternative foods. Subsistence mountain goat hunters were regulated utilizing the harvest-tracking strategy. Currently, 4 areas have been designated for Tier II subsistence hunts on the Kenai Peninsula. The Tier II season began 1 August instead of 10 August and closed 30 September. A follow up registration hunt was allowed if harvest quotas had not been met. These registration hunts were limited to residents of Alaska who qualified for subsistence.

RESULTS

In annual population estimates using the most recent aerial surveys, the mountain goat population remained relatively stable from 1968 to 1981 and then steadily increased through 1992 (Fig. 2). This

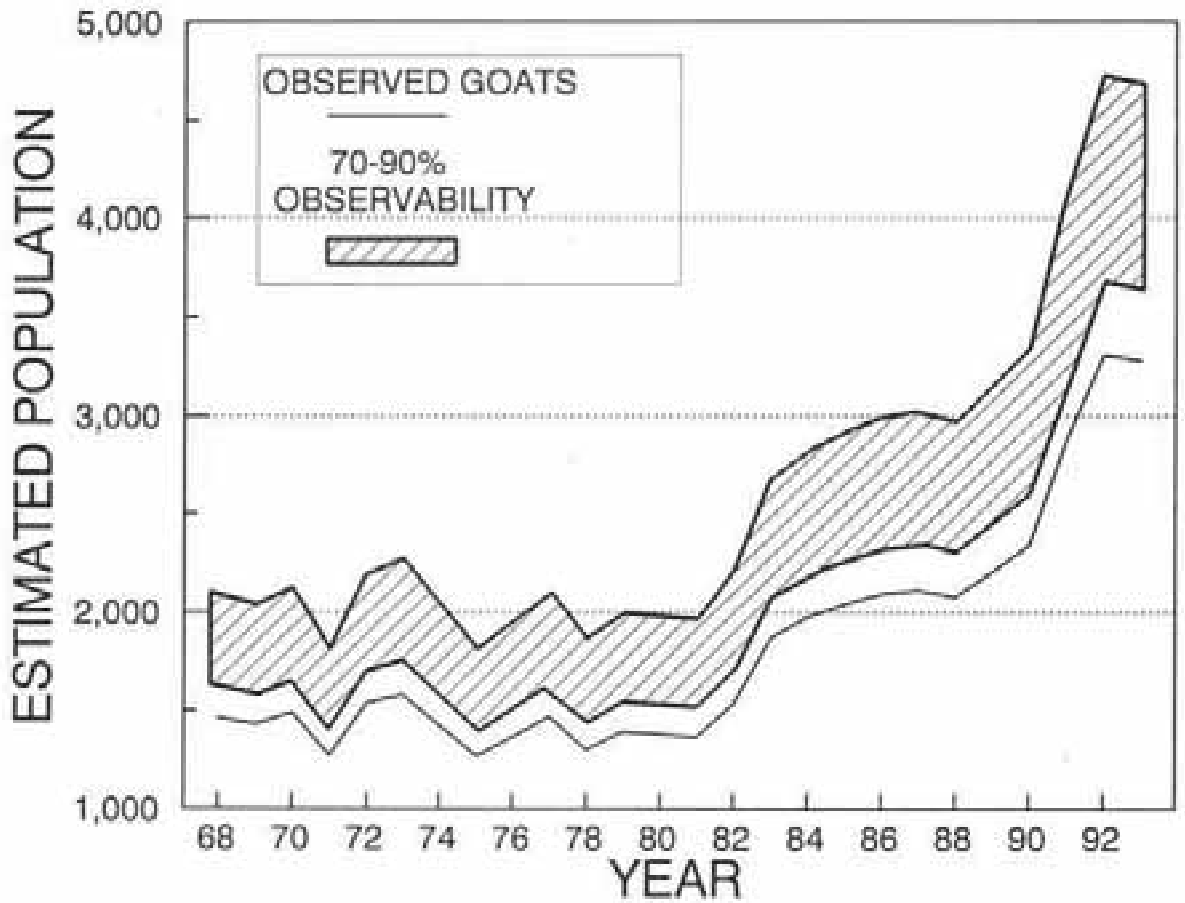

Figure 2. Kenai Peninsula mountain goat population, 1968-1993.

technique has been used to identify long term population trends as was noted with almost a three fold increase in the Kenai goat population. However, some limitations were noted: depending on the number of annual surveys completed, there may be a lag in recognizing population changes; localized increases and declines were not readily evident since all survey information was combined.

As the mountain goat population size increased under our management system, population objectives were revised upward in 1989 (Holdermann 1990) and again in 1993 (Del Frate 1992b). The current population estimate is 4,500 to 5,800 goats.

Trend area survey results during the period 1968-1987 indicated kids:100 older goats and percent kids observed ranged from 20:100 to 44:100 and 17 to 31%, respectively. Kid percentage during annual surveys in the West Slope and Blying Sound regions declined gradually in 2 of 3 trend areas during the last decade (Del Frate 1992b).

Harvest rates for individual count areas were increased from 5% to 7% of total countable goats to try to stabilize goat numbers within management objectives. Additional increases in quotas may be necessary if the harvest rate of 7% is inadequate.

DISCUSSION

The original permit system was instituted to disperse hunting pressure, limit harvests in highly accessible areas, and maintain hunter opportunity (Spraker 1981, 1983). After the 1984 season, Spraker (1986) recommended "adjusting" the permit allocation to meet the increasing population. Smith (1984) suggested that a population tracking strategy (Caughley 1977) was advantageous for mountain goat management. Since then, harvest has been based on predetermined population objectives and adjusted for long term environmental trends. Parameters such as sex ratio in the harvest and mountain goat distribution have been included (Holdermann 1986).

The drawing permit system was initiated in 1982 when we realized the registration permit system failed to provide the necessary safeguards to control hunting effort and to prevent overharvest. Localized overharvest problems generally occurred in areas with good access. Using drawing permits, hunt areas with as few as 30 goats could be opened. In addition, hunters could be distributed more evenly across the Peninsula and the "gold rush" style of hunting would be eliminated.

Success rates for drawing permit hunters differed substantially between years. For example, hunt area 339 harvests have varied from 1-8 goats annually with success rates of 10% to 100%. Registration hunts were allowed only when harvest numbers were below quotas. By combining both drawing and registration permit systems we can maximize hunter opportunity and achieve harvest objectives while protecting smaller subpopulations of goats. Where there are small populations of goats or good access we can only issue drawing permits since the possibility of overharvest is high. Annual adjustments in the number of permits issued often were necessary to adjust for the desired harvest. By comparison, areas with moderate to difficult access have been managed well using registration permits. If an area had a high probability of overharvest, a registration season was not authorized regardless of surplus goats.

Weather also is a factor that affects in-season management by affecting hunter success rates. Extended periods of poor weather prevent hunters from traveling to hunt areas or reaching goats in difficult terrain. Drawing permit systems generally cannot be adjusted for unpredictable and variable harvest rates. The addition of the registration permit system allows in-season adjustments to enable the Department to achieve harvest objectives.

Several conditions of the permits allow personal contact between the Department and hunters. Information on animal condition, age, and sex, as well as methods of transportation, and success rates allowed us to gain insight concerning the results of our management program. We provided a handout to hunters describing the life history of goats, how to identify billies in the field and specific maps showing the description of hunt areas.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

There are several benefits associated with the current mountain goat management system on the Kenai Peninsula. Each type of permit allows for specific objectives to be met while still maintaining hunter opportunity and protecting wildlife resources. However, manpower for data entry and analysis increases with in-season management. In areas where unlimited participation hunts are no longer viable, a dual permit system may be applicable.

Since the beginning of the harvest tracking strategy on the Kenai Peninsula the mountain goat population has experienced continuous growth. The decline in the proportion of kids may be an indication that the Kenai Peninsula goat population is nearing carrying capacity. Declining habitat conditions may reduce the productivity of female goats (Adams and Bailey 1982) or perhaps density dependant reductions may be occurring (Swenson 1985). Both theories need further investigation on the Kenai.

Weather patterns generally have been moderate to mild with only a few exceptions. Poor winter conditions have been reported 3 times since 1978 (Nichols 1980b, Del Frate and Spraker 1991, Del Frate 1992c). If the Department suspects high overwinter mortality, allocation of permits can be adjusted to account for winter severity. Late July surveys may confirm suspicions and we can further adjust registration permit allocations.

The addition of a registration permit hunt system that follows the drawing system is not without its faults. This type of in-season management is labor intensive. Personnel need to be available to issue permits on demand as well as check hunters in and out of hunts. Since the number of registration permits are unlimited, access becomes critical to whether or not an area should be opened. Areas with good access stimulate interest in some hunters who would otherwise not attempt to hunt goats. In some areas on the Kenai well over 100 permits have been issued in less than 5 days.

Smith (1984) suggested that mountain goat populations followed "boom or bust" cycles based on extended periods of moderate or severe winters. Mountain goat management on the Kenai Peninsula recognizes the potential for these cycles. We can take advantage of the "booms" by increasing hunter participation and harvesting additional animals. In the event of a "bust" we can protect the remaining animals through conservative allocation of permits. If necessary, individual hunt areas can be closed until populations sufficiently recover. The keys to the success of this program are the manager's working knowledge of mountain goat biology and hunter demographics.

This system of mountain goat harvest management developed on the Kenai Peninsula may have application elsewhere. Advantages are: (1) effective dispersal of hunting effort by allocation of permits by hunt areas; (2) reduction in the risk of localized overharvest in areas with easy access; (3) specific hunt area objectives; and (4) long term use of trend areas facilitates assessment of hunting and environmental effects on mountain goats.

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HORN GROWTH IN MONTANA BIGHORN RAMS

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Abstract: Annual growth increments of 59 bighorn rams (*Ovis canadensis canadensis*) from 18 Montana hunting districts were analyzed to test several current hypotheses concerning horn growth. Fluctuating asymmetry measurements were used to test the hypothesis that the small horn syndrome of certain herds resulted from population bottlenecking and a resulting loss of genetic variability. Mineral analyses were used to test the hypothesis that horn size differences can be explained by mineral composition differences which serve as indicators of major soil fertility differences among ranges. Neither of these hypotheses was supported by the analytical results. The general pattern of growth was highest in the middle years of life. The sheep from ranges producing large horns showed greater annual growth from the 2nd or 3rd year through life than did the sheep from ranges yielding smaller horn sizes. Patterns of horn growth in transplanted sheep populations resembled the parent population but had considerably larger annual growth increments. Fluctuating asymmetry values were smallest in the sheep from areas producing small horns. This suggests that loss of genetic variability was not a major influence on these sheep. Asymmetry values in transplanted populations resembled the parent population and sibling populations more than unrelated populations. When climatic effects were evaluated, the annual variation in precipitation accounted for about 30% of the annual variation in horn growth after the effects of age were accounted for.

The horns of bighorn sheep differ somewhat in size among various ranges of this species (Stewart and Butts 1982). It is presumed that this variation is due to both genetic and environmental factors. The relative contribution of each of these factors to the horn variation has never been determined. More detailed information concerning horn growth would be of benefit in managing the species. In an attempt to explore horn growth, data on the annual growth increments from 59 rams representing 18 Montana hunting districts were analyzed.

I wish to thank the many members of the Montana Fish, Wildlife and Parks Department who measured the horns and collected the drill shavings produced in the identification plugging of the horns.

The current study focused upon the fluctuating asymmetry of the annual growth increments, the overall growth patterns, and the relationship of horn growth to climate. Fluctuating asymmetry refers to the bilateral differences in growth seen between the right and left horns of an animal. Such lopsidedness has been used as an index to inbreeding in small populations of cheetah (*Acinonyx jubatus*) (Wayne et al. 1986), grizzly bears (*Ursus arctos*) (Picton et al. 1990) and other species (Leamy 1984). Inbreeding increases the fluctuating asymmetry but environmental stress may increase it as well (Leamy 1984).

METHODS

Tape measurements of circumference and annual increment length on the outside curve of each horn were made when sheep heads were brought in for registration and marking. All sheep analyzed in this study were killed in 1983 and 1984. The methods used for mineral analysis have been described previously (Picton and Eustace 1986).

STATA 3.1 (Computing Resource Center, Santa Monica, CA.) was used for all statistical analysis. The F test for equality of standard deviations and the T test for equality of means were used. Because of sample sizes and historical and regional affinities, adjacent hunting districts were grouped together for some analyses.

Fluctuating asymmetry was measured by subtracting the measurement of each annual increment of the left horn from that of the right horn. The differences were totalled to give an asymmetry index for the animal. Only data from the base through the fifth increments were used for comparisons because of differences in ages and brooming in the terminal increments. The analysis was repeated using the circumference at each annual increment. An index to the amount of horn tissue laid down each year was obtained by multiplying the annular circumference by the length

Table 1. A comparison of average horn lengths of bighorn rams over five years of age from different ranges in Montana, 1983 and 1984.

Area	n	Mean age	Mean length (cm)
Flint Range	4	8.5 ± 2.5	95.3 ± 9.0
Rock Creek	3	6.7 ± 0.6	91.8 ± 5.2
Gallatin-Hilgard	18	6.9 ± 1.6	77.4 ± 9.3
Highland Mts.	4	5.8 ± 1.5	90.2 ± 8.1
Sun River	8	7.3 ± 1.3	88.6 ± 7.3
Beartooth-Absaroka	11	7.6 ± 1.4	81.5 ± 10.7

of the annual increment. This was felt to be more sensitive to the actual metabolic processes of horn growth than the volume estimates used by other workers (Stewart and Butts 1982) because it is a better representation of the actual amount of horn tissue that encloses the volume.

Monthly precipitation totals and growing season data were obtained from weather station records (NOAA 1975-1984). Weather stations with weather fluctuations similar ot that of the bighorn sheep ranges represented by the samples were selected. Thus, the weather station serves as an index to the weather of the sheep range as follows: the Gison Dam weather station data was used for the Sun River hunting districts, the Phillipsburg Ranger Station weather data was used for the Rock Creek and Flint Range sheep ranges, the Wise River weather station was used for the Highland Mountains sheep ranges, Hebgen Lake weather records for the sheep ranges located in the southern portions of the Gallatin and Hilgard mountain ranges., and Cooke City weather for the Beartooth and Absaroka Mountains sheep ranges.

RESULTS

Horn Length

The Flint Range, Rock Creek and Highland Mountains areas are notable for their production of large rams (Table 1) over the last 20 years. These areas have all received transplant animals from Sun River. The Beartooth-Absaroka area includes the highest mountains in Montana. Two of the sheep populations in this metapopulation unit have been judged to be in poor condition by population parameters (Martin 1985).

Asymmetry

Asymmetry as a percentage of total increment length averaged lowest (0.3 percent) in the populations of the south Gallatin - Hilgard range areas. The highest average length asymmetry (3.4 percent) was seen in the Sun River areas. The horn surface area index was used to compare the fluctuating asymmetry of different herds (Table 2). The F test was used to assess the variation in fluctuating asymmetry using the indices of asymmetry. Horns from the Sun River region did not differ in asymmetry from those in the Rock Creek-Flint Range or Highland Mountain areas. Some transplants of sheep from the Sun River were made in these areas since 1960. Sun River sheep also did not differ in asymmetry from the Gallatin-Hilgard sheep but did differ from those in the Beartooth-Absaroka area. Beartooth-Absaroka sheep had significantly less variation in asymmetry than did any of the other areas except for the Highland Mountains.

Annual Horn Growth

The amount of surface area added to the horn was small during the first year of life, maximum during 3 years of age, and then declined for the remaining years of life (Table 3). On average, the synthesis of horn tissue declined by 14.5 per cent per year after the peak year of growth. The rate of decline of horn growth appeared to be similar for all populations. Regression analysis indicated that age explained between 42 and 91 per cent of the variation in annual horn growth within the various areas (Table 4).

Relationship of Horn Growth and Climate

Stepwise multiple regression was used to explore the relationship between annual horn growth and monthly total precipitation (Table 4). In general, precipitation explained about 30% of the

Table 2. A summary of the asymmetry of horn surface area indices for five Montana bighorn sheep areas, 1983 and 1984.

Area	n	Mean index asymmetry	Mean % asymmetry	Area differ index (P<.05)
Flint-Rock	11	13.4	0.69	Beartooth
Highland Mt	5	12.7	0.57	
Sun River	8	10.2	0.54	Beartooth
Gallatin-Hilgard	19	9.5	0.57	Beartooth
Beartooth-Absaroka	11	8.8	0.54	All except Highland

variation in horn growth remaining after the effects of age were accommodated. However, there were considerable differences among areas (6.9% to 77.8%).

Relationship of Annual Horn Growth and Mineral Content

The Fe, Al, Mg, P, Ca, Pb and Zn levels reported previously (Picton and Eustace 1986) did not show significant correlations with the annual growth increments. No consistent patterns emerged from the data.

DISCUSSION

The Flint Range, Rock Creek, and Highland Mountain areas have been prime areas for the production of large horns for a number of years. These areas have received transplant of sheep from the Sun River population. The Flint Range and Rock Creek area had existing populations which were supplemented by the transplants. The Highland Mountains population represents an entirely new population on historic range. This population is characterized by exceptionally rapid

Table 3. A comparison of annual horn growth using the surface area indices for five population units in Montana, 1983 and 1984.

Age	Flint-Rock	Highland	Sun River	Gallatin-Hilgard	Beartooth-Absaroka
1	18.9	12.5	17.7	9.2	6.9
2	83.1	121.6	98.1	62.2	54.4
3	105.4	127.8	86.2	76.6	66.6
4	90.7	93.1	69.5	66.2	63.5
5	72.5	52.0	54.0	57.1	58.2
6	50.1	37.7	36.8	36	45.6
7	43.1	-	31.7	35.6	32.3
8	27.5	-	17.6	18.7	21.4
9	15.9	-	9.2	16.3	15.1

Table 4. The proportion of annual horn growth explained by age, precipitation, or unexplained. The months in which precipitation has a major positive or negative effect are given.

Area	Age	% Age explain	%Ppt explain	% Un-explain	Important months N D J F M A M J J A S O
Flint	<2	42	6	52	F
-Rock	3+	74	7	19	M A M J O
Highland	<2	91	7	3	A M S
	3+	68	22	10	M J J S O
Sun River	<2	-	-	-	
	3+	71	2	27	N J F M J
Gallatin	<2	69	6	25	N M A M J J A
Hilgard	3+	55	8	37	N M A M J J A
Beartooth	<2	47	7	46	D F M A
Absaroka	3+	74	5	21	J F A J O

horn growth rates in the second and third years of life which carried over into the fourth year in all except the Sun River. Historically, the Sun River population persisted for many years at ecological carrying capacity and then underwent a major expansion following reduction in the number of elk (*Cervus elaphus*) on the range (Picton 1984). The sheep for the transplants were obtained during this period of increase.

Steward and Butts (1982) proposed that the difference in horn size among different populations can be related to population bottlenecking and consequent inbreeding in this century. Fluctuating asymmetry can be used to test this hypothesis because it is believed to increase as inbreeding increases (Leamy 1984). Inbreeding reduces the effectiveness of growth control resulting in an increase in "lopsidedness" in the animal (Leamy 1984, Palmer and Strobeck 1986). Thus, fluctuating asymmetry should increase in areas that historically had a major period of population constriction. The Gallatin-Hilgard and Beartooth-Absaroka areas might be expected to show high levels of asymmetry but instead were notable for the low levels of asymmetry. The latter population lies northeast of Yellowstone Park; the former area is northwest of the Park. The fluctuating asymmetry analysis does not support the population bottlenecking hypothesis. The apparent lack of a significant difference in asymmetry between the Highland herd and the Beartooth-Absaroka sheep may have been due to the small number of samples for the Highland herd (n=5).

Hypotheses that deficiency or insolubility of particular minerals interfered with horn growth (Picton and Eustace 1986) were tested using this detailed database. The analysis of annual horn growth patterns and their mineral content produced no support for the hypotheses that these minerals were limiting. Schwantje (1986) pointed out that low levels of copper and selenium can produce subclinical problems in domestic sheep and perhaps bighorn sheep. Although Cu levels were closely examined for a relation to horn growth, none was found. While horn tissue can be expected to be a physiological recorder of conditions present during its formation, it is probably not as sensitive as the live tissue used by Schwantje (1986).

The pattern of horn growth seen here, with peak growth during years 2, 3 and 4 is similar to the inverted U pattern described for Dall sheep (*Ovis dalli dalli*) (Bayer and Simmons 1984, Konig and Hoefs 1984). While it cannot be specifically confirmed, it appears that areas notable for large horn sizes have particularly high rates of growth in the early years of life.

The relationship of climate to the productivity of sheep also has been reported (Picton 1984). The use of weather station precipitation represents a rough assessment of the importance of climate and the probable effects of year to year variation in nutrition on horn growth. Use of an effective precipitation model for each range area combined with distribution information would improve the assessment. Both positive and negative relationships were seen when comparing monthly precipitation and horn growth. However, I feel that a more detailed analysis is necessary before it can be concluded whether increased precipitation during a given month will have a positive or negative effect on horn growth.

MANAGEMENT IMPLICATIONS

In management terms, it appears that the sheep of the high altitude ranges surrounding Yellowstone Park may represent an adaptive suite that includes smaller tightly curled horns. It is suggested that further evaluation be done before supplemental plants of sheep of the larger curl lineages are made in the area. Comparable data from the neighbouring herds in Wyoming (Shoshone River and Whiskey Mountain areas) would be particularly valuable. Bighorn sheep from the Sun River lineage seem particularly able to make use of new habitats and should be considered when making reintroductions into currently unoccupied ranges.

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SUMMER ACTIVITY PATTERNS OF BIGHORN EWES IN THE NORTHERN GREAT PLAINS

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Abstract: Eight bighorn ewes (*Ovis canadensis californiana*) were captured and fitted with motion-sensitive transmitters in early 1992. Their activity patterns were monitored with a telemetry/data recording system during the summers of 1992 and 1993. Concurrent behavioral observations indicated that the system recorded activity/inactivity with ≥ 95% accuracy. The ewes were more active during the daytime and PM twilight than during the night or AM twilight ($P < 0.01$). Peak activity periods occurred in the morning soon after sunrise, and in the afternoon/evening, which tended to be the most active time of the day ($P < 0.05$). Activity levels did not differ on days when temperature was > 23 C, compared with days ≤ 23 C ($P > 0.05$). However, the ewes tended to be more active on wet days than on dry days ($P < 0.01$ in 1992).

Knowledge of activity patterns can yield important information about the ecology and behavior of ungulates. However, data are difficult to obtain. Long hours of observations are required, study animals may move out of view, and the presence of observers may affect the behavior of the animals. Moreover, data on 24 hr activity budgets, including nocturnal patterns, of bighorn sheep are lacking. Radio telemetry has facilitated research of activity patterns, and new advances with automated telemetry allows workers to collect activity data continuously over extended periods. Previously, the data were collected on strip chart recorders (e.g.., Merrill 1985, Hamr and Czakert 1986, Kufeld et al. 1988), but these require intensive monitoring. Computerized data recording devices interfaced with telemetry equipment have been used on mule deer (Kie et al. 1991, MacDonald 1990, Peterson and MacDonald In Prep.) but not on bighorn sheep. Use of this technology could help increase knowledge of ungulate ecology in a variety of regions and environmental conditions.

Relatively few ecological studies of bighorn sheep have been conducted in the Great Plains region (Brundige and McCabe 1986, Fairbanks et al. 1987, Berger 1991). Fairaizl (1978, 1980) provided the only previous reports on the reintroduced population of bighorns in the badlands of North Dakota, and his research focused on population estimates and food habits. Behavioral studies of these sheep in their new environment have not been conducted.

The objectives of this study were: (1) implement and validate an automated telemetry monitoring system to evaluate 24-hr activity patterns of bighorn ewes in northern Great Plains; (2) determine summer activity patterns of ewes during the different periods of the day; and (3) analyze the influence of temperature and precipitation on activity patterns.

Funding for this study was provided by Cenex and Meridian Oil Companies, North Dakota Game and Fish Dept., and the U.S.D.A. Forest Service. We thank Dr. C. Peterson for instructions on the telemetry/data logger implementation and programming, and Dr. J. Lang for lending his data logger. We also acknowledge the Dept. of Biology, University of North Dakota, for administrative support.

STUDY AREA AND BIGHORN SHEEP POPULATION

The research was conducted at the 14 km^2 Magpie Creek study area, 1.5 km east of the confluence of Magpie Creek and the Little Missouri River in McKenzie County of western North Dakota. Elevation ranges from 646-803 m. The area is rugged and dissected by steep coulees which were formed due to erosion of the soft silt and clay since the Pleistocene. The plant communities are a complex mosaic that reflect the varied terrain. Plateau tops and gentle side slopes (<50%) are dominated by threadleaf sedge (*Carex filifolia*), needle and thread (*Stipa comata*), western wheat grass (*Agropyron smithii*), and blue grama (*Bouteloua gracilis*). The steep southerly facing slopes (≥ 50%) are either non-vegetated or dominated by xerophytic shrubs such as sagebrush (*Artemisia tridentata* and *A. cana*), and rabbitbrush (*Chrysothamnus* spp.). North facing slopes are dominated by Rocky Mountain juniper (*Juniperus scopulorum*). Complexes of shrub communities, including chokecherry (*Prunus virginiana*), snowberry (*Symphoricarpos occidentalis*), and skunkbrush (*Rhus trilobata*), are interspersed within the primary habitats. During most of the past century, livestock grazing was the primary land use and it continues in the Magpie Creek area. During the past 15-20 years, oil development has become increasingly widespread in the Little Missouri badlands, and the current density of active oil wells within the study area is 1.6 wells/km^2.

Audubon's bighorn (*O. c. auduboni*) previously occupied the badlands, but they were extirpated by the early 1900s (Fairaizl 1978, Knue 1991). Eighteen California bighorns were introduced to the Magpie Creek area in 1956 (Fairaizl 1978, Knue 1991), and by 1975, the area was inhabited by at least 30 sheep (Fairaizl 1978). The herd count totalled > 40 sheep as recently as 1990 (W. Jensen, North Dakota Game & Fish Dept. pers. comm.); however, only 18 individuals have been observed within the Magpie Creek study area since our research commenced in 1992.

METHODS

Eight ewes and 1 ram were captured using a net gun fired from a helicopter during March of 1992. Each ewe was ear-tagged and fitted with a radio-collar that was equipped with a motion-sensitive tip switch (Telonics Inc., Mesa, Arizona). The ram was ear-tagged and released. Radio signals from each ewe were recorded for 30 sec, every 5 min, 24 hr/day by a telemetry/data recording system. The signals were received by an omnidirectional antenna that was connected to a Telonics TR-2 receiver/scanner and Telonics TDP-2 data processor. The telemetry equipment was interfaced with a Campbell Scientific CR10 data-logger (Campbell Scientific, Logan, Utah) (MacDonald 1990, Peterson and MacDonald In Prep.). The system was powered by a 12 V battery that was recharged with a 5 w solar panel. Data were stored and periodically down-loaded onto a personal computer.

The telemetry system recorded whether an animal was active or inactive. Active behaviors included feeding, walking, running, and social activities. Inactive behaviors included bedding and standing still. To validate accuracy, 5 of the radio-collared ewes were observed directly while the system was operating, and the recording was compared with observed activity. Activity analysis was conducted by compiling data from randomly selected 24 hr periods during June, July, and August of 1992 (n = 10) and 1993 (n = 14). Missing data were discarded from the analysis. Temperature and precipitation data were collected at Fairfield weather station, located 37 km southeast of the study area.

Activity data for the ewes were combined because field observations indicated that the radio-collared ewes usually remained in the same group (Sayre unpublished data), thus their activity patterns were not independent. The proportion of time ewes were active were averaged for each hour and for different periods of the day. The 24 hour cycle was categorized into 4 periods based on civil twilight (Anonymous 1992, 1993): AM twilight (beginning when the sun was 6° below the horizon; daytime (sunrise to sunset); PM twilight (sunset until the sun was 6° below the horizon); and night (between the end of PM twilight and the beginning of AM twilight). Daytime was subsequently divided into 3 periods: morning (the first 4 hours following sunrise), mid-day (from > 4 hours after sunrise until 4 hours before nightfall), and evening (4 hours prior to nightfall). Times were recorded at Mountain Daylight Time. Two levels were analyzed to evaluate relationships between activity patterns and ambient temperature: ≤ 23 and > 23 C. This temperature was used because it is the best available estimate for upper critical temperature (UCT) of a bighorn ewe. Information on UCT for northern bighorn sheep are lacking, and 23 C was used as a threshold because it has been reported as the average UCT for mule deer (Parker and Robbins 1984, Parker and Gillingham 1990), a ruminant that is approximately the same size and body shape as a bighorn sheep. In addition, 2 levels for precipitation were used: wet and dry. We analyzed this variable because the bentonite clay ridges, used as the primary escape terrain by the sheep, become extremely slippery when wet. We hypothesized that the behavior patterns could be different on wet days because field observations indicated that the sheep had difficulty negotiating the steep slopes. Wet days were defined by field observations, and/or when ≥ 0.5 cm was recorded during the 24 hr period that activity data were recorded, or when ≥ 1.0 cm of precipitation was recorded during the previous day (the bentonite remains slippery for > 24 hr after substantial rainfall).

The data were subjected to repeated measures ANOVA, with activity as the dependent variable, and year, temperature, and precipitation as the independent variables. Paired t-tests with the Bonferroni inequality (Snedecor and Cochran 1989) were used to compare activity levels during different periods of the day. Influence of weather variables on activity levels were compared with the two sample t-test. Statistical analyses were conducted with SAS computer programs (SAS 1985).

RESULTS

When compared with visual observations, the telemetry monitoring system correctly recorded active behavior 93 of 95 times (97.9%), and inactive behavior 109 of 114 times (95.6%). However, preliminary analysis of the data indicated that the radio-transmitter from 1 ewe malfunctioned. Therefore, data from this animal were excluded from further analysis.

Hourly activity patterns indicate that the ewes followed a diurnal activity schedule during summer (Fig. 1). Ewes were relatively inactive at night and displayed peaks of activity at about 0600-0700 and about 1400-1800. During a mid-morning lull (0900-1100), activity levels were reduced by at least 50% when compared to peak times. The ewes typically had 3- 4 activity bouts/day.

Statistical analysis of the activity patterns indicated that the ewes were significantly less active ($P < 0.001$) in 1992 than in 1993. Thus the data were analyzed separately by year, even though daily trends between years were similar. During both summers, the ewes were less active at night and AM twilight, and more active during the day and PM twilight ($P < 0.01$) (Table 1). Analysis of data from different daytime periods, indicated a slight decrease of activity from morning to mid-day ($P > 0.30$) in 1992, but revealed significantly greater activity during the evening period ($P \leq 0.01$). In 1993, the ewes were more active in the evening than in the morning ($P < 0.05$) but the other comparisons were not different ($P > 0.15$).

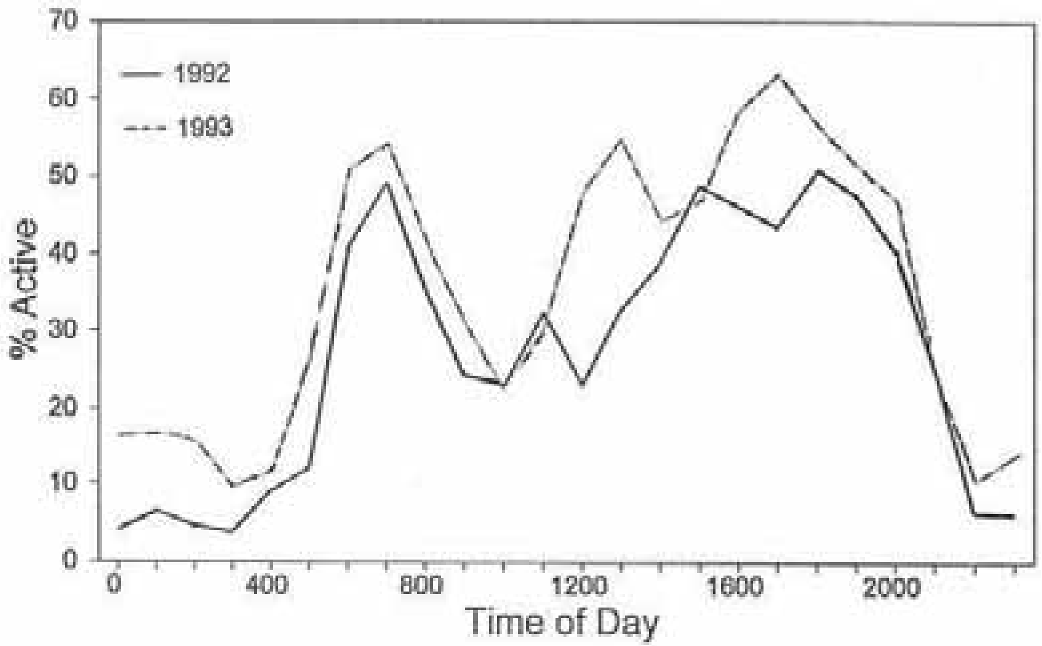

Figure 1. Average 24 hour activity patterns of 7 bighorn ewes during summers of 1992 (n = 10 days) and 1993 (n = 14 days) at Magpie Creek, North Dakota.

Table 1. Proportion of time (%) bighorn ewes were active during segments of 24 hour cycle and during daytime at Magpie Creek study area[a].

	1992		1993	
Period	Mean	SE	Mean	SE
AM twilight	10.2A[b]	2.7	13.5A	2.6
Daytime	35.2B	1.4	44.7B	1.3
PM twilight	34.4B	5.5	39.2B	5.8
Night	5.7A	0.5	12.5A	1.5
Morning	33.9A	2.1	45.9A	2.5
Mid-day	31.8A	1.4	41.2B	2.4
Evening	42.6B	2.8	52.5B	3.1

[a] Ewes (n = 7) were monitored for 10 days in 1992 and 14 days in 1993.
[b] Means within columns with different letters are statistically different ($P \leq 0.05$, adjusted for Bonferroni inequality).

The average summer temperature was 16.7 C in 1992 and 16.2 C in 1993. These were relatively cool compared to the average seasonal temperature of 19.7 C (National Weather Service). Temperatures on days that activity data were recorded did not deviate from the average of each year ($P > 0.30$). Daytime activity levels did not differ when the temperature was $\leq$ 23 C compared to > 23 C ($P \geq$ 0.19) (Table 2). However, the ewes tended to be more active on wet days in 1992 ($P < 0.01$) (Table 2). During 1993 the activity levels during the wet daytime periods were slightly higher than on dry days, but the differences were not significant ($P > 0.20$).

DISCUSSION

The telemetry recording system provided accurate recordings of general activity patterns. Although Kie et al. (1991) reported high r^2 values ($\geq$ 0.91) for mule deer at the level of walking, foraging, and resting, we did not quantify behavior at this resolution because the sheep frequently fed on steep hillsides with their head up, and we were not able to differentiate feeding from other activities. Inaccurate recordings occurred either when the animals were bedded and they moved their head up and down during the 30 sec scan period, or when the animals were standing or foraging without moving enough to tip the mercury switch.

Nocturnal behavior patterns of bighorn sheep are poorly understood. Data obtained in this study indicated that during the summer, bighorn ewes were relatively inactive at night. Although nocturnal observations were not conducted, field observations indicated that the ewes stayed within the same area once they bedded down for the night (Sayre, unpubl.

Table 2. Daytime activity levels of bighorn ewes in relation to temperature and wet weather (wet days had $\geq$ 0.5 cm precipitation, and/or $\geq$ 1.0 cm on previous day; explanation and rationale in text), at Magpie Creek, North Dakota.

Year &	[$\leq$ 23 C][a]		[> 23 C][b]			Dry[c]		Wet[d]		
Period	x	SE	x	SE	P	x	SE	x	SE	P
1992										
Daytime	35.6	1.8	35.1	2.1	0.93	31.5	1.0	38.9	1.4	0.004
Morning	34.4	4.1	33.7	2.8	0.89	30.2	2.5	37.6	2.8	0.090
Mid-day	34.1	1.2	30.9	1.9	0.19	28.4	1.5	35.3	1.0	0.009
Evening	39.3	4.8	43.9	3.7	0.49	38.9	3.5	46.5	4.3	0.200
1993										
Daytime 43.9	1.6	46.8	1.8	0.29	43.3	1.6	45.6	2.4	0.290	
Morning	43.8	3.5	50.4	3.6	0.22	43.2	4.2	49.1	3.0	0.270
Mid-day	41.1	2.7	40.6	5.3	0.90	38.6	3.0	44.3	3.5	0.250
Evening	52.6	3.5	51.3	5.7	0.86	51.6	5.2	53.1	1.3	0.790

[a] n = 3 days in 1992 and 10 days in 1993.
[b] n = 7 days in 1992 and 4 days in 1993.
[c] n = 5 days in 1992 and 8 days in 1993.
[d] n = 5 days in 1992 and 6 days in 1993.

data). The activity that did occur probably represents repositioning and movement among bed sites during the night. Diurnal observations indicated that, during bedding periods, the animals stand and reposition themselves every 30-120 min. Additional research on nocturnal behavior patterns of bighorn sheep is needed.

Circadian activity levels increased > 2 hours/day from 1992 to 1993. A number of factors may have contributed to this increase, including weather, lambing success, predator activity, forage availability and quality, or other disturbances. The activity data in 1993 were collected on relatively more wet and cool days than in 1992 (Table 2). Furthermore, 3 ewes successfully reared lambs in 1992, but no lambs were alive after 1 June 1993. In 1992 the ewes tended to stay closer to their primary lambing terrain than in 1993 (Sayre, unpubl. data), thus their travel time may have been less. Disturbances by coyotes also were observed more frequently in 1993 than in 1992 (Sayre, unpubl. data), which may have contributed to the increased level of activity. Likewise, sightings of rams and ram harassment of the ewes was greater in 1993 than in 1992 (Sayre, unpubl. data). Data on the availability and quality of forage were not collected. However, the timing and stocking rate of cattle grazing did not differ between the 2 years, (Bruce Rogers, U.S. Forest Service, pers. comm.). The effects of other disturbances, such as oil development or interactions of ewes with cattle are yet to be analyzed.

Although activity levels did not vary in relation to the hypothesized threshold of 23 C, field observations have indicated that the ewes sometimes increased daytime bedding intervals on hot and sunny days by resting on the shady side of the ridges (Sayre, unpubl. data). A higher temperature threshold may exist, and research is continuing to determine whether the ewes alter activity patterns when the temperature is high. It is not clear why ewes tended to increase activity levels during wet days. Energetically, they may be less stressed because the cloud-cover would substantially reduce the operative temperature (Parker and Gillingham 1990). In addition, travel by bighorns on steep bentonite-clay ridges appears to be more difficult on wet days, therefore, ewes may be spending more time foraging on less slippery grass and shrub habitats resulting in overall increased activity levels. Data collection is continuing so that telemetry activity recordings can be corroborated with observed behavior and habitat use under varying environmental conditions.

Eccles (1983) reported that semi-captive bighorns in British Columbia averaged 5 diurnal activity peaks during the summer, while Davis (1938), and Van Dyke (1978) reported only 2 or 3 daily peaks for wild sheep in Wyoming and Oregon, respectively, which is closer to the telemetry recordings of ewes at Magpie Creek. The higher number of activity peaks reported by Eccles (1983) may be an artifact due to semicaptivity.

Finally, the data presented in this report are representative of a sample of data from only 1 herd during the summer. Extrapolation of the Magpie Creek data to other populations, or to other seasons should be viewed with caution.

MANAGEMENT RECOMMENDATIONS

Human activities should be scheduled at times that are least disruptive to bighorn sheep. Therefore, we recommend that vehicle traffic within sensitive areas, such as lambing habitat, should be limited to times when the sheep are more likely to be inactive and secure on escape terrain. Specifically, based on the information presented in this report, the early morning prior to 0400, or mid-morning from 0900-1100 would be the best times to allow human activity in close proximity to the sheep.

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EVALUATION OF BIGHORN SHEEP IN THE TEN LAKES SCENIC AREA OF MONTANA

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Abstract: Demographic characteristics, distribution and movements of the Phillipps Creek herd of bighorn sheep (*Ovis canadensis canadensis*) in Montana were investigated during July through September 1991 and all of 1992. The most conservative population estimate for December 1992 was 82. Lamb:ewe ratio in June 1992 was 90:100 and declined to 47:100 by December. The herd spent the rut, winter, and spring periods (mid November through mid May) in British Columbia. The spring range was an enlarged winter range. Two lambing/nursery areas were located in Montana, 17 and 24 km southeast of the winter/spring range. Mixed groups (ewes, lambs, young rams) used areas north and south of the international border, from mid June through mid November. During this same period, ram groups were most often observed south of the border.

In 1977, the Montana Department of Fish, Wildlife and Parks (MDFWP) began documenting reports of bighorn sheep in the Ten Lakes Scenic Area (TLSA) of northwest Montana (MDFWP, unpubl. data). The Fortine Ranger District of the Kootenai National Forest also received reports of sheep in the area over many years and staff observed bighorn sheep during an aerial survey in 1989 (G. Heinz, Wildlife Biologist, U.S. For. Serv., pers. comm.). The existence of this bighorn sheep herd has been known for at least 40 years by the local residents in British Columbia (A. McDonald, Grasmere, B.C., pers. comm..).

The primary objective of our study was to conduct ground surveys during all seasons of the year to determine abundance, composition, and productivity of the bighorn sheep population that inhabits the TLSA in summer. We also describe the distribution and movements of the herd.

This project was designed initially as an observational field study. After the first field season, the cooperators decided that due to the limited access and rugged topography of the area data collection could be enhanced by putting radio-collars on some bighorns. However, because of a limited budget for flying, the basic study plan was not altered.

The study was funded cooperatively by the Ministry of Environment and the East Kootenay Wildlife Association in Canada; the USDA Forest Service: Kootenai National Forest and MDFWP in the United States; and the Foundation for North American Wild Sheep.

STUDY AREA

The study area (Fig. 1) includes a portion of the southwestern end of the Galton Range in British Columbia (B.C.) and the northwestern end of the Whitefish Range in Montana. The TLSA (2,603 ha) is within the Kootenai National Forest, immediately south of the international border. The western boundary of the study area is formed by the Rocky Mountain Trench.

METHODS

Bighorn sheep were captured with a drop-net at 2 different sites, in February and March 1992. Sites were baited daily with alfalfa hay and apple mash or whole apples. A mineral block and a pan of granular minerals, containing vitamin E-selenium, also were available at each site. Captured bighorns were hobbled and blindfolded. Sex, age, and any identifying marks were noted. All animals were marked with a numbered ear tag and a shot of vitamin E-selenium (1 cc adults, 0.5 cc lambs, I.M.) to guard against capture myopathy (Hebert and Cowan 1971, Dalton et al. 1978, Kock et al. 1987). Radio-collars were attached to 9 bighorns.

Bighorn sheep were located by hiking or driving to likely locations within the study area and looking for them with a 7x binocular or a 15-60x variable power telescope. Additionally, aerial survey flights in fixed or rotary wing aircraft were conducted approximately once per month to locate and

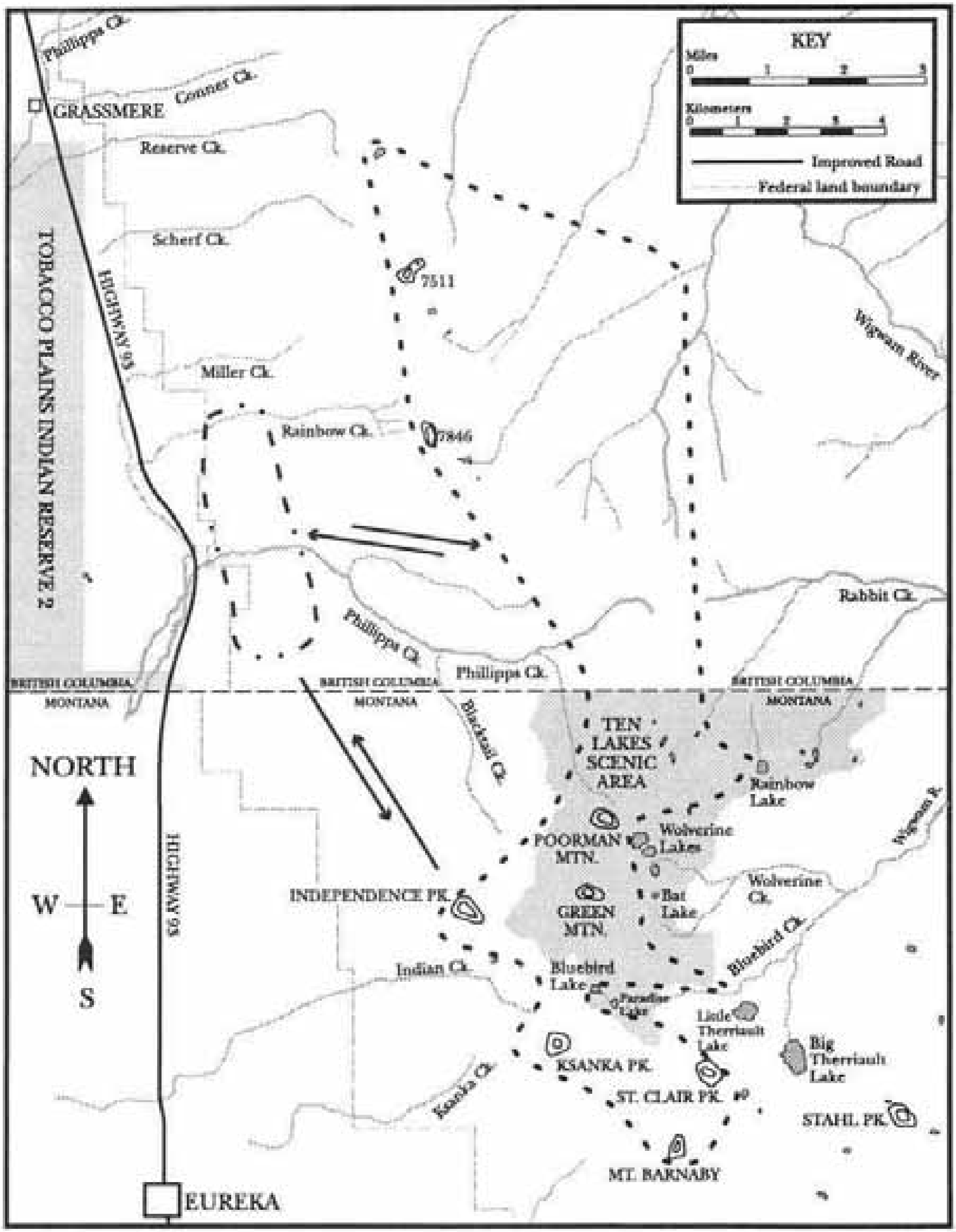
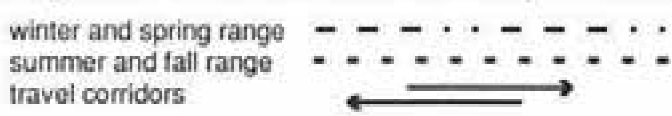


Figure 1. Seasonal ranges and travel corridors of the Phillips Creek bighorn sheep herd.



observe bighorns. Later, radio telemetry was used to locate bighorns during fixed wing aerial surveys and on the ground.

Once located, the number in the group and the age and sex class of each individual, according to their horn size and shape and body size (Geist 1971), was identified. The location of each observation was recorded on an aerial photograph or topographic map so the site could be visited later to determine habitat type and measure topographic characteristics. The timing of each season is based on the activities of the bighorn sheep herd.

Observations from 12 days during December 1992 were used to estimate the size of the bighorn population. Two population estimates were calculated: one using the Schumacher-Eschmeyer equation (Caughley 1977), one using a technique developed by Miller et al. (1987), in which the authors modified the standard capture-recapture technique so that the geographic closure requirement was not necessary. The maximum number of bighorn sheep observed in each age and sex class during the same period (December 1992) was used to estimate the size of the population and calculate the percentage of the population in each age and sex class. Lamb/ewe ratios were calculated according to Bowden et al. (1984).

A yearly home range of the herd was calculated using the harmonic mean method (Dixon and Chapman 1980). The accurate determination of a harmonic mean home range is dependent on 2 assumptions: locations are independent of each other and the probability of detecting an animal is proportional to the amount of time the animal spends in that area (Samuel et al. 1985). Further, the use of fewer than 50 locations to determine harmonic mean home range results in an enlarged home range (Jaremovic and Croft 1987). These requirements were addressed by using 84 observations and radio locations obtained during aerial surveys. The calculation of seasonal home ranges would have required the division of the 84 locations into at least 2 groups. Therefore, it was decided a yearly home range was the most accurate home range that could be determined.

RESULTS

Sixteen bighorn sheep were captured and marked in 2 trapping attempts. Radio-collars were put on 6 females and 3 males. Upon release, no bighorns showed any symptoms of capture myopathy, as described by Dalton et al. (1978). No animals were injured or killed during the trapping or handling procedure.

The Schumacher-Eschmeyer equation produced an estimate of 92 (0.95 CI = $70 \leq X \leq 132$) individuals during December, 1992. The technique developed by Miller et al. (1987) provided an average population estimate of 82 (0.95 CI $49 \leq X \leq 106$) during the same period (see Table 1 for data used to calculate estimates). Using the conservative estimate of 82, we estimate the population contained 34 females, 32 males and 16 lambs during December 1992.

The observed lamb/ewe ratio for February 1992, was 34:100 (0.95 CI, $19 \leq X \leq 49$) (Fig. 2). By April it had dropped to 10:100 (0.95 CI, $0 \leq X \leq 22$). Productivity during 1992 was high. The observed lamb/ewe ratio for June was 90:100 (0.95 CI, $70 \leq X \leq 100$). The lamb/ewe ratio declined throughout the summer and by December it was 47:100 (0.95 CI, $41 \leq X \leq 53$).

Mixed groups of ewes, rams, and lambs wintered on the hills and benches 3 km north of the international border (Fig. 1). Phillipps Creek bisects the winter range (Fig. 1). A portion of the area used by bighorn sheep south of the Creek is private land. Much of the forested private land has been logged and the remaining over story canopy cover is <10%.

Ram groups were seen regularly in the same area as mixed groups, during January. However, after 5 February, few mature rams were encountered. A group of rams was seen on 24 March, on the ridge north of Rainbow Creek. Subsequent visits revealed several rams using this area.

The spring range was an expanded winter range. In late April, radio-collared ewes began making movements east up the Phillipps Creek drainage and south along the west face of the mountains. However, they returned to the core winter range. On 14 May, they began moving to lambing/nursery areas and did not return. Only 1 ram group was observed during spring, on the ridge above Rainbow Creek.

Two lambing/nursery areas were identified south of the international border. Ewes with their lambs used the south face of Mt. Barnaby, 24 km southeast of the winter range. They also were found on the south face of "No Grizzly Ridge", 17 km southeast of the winter range and 1 km northwest of Little Therriault Lake.

During summer, most radio-collared ewes moved back and forth across the international border several times. They traveled throughout the TLSA and were observed 12 km north of the Border

Table 1. Data used to calculate population estimates for Phillipps Creek bighorn sheep herd, 1992.

M Number of marked animals in the area	m Number of recaptured animals in each sample	n Number of animals in each sample
7	7	53
6	4	46
6	3	25
7	4	58
7	1	20
6	4	54
7	2	15
5	0	33
6	3	44
7	2	35
6	1	27
6	3	36

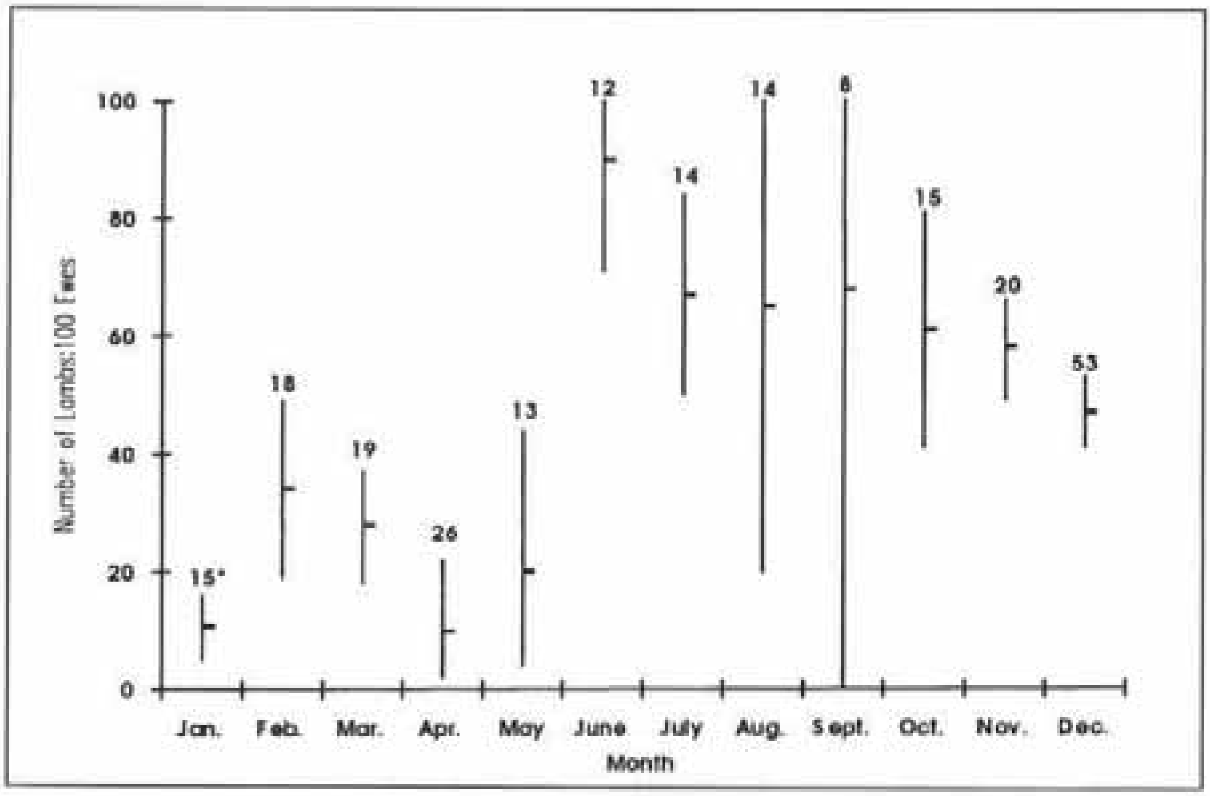


Figure 2. Number of lambs:100 ewes and 95% confidence intervals for the Phillipps Creek bighorn sheep herd, 1992 (* Number of observations).

in B.C. (Fig. 1).

Rams appeared to move less than mixed groups and spent most of the early and late summer in the Ksanka Peak area in the southern portion of the summer range. Poor Man Mountain and the Ten Lakes Basin, immediately to the east, were used during mid-summer. Small groups of rams were observed in other parts of the range throughout the summer. Some mixed groups moved north into B.C. and remained there during fall. Others remained in the TLSA until they moved onto the west face of the mountains. Ram groups were most often observed in the Ksanka Peak-Independence Peak area.

The herd returned to the winter range area and the rut started in mid-November (Fig. 1). Most of the mating activity occurred south of Phillipps Creek. After mid-December mixed groups began redistributing over the winter range.

Based on radio-locations, observations, and reports from hunters, 2 travel corridors were identified (Fig. 1). One route took the bighorns east-west along the ridge north of Phillipps Creek. On the other route, bighorns traveled north south along the west side of the mountains when moving between winter and summer ranges.

The area included in the yearly 0.95 harmonic mean home range was 207 km^2.

DISCUSSION

The Schumacher equation (Schumacher-Eschmeyer 1943) is one of a number of techniques based on the mark-recapture method. All such techniques include several assumptions that must be met to produce an accurate estimate. The assumptions are: geographic and demographic closure of the population, correct identification of marked animals, independent probability of capture, and no loss of marks (Caughley 1977, Neal et al. 1993). The method developed by Miller et al. (1987) is also based on mark-recapture techniques. However, it has been modified to correct for a lack of geographic closure. In this study, the 2 methods produced similar estimates of the size of the Phillipps Creek herd, resulting in increased confidence in the estimate.

In unhunted populations, bighorn rams may equal or outnumber ewes (Buechner 1960, Woodgerd 1964). A nearly equal male:female ratio (0.9:1) has been reported for a lightly hunted bighorn population (Cowan and Geist 1971). The Phillipps Creek herd has a sex ratio (0.94), similar to lightly hunted bighorn populations.

Caughley (1974) demonstrated that age ratios do not necessarily reflect changes in wildlife population trend. He showed that both increasing and decreasing populations could have similar age ratios. More specifically, Geist (1971), Festa-Bianchet (1992), and Jorgenson (1992) have discussed the difficulties of using age ratios to predict trends in bighorn sheep populations. The only reliable information that can be gathered from the high lamb:ewe ratio documented for this population during June 1992, is that most females in the population produced viable offspring. The declining ratio from June through December, demonstrates that summer-fall lamb loss may be fairly high.

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EFFECTS OF AGE OF PRIMIPARITY UPON HORN GROWTH IN BIGHORN EWES.

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Abstract: The effects of age of first lambing upon changes in horn length were investigated in a marked population of bighorn sheep (*Ovis canadensis*) in Alberta. Two-year-old ewes that raised a lamb had longer horns at the beginning of the summer (June 5), but grew less horn during summer (June 5 to September 15) than other two-year-old ewes. Horn length of 3-year-olds was independent of age of primiparity.

Several recent studies suggest that animals adjust reproductive effort to reproductive potential (Boyce and Perrins 1987, Pettifor et al. 1988, Stearns 1992, Pettifor 1993;). Age of primiparity (first birth) should largely be determined by variations in individual quality. Individuals that will, on average, profit from early reproduction, should reproduce at a younger age than individuals for whom the fitness costs of early maturation are likely to exceed its benefits.

If this prediction is correct, within a population, individuals that mature early should be of better quality than late-maturing individuals. The post-reproductive growth of early-maturing individuals could be slowed by their investment in reproduction, but not enough to offset the fitness gains of early reproduction. There is, however, little information on the consequences of variation in age of primiparity for subsequent growth of female ungulates. Green and Rothstein (1991) found that bison (*Bison bison*) cows that first calved at 2 years of age were smaller at age 3 than cows giving birth for the first time at 3 or 4 years of age.

In a previous paper (Jorgenson et al. 1993a), we examined the causes of variation in age of first reproduction in bighorn sheep ewes at 2 different study sites. On average, ewes that produced a lamb at 2 years had longer horns as yearlings than ewes who postponed their first lambing until later, but there was considerable overlap in horn length between the two groups. For example, horn length at 15 months of age at Ram Mountain, Alberta varied from 8 to 18 cm (plus a very small ewe with horns of only 4 cm) for ewes that failed to produce lambs at 2 years of age, and from 10 to 18 cm for ewes that produced lambs at 2 years. At Sheep River, Alberta, the horns of 15-month-old ewes that produced lambs the following year were about 20% longer than the horns of 15-months old that failed to lamb as 2-year-olds (17.3 vs 14.4 cm) (Jorgenson et al. 1993a).

Here, we explore the consequences of variation in age of first reproduction upon subsequent horn growth of bighorn ewes in the Ram Mountain population. We expected less horn growth for ewes that produced and nursed lambs at 2 years of age compared to nonparous ewes of the same age.

Financial support was provided by the Natural Sciences and Engineering Research Council of Canada and the Fonds pour la Formation de Chercheurs et l'Aide à la Recherche (Québec) (operating grants to MFB), the Alberta Recreation Parks and Wildlife Foundation (grants to JTJ), and the Alberta Fish & Wildlife Division. Numerous people helped us capture and observe bighorn sheep and we express our gratitude to them. Earlier drafts of the manuscript were constructively reviewed by J. T. Hogg, W. J. King, M. J. Pybus and S. C. Stearns.

STUDY AREA AND METHODS

Ram Mountain (52°N, 115°W, elevation 1082 to 2173 m) is separated from the main Rocky Mountain range by 30 km of coniferous forests. A corral trap baited with salt allowed multiple captures of almost all ewes each year, and over 95% of the population was marked individually in most years. Trapping took place between late May and late September or early October. Horn length was measured with a measuring tape to the closest mm along the front of the horn, from the hairline to the tip. We used the average length of the 2 horns, unless one was obviously broken, in which case we measured only the most intact horn. If both horns were broken, the ewe was excluded from the sample. The lactation status of ewes was checked at capture by visually inspecting the udder and attempting to squeeze out milk and during observations by noting lamb suckles.

Between 1972 and 1981, the population was kept at 95 - 110 sheep by yearly removal of 12-24% of adult ewes (Jorgenson et al. 1993b). Removals ceased in 1981 and the population increased to 210 sheep by 1992. Only one of 50 2-year-olds produced a lamb during 1989-1991. Therefore, only ewes born before 1987 were considered in our analyses.

Summer horn growth of 2-year-old ewes was approximately linear (Figs. 1 and 2). We adjusted horn lengths to common dates by linear regression with May 25 as day 1. We chose June 5 (day 12) for early-summer horn length, and September 15 (day 114) for late-summer horn length comparisons. We used individual horn growth rates to adjust horn length for ewes with at least 40 days between first and last capture. For ewes caught only once in a summer (6% of ewes), we used an overall regression of horn length on date calculated for all captures of ewes of the same age and reproductive status (barren, lost lamb, or weaned a lamb). Horn length was adjusted only if a measurement was available within 50 days of the desired date; otherwise the ewe was excluded from the sample. The average time between adjusted and measured horn length was 8.8 days ± 0.7 SE for June 5, and 27.4 ± 1.3 days for September 15.

Overwinter horn growth was calculated for individual ewes by subtracting length on September 15 from length on June 5 the following year. More detailed descriptions of our study area and methods are presented elsewhere (Jorgenson et al. 1993a, 1993b).

Definition of Variables

Early producer. A ewe that produced her first lamb at 2 years of age.

Late producer. A ewe not known to produce her first lamb at 2 years.

Successful early producer. An early producer whose lamb survived to early October, the approximate time of weaning.

Statistical Analyses

We used ANOVA to compare three groups of ewes: late producers, early producers whose lamb died, and successful early producers. Sex of lamb reared by 2-year-old ewes had no effect upon maternal mass changes (Bérubé et al. in prep.), therefore data for mothers of lambs of either sex were pooled. ANOVAs were followed by Scheffé tests to detect pairwise differences between the three groups (Sokal and Rohlf 1981). The sample of 2-year-olds that produced but lost their lambs was small; therefore, some comparisons were limited to t-tests between successful early producers and late producers.

RESULTS

Overwinter horn growth of yearling ewes was independent of their reproductive status the following year: it averaged 2.5 ± 0.3 cm for late producers (n = 40), 3.0 ± 1.1 cm for unsuccessful early producers (n = 5), and 2.8 ± 0.4 cm for successful early producers (n = 12) ($F_{2,54}$ = 0.28, P = 0.76). Early producers already had longer horns as yearlings (Jorgenson et al. 1993a). On June 5 at 2 years of age, successful early producers still had longer horns than late producers ($F_{2,94}$ = 4.91, P = 0.009, pairwise difference P<0.05, Scheffé test). For 2-year-old ewes, horn length and horn growth during summer differed with reproductive status (Fig. 3).

During summer (June 5 to September 15) as 2-year-olds, late producers had greater horn growth (4.1 ± 0.2 cm, n = 55) than successful early producers (3.1 ± 0.3 cm, n = 14; t_{41} = 4.52, P = 0.001). The horns of unsuccessful early producers grew considerably (4.4 ± 0.7 cm) but only 3 were captured sufficiently near the beginning and the end of the summer to calculate horn growth, so they were not included in the analysis. Despite greater summer horn growth, by September 15 late producers still appeared to have shorter horns than successful early producers (Fig. 3), although the differences between groups were not significant ($F_{2,78}$ = 2.81, P = 0.07).

The horns of some 2-year-olds grew between September 15 and June 5, while those of others became shorter. Overall, horn growth over winter was not affected by reproductive status at 2 years ($F_{2,61}$ = 0.62,P = 0.5), averaging 0.3 ± 0.2 cm. The horns of 3-year-olds on June 5 did not differ according to reproductive status at 2 years ($F_{2,69}$ = 0.95, P = 0.4), and averaged 20.6 ± 0.3 cm (Fig 3).

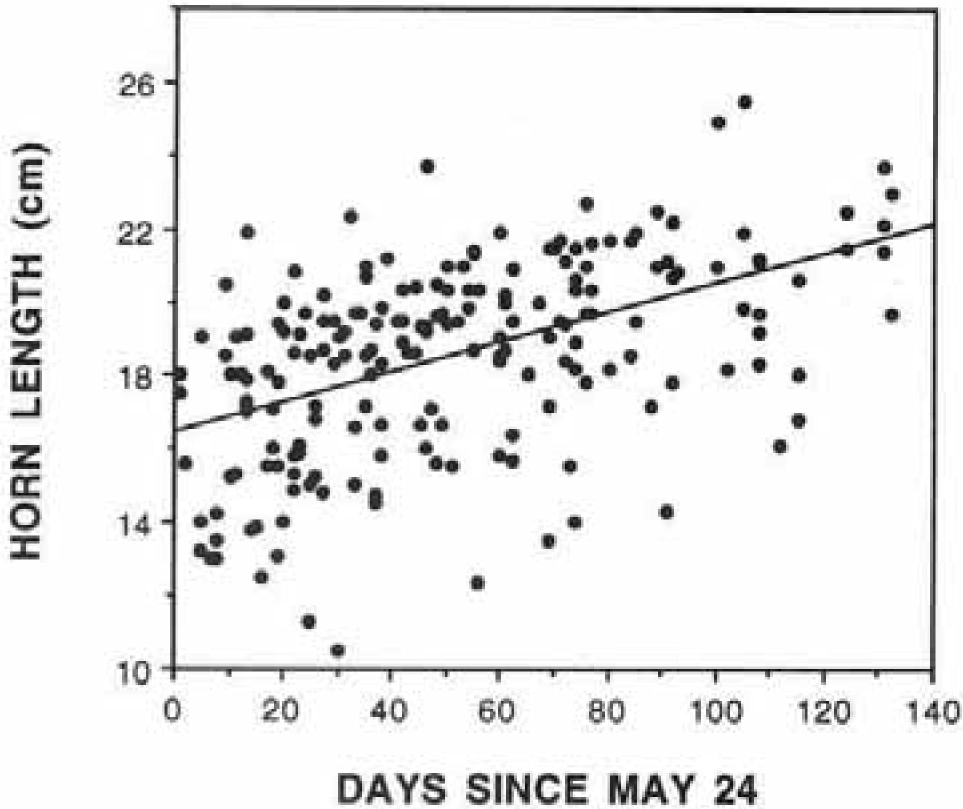

Figure 1. Horn length of all 2-year-old bighorn sheep ewes captured at Ram Mountain, Alberta, 1975 to 1984 (r^2 = 0.25).

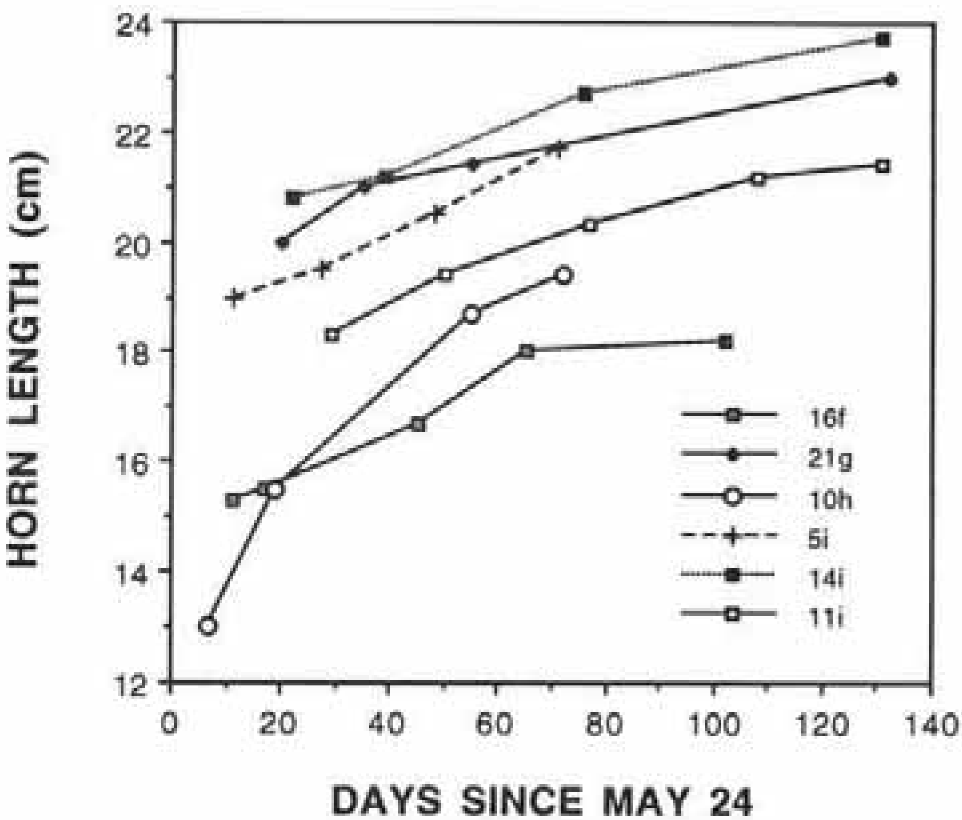

Figure 2. Horn length of individual 2-year-old bighorn sheep ewes captured at Ram Mountain 4 or more times during a summer.

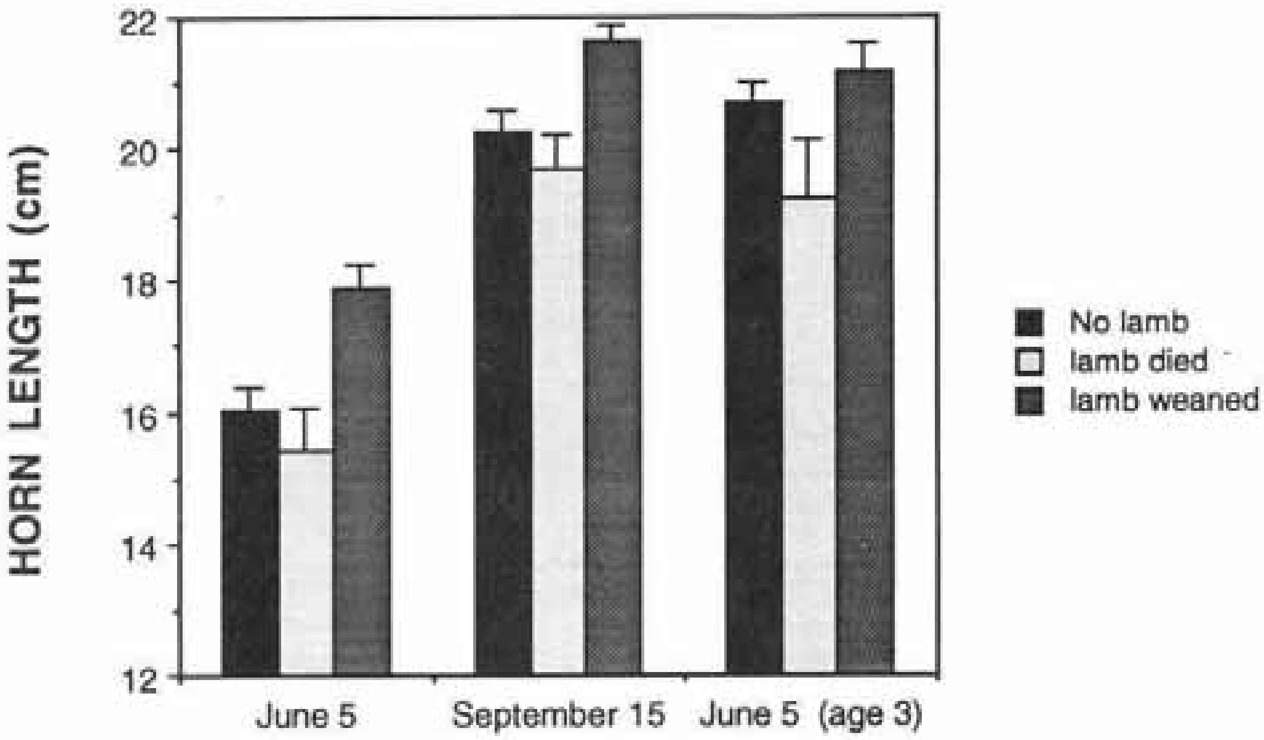

Figure 3. Horn length of 2 and 3-year-old bighorn ewes ($\bar{x} \pm$ SE) of different reproductive status at Ram Mountain, Alberta, 1975 to 1989.

DISCUSSION

We predicted that early reproduction should have negative effects upon horn growth. Horn growth of yearlings between September 15 and June 5 was not affected by pregnancy. This result, however, does not imply that pregnancy had no effects on growth. Horn growth during summer was linear and presumably continued after late September. By the time of the rut in late November or early December, however, ewes had probably either stopped growing their horns or their horn growth rate had considerably diminished. In Dall sheep (*Ovis dalli*), yearlings cease horn growth by mid-November (Hoefs and Nette 1982), and bighorns likely exhibit a similar pattern because by then they subsist on low-quality forage. Therefore, it is likely that much of the horn growth that we measured between mid-September and early June actually took place between mid-September and December, before any ewes conceived. If our suggestion is correct, then pregnancy could not affect changes in horn length from 1 to 2 years of age.

As expected, horn growth of 2-year-olds nursing lambs through summer was less than for non-lactating 2-year-olds. This result suggested a short-term trade-off between reproduction and growth: ewes that produced milk were unable to grow their horns at the same rate as non-lactating ewes. Parous 2-year-olds whose lambs died did not bear the costs of lactation. They gained horn length over the summer at a rate similar to that of nonparous 2-year-olds, confirming the negative effect of lactation upon horn growth.

Our results suggest an energetic cost of lactation, which was reflected in lower horn growth. The functions of horns in bighorn sheep females, and in other female bovids (Packer 1983), however, are unclear. It is not known whether a few centimeters difference in horn length may affect a female's life history. Social relationships among females in bighorn sheep appear to have little effect upon reproductive success (Eccles and Shackleton 1986, Festa-Bianchet 1991) and it may be premature to interpret our results as indicators of a long-term life-history cost of early reproduction.

By age 3, age of primiparity had no significant overall effects upon horn length. This finding contrasts with results obtained for body mass in reindeer, *Rangifer tarandus*, (Leader-Williams and Ricketts 1982) and bison (Green and Rothstein

1991) , where early producers suffered a decrease in body growth. Early reproduction may affect growth in bighorn sheep less than in other ungulates, suggesting that bighorns may recover from the energetic costs of reproduction by exploiting summer forage.

MANAGEMENT IMPLICATIONS

Accurate horn length and horn annuli measurement of bighorn ewes could be useful as an index of the frequency of reproduction among 2-year-olds. In Japanese serow (*Capricornis crispus*), reproduction has a negative effect on female horn growth, and horn annuli reflect a female's reproductive history (Miura et al. 1987). Miura et al. (1987) were able to measure all horn annuli in Japanese serow. In that species, similarly to other rupicaprids, annuli are fairly evident. In bighorn sheep, annuli are difficult to identify for ewes older than 5-6 years. However, an accurate measurement of the first 4 annuli usually is possible. By comparing measurements of the first 3 annuli of different ewes from the same population one should be able to estimate the frequency of early reproduction. This indirect way of assessing reproductive performance would be useful in several ways. For example, it would help in estimating population growth rates and in assessing population status: our study at Ram Mountain revealed that one of the first consequences of increasing population density was an abrupt drop in the frequency of reproduction among 2-year-old ewes (Jorgenson et al. 1993a). It would also be a useful criterion for assessing habitat productivity, as reproduction in 2-year-old ewes is likely indicative of high-quality habitat (Geist 1971).

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SOCIAL STATUS AND NANNY-KID SEPARATION IN ROCKY MOUNTAIN GOATS.

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Abstract: The social structure of Rocky Mountain goats (*Oreamnos americanus*) in the Gore Range of central Colorado was studied using a cardinal ranking system. On average, nannies with kids were most dominant, followed by billies, adult females without kids, male 2-year-olds, female 2-year-olds, female yearlings, and male yearlings. Nannies with kids ranked 1 through 3 had larger spacing between cardinal values than mountain goats ranked 3 and below indicating that the relationship between dominant nannies was relatively well established. Nannies with kids interacted 2 to 10 times more among themselves than with non-nanny goats but, the overall average level of aggressive interactions for nannies was lower than for non-nanny goats (Kruskal-Wallis $p<0.05$). It was hypothesized, and demonstrated (Kruskal-Wallis $p<0.01$), that lower ranking nannies at the salt lick would be separated from their kids more frequently than high ranking nannies.

Early studies on dominance in social animals usually were descriptive accounts of social organization. Gradually, ordinal ranks, based on dyadic matrices replaced the descriptive accounts with more quantitative studies (Thouless and Guinness 1986, Holekamp and Smale 1992). However, the use of ordinal ranks for structuring animal societies suffers from several problems: 1)difficulty in assessing the magnitude of difference in dominance among individuals; 2) difficulty in comparing dominance matrices based on different herd sizes and observation periods; and 3) difficulty in employing statistical techniques to relate dominance rank to other qualities of interest (Boyd and Silk 1983). To overcome these draw-backs, cardinal ranking systems have evolved.

Cardinal ranking methods incorporate information about interactions that end in wins, losses, and ties to generate an index of dominance rank. This paper describes the social organization of Rocky Mountain goats using a cardinal ranking system from data of 14 herds observed congregating at mineral licks during the summer months of 1992 and 1993.

Observations that led to the investigation of social structure included: 1) aggressive interactions between cohorts for access to salt lick holes; 2) a tendency for nannies to aggressively interact specifically with other nannies; and 3) separations of kids from nannies who lost in aggressive interactions. Frequency of nanny-kid separations (Hopkins et al. 1992), maintenance of proximity (DeBock 1970, Hutchins 1984), and distances between nanny and kid (Chadwick 1983) have been evaluated.

We hypothesized that nannies who were chased or displaced from the salt lick by other nannies were of low ranking status. Furthermore, we hypothesized that low ranking nannies were becoming separated from their kids more often than high ranking nannies.

METHODS

Population

The mountain goats studied were members of a population of approximately 125 animals in the Gore-Eagle's Nest Wilderness Area of the north central Colorado Rocky Mountains west of the Continental Divide. Observations were restricted to Elliott Ridge, a long narrow alpine ridge with numerous salt licks (Hopkins et al. 1992). Mountain goats entering the salt lick area together during any one observation period were considered a herd sample. All nannies were identified as individuals by tags, collars, pelage patterns, scars, or broken horns. Two-year-olds were classified visually as animals ranging in height and horn size between the majority of all adults and yearlings at the salt lick. Gender was determined by urination postures and during opportunities to observe genitalia. Mother-offspring relations were established on the basis of nursing and close association. Agonistic and separation data were collected for individuals in 14 herds ranging in size from 10 to 45 animals, with a mean herd size of 21. A total of 93 hours was spent in behavioral observation.

Analysis

Dominance hierarchy structure was assessed by scoring win- loss outcomes in competition between individuals (Chase 1974). In this study, dominance is defined as an individual's ability to acquire access to a salt lick hole and defend it from competitors. A win was tallied when an individual chased another away with a rush, horn, or present threat (Chadwick 1983) or if by moving towards a salt lick hole it displaced an individual that was there originally. These events are marked by the approach of a challenger, the encounter, and the resulting win or loss. The wins and losses were tallied in dyadic matrices.

Ordinal Ranking with Dyadic Matrices

Analysis involved three steps. First, mountain goats were ranked ordinally through placement along a dyadic matrix. Ordinal ranks were the arrangement of mountain goats based on win/loss outcomes, where losers had the lowest placement relative to others in a dyadic (sociometric) matrix. Each dyadic matrix used the common convention of listing losers along the top and winners along the left column respectively. The matrix was sorted to maximize the total of entries listed in the upper triangular portion of the matrix. This procedure placed animals in ordinal positions of dominance from most dominant on the top of the left column to least dominant on the bottom. The most dominant animal is placed at ordinal number 1 and less dominants take higher numbers relative to their positions lower down in the hierarchy. Nannies and their kids are listed together as one individual in the dyadic matrix. Lone kid interactions are ignored because these do not constitute a determination of rank within the herd. Such interactions include play behaviors with other kids and rejection of lost kids by nannies to whom the kid does not belong.

Cardinal Ranks Obtained from the Estimator of Probable Dominance

Secondly, cardinal ranks were derived from the ordinal ranks (Equation 1) . Cardinal ranks were values derived from the total number of wins per total number of contests. Unlike ordinal ranks, they help to normalize the rank values for all mountain goats found in different size herds and observation periods.

$$R_j = R_i + 2\left[\frac{A_{ij}}{A_{ij} + A_{ji}}\right] \quad (1)$$

The alpha goat is given an ordinal rank of i = 1 and a cardinal rank, R1 = 1.00 . To calculate each subsequent rank we let j = i + 1 . This means that the cardinal rank, Rj, of each goat was calculated from the next higher up, Ri, in ordinal rank. This allowed subordinate ranks to be determined relative to each ordinally higher ranking goat. Aij is the number of wins by ordinal j against ordinal i. Aji is the number of wins by ordinal i against ordinal j.(Aij + Aji) equals the total contests between i and j. The expression Aij/(Aij + Aji) is the ratio of wins by the higher ordinal rank to the total number of contests fought; it has a range of [0,1]. It is also the estimator of probable dominance of j over i.

If i and j win equal numbers of contests against one another then the estimated probability of dominance is 0.5, which means that i is not shown to be dominant to j. The cardinal rank, Rj, provided by Equation 1 will be equal to Ri when the data fails to support dominance. This is achieved by subtracting 0.5 from the estimator of probable dominance to obtain a range of [-0.5,0.5]. This expression is then multiplied by 2 to make it consistent and comparable to the whole number ordinal ranking system by giving the rank difference a range of [-1,1]. If i wins all contests against j then Rj = Ri + 1 making the cardinal ranking system comparable to the ordinal ranking system.

Dominance is increasingly well established as series rank differences get closer to one. The series ranking given by Equation 1 is particularly useful in quantifying how well various ages or sexes of animals are placed in a hierarchy. We define the rank difference, (Rj = Rj - Ri . These rank differences can be averaged for age and sex groupings.

Equation 1 is undefined where (Aij + Aji) = 0. The dyadic matrices were fairly sparse. Arbitrary selection of any two goats will usually give the undefined result, but in such cases Equation 1 is not applicable. The equation depends on first properly ranking the goats ordinally in a dyadic matrix and calculating the cardinal ranks starting with the alpha goat. Most of the contests were fought between goats of close ordinal rank. If contests had been fought randomly, independent of ordinal rank, then Equation 1 would not be a useful estimator of cardinal rank. There were a few cases where (Aij + Aji) = 0 between adjacent ordinal ranks because there were no contests. We adopted a convention that assumed such cardinal ranks to be equal. The main reason for this assumption is that some of the nannies were the first to take possession of one of the several salt lick holes and remained unchallenged during the entire period of observation. Randomness in nanny-kid separations based on ranks was evaluated with a Kruskal-Wallis (K-W) test (Devore 1991).

Herd Sample Normalization of Cardinal Ranks to a Scale of Ten

One problem with Equation 1 is that the cardinal ranks of the lower ranking animals have a high dependency on herd size. The maximum possible cardinal rank number is equal to the number of animals in the herd, but could only occur if all dominants won all contests against their subordinates. Nevertheless, larger herds will force the subordinate ranks downward relative to smaller herds. An improvement to the method would minimize any herd size dependency in dominance ranking.

After herd sample has been ranked using Equation 1, a conversion factor is calculated that allows the ranks to be adjusted to a scale of ten. This means that for every herd sample the maximum rank number is 10 with all other ranks multiplied by the same conversion factor. The conversion factor, c, is calculated by Equation 2:

$$c = \frac{10}{R_{MAX}} \qquad (2)$$

R_{MAX} is the maximum rank number obtained from the herd sample using Equation 1. After Equation 2 has been applied, cardinal ranks are confined to a scale of 10. Any number could be substituted for 10 in Equation 2. If it is equal to the herd size, the cardinal ranks will be closest to the ordinal ranks. The value, 10, itself is not important. Its importance lies in the fact that the conversion factor reduces the effect of herd size on cardinal rank and allows valid comparisons to be made from one herd sample to the next regardless of size.

Definitions, Terminology, and Notation

The following terms are used: a nanny is an adult female with a kid. Female goats without kids are designated simply as 'females'. Kids are designated lower ranking or higher ranking according to the ranking of their mothers. Billies are adult males (3 years or older), younger males are subadults. Each goat in each herd is designated by an uppercase letter starting with "A" for the most dominant. These designations are valid only within the context of a given herd. Lowercase "k" indicates a kid, for example "Ak" is a nanny with kid. Lowercase "b" indicates a billy, "m" indicates a male subadult, and "f" indicates an adult female without a kid. An accompanying number indicates age in years. For example "Fm1" is a sixth ordinal ranking male yearling, "Eb" is a fifth ranking billy. Cohort refers to any nearest ranking goat relative to another. Peer groups are mountain goats with the same or similar cardinal rank values, meaning that peer group mountain goats may be similar in rank with only fractional difference in values. When a nanny and kid lose sight of one another and either animal exhibits searching behavior, or bleats, the event is called separation.

Definitions for cardinal rank statistics include rank average (R_{AVG}), standard deviation of ranks (SD_R), rank minimum (R_{MIN}), rank maximum (R_{MAX}), and average difference between ranks (ΔR_{AVG}). The average difference in rank was used to evaluate the linearity of the hierarchy for various sex-age groups. Highly linear sex-age groups have higher average rank differences (ΔR_{AVG}). Less linear sex-age groups, or peer groups, have lower average rank differences.

RESULTS

Rankings

Nannies occupied the three most dominant positions in 12 of 14 herd samples. In herd H a billy held the third most dominant position and in herd A there were only two nannies. Nannies had the highest average rank difference, suggesting their dominance relationships to one another were well established (Table 1). The remaining sex-age groups had average rank differences near 0.5 except for male yearlings who were considerably lower than the rest.

Average rank differences were calculated using the herd ranks obtained only from Equations 1. The series ranks obtained from Equation 1 alone emphasized contest results between adjacent peers. Equation 2 was applied to emphasize herd placement and reduce the dependency, especially of the lower ranks, on herd size (Table 2). The

Table 1. Cardinal Rank Statistics. Series ranks using only Equation 1.

	Nanny	Female	Female 2-yr-old	Female yearling	Billy	Male 2-yr-old	Male yearling
R_{AVG}[a]	3.12	6.58	7.60	8.56	6.31	7.68	8.42
SD_R	2.12	1.94	3.08	2.82	2.44	2.96	2.90
R_{MIN}	1.00	4.00	3.44	3.83	2.44	3.67	3.60
R_{MAX}	9.64	10.00	13.33	13.33	9.64	13.33	13.33
ΔR_{AVG}	0.73	0.72	0.48	0.52	0.59	0.46	0.29

[a] Definitions provided in text.

Table 2. Cardinal Rank Statistics. Herd normalized cardinal ranks using Equations 1 and 2.

	Nanny	Female	Female 2-yr-old	Female yearling	Billy	Male 2-yr-old	Male yearling
R_{AVG}[a]	3.24	6.42	7.64	9.02	6.27	7.57	8.83
SD_R	1.72	1.60	1.58	1.35	1.93	1.54	1.36
R_{MIN}	0.75	3.75	4.52	4.91	2.93	4.70	5.44
R_{MAX}	7.48	10.00	10.00	10.00	10.00	10.00	10.00

[a] Definitions provided in text.

Table 3. Sex-age Group Distribution (%) in Normalized Herd Ranks using Equations 1 and 2.

Rank	Nanny	Female	Female 2-yr-old	Female yearling	Billy	Male 2-yr-old	Male yearling
0-2	31.5	0	0	0	0	0	0
2-4	37.0	8.3	0	0	22.2	0	0
4-6	24.7	33.3	19.2	8.0	27.8	25.0	7.1
6-8	6.9	50.0	38.5	16.0	38.9	32.1	14.3
8-10	0	8.3	42.3	76.0	11.1	42.7	78.6

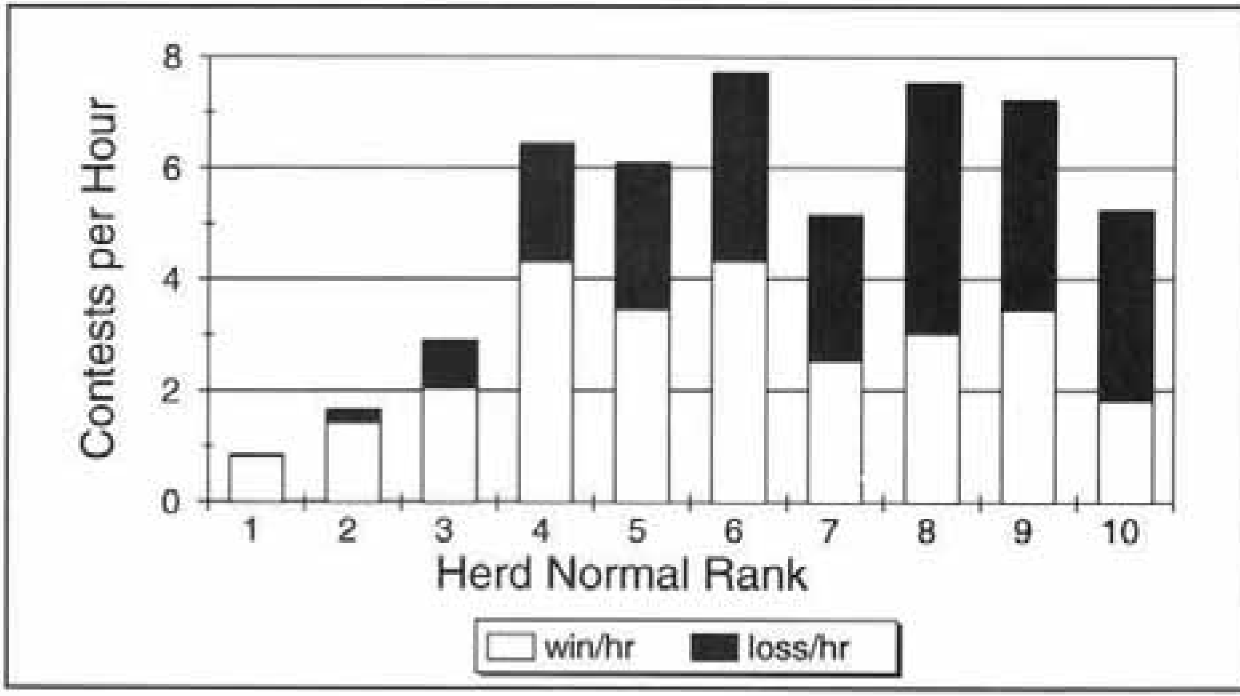

Figure 1. Mean number of agonistic encounters observed per hour versus cardinal rank for all 14 herds of Rocky Mountain goats on Elliott Ridge.

standard deviations of cardinal ranks are higher when only Equation 1 is used (see Table 1). This higher standard deviation results from variance in the herd sizes from which samples were taken. The standard deviation using herd normalized ranks is low for male yearlings. This coincides with the low average rank difference for this sex-age group.

The percentage of mountain goats distributed at various herd normalized ranks was calculated (Table 3). Kidless females showed a significant ($P<0.05$) difference from nannies. Male and female yearlings and 2-yr-olds are similar, respectively, in rank distribution despite male yearlings' much lower average rank difference.

Aggression in Herd Normalized Ranks

Mountain goats with herd normalized ranks of 4 through 10 had more agonistic encounters per hour than goats ranked 1-3 (Fig. 1). Dominant mountain goats (rank 1-3) had more wins relative to losses but this relationship reversed for subordinate goats. In small herds, we observed the top-most nanny being challenged a few times by the next highest ranking nannies, but almost never by lower ranking goats. However, in large herds the top-most nanny was challenged by, but usually defeated, goats who were not nannies with kids.

Contests with Top Ranking Nannies in Large Herds

Behavior of one female yearling (Ff1) in herd J indicates how females may move towards dominance positions within a herd. The yearling had over four times as many agonistic encounters with high ranking nannies as her cohorts. She won 9 of 29 contests with Dk and 11 of 28 with Ek (Table 4). She was chased by Ak 22 times with no wins. Lower ranking nannies in large groups were also seen to compete with higher ranking nannies more frequently than cohorts (Table 5). Herds J and L were used to evaluate which sex-age groups were more likely to compete with top ranking nannies. These herds were selected because observation times were 17 hours over 3 days for J and 14 hours over 2 days for L. These times were well in excess of those for the other large herds and provided the only opportunities to make significant observations of subordinate goat behavior toward dominant

Table 4: Dominance matrix of mountain goat herd J (22 animals) on Elliot Ridge, 1993 after 17 observation hours.

Winners		Losers															
		Ak	Bk	Ck	Dk	Ek	Ff1	Gm2	Jm2	Hk	If	Kf2	Lm2	Mf2	Nm1	Of1	Pb
1.0 [a]	Ak [b]	-	7 [c]	1			22	1									
2.0	Bk		-	14		3		1									
3.0	Ck			-		12				2	1						
3.0	Dk				-	14	20	11		4	2						
3.1	Ek			1	12	-	17	8		5	1						
3.3	Ff1				9	11	-	5									
4.3	Gm2							-		11	1						
4.3	Jm2								-	2	1						
5.3	Hk			1	1	4				-	4					5	1
6.3	If										-	9	12	13			2
6.3	Kf2								10		1	-	17	13		2	1
7.0	Lm2								9			3	-	2			
7.3	Mf2								4		1	12	1	-	1		
7.3	Nm1														-	5	2
7.4	Of1														4	-	5
8.1	Pb														3	1	-

[a] Series rank.
[b] See text for letter definitions.
[c] Wins by goat listed on row against goat listed in column.

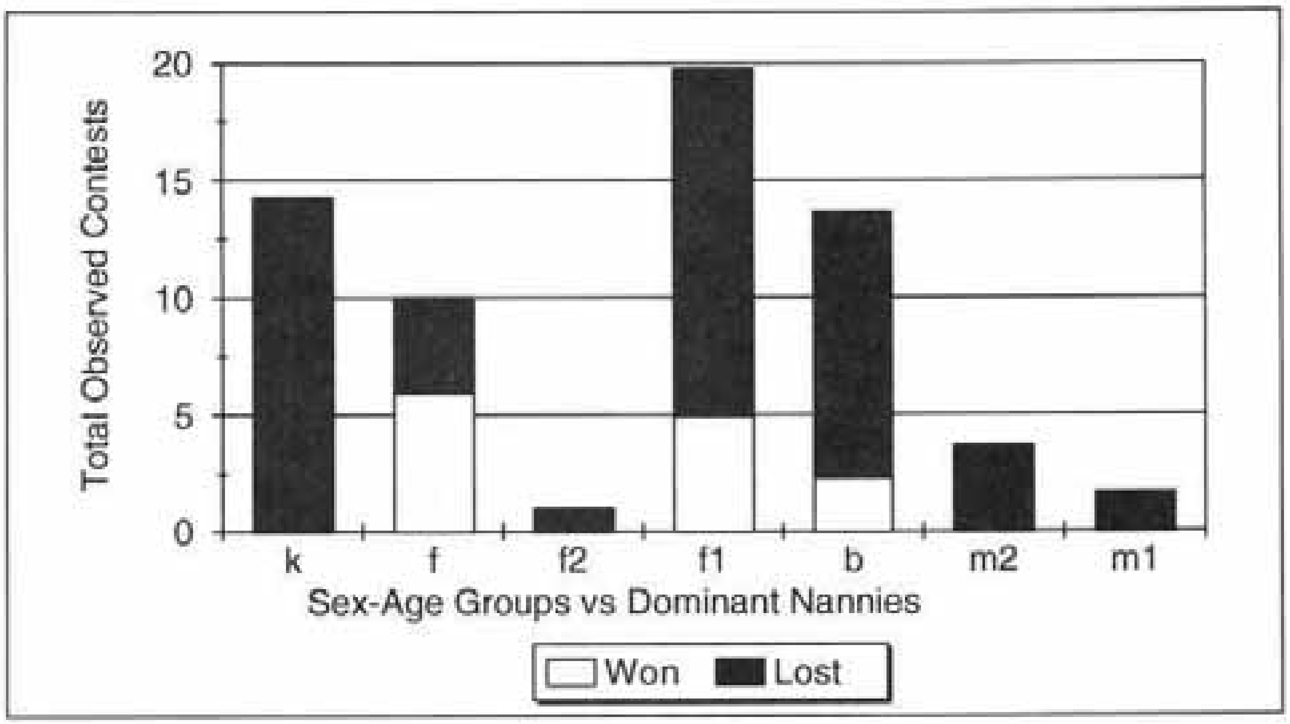

Figure 2: Agonistic encounters between subordinate goats and dominant nannies in herds J and L averaged for individuals in listed sex-age groups. k = nanny with kid, f = female without kid, f2 = female 2-year-old, f1 = female yearling, b = billy, m2 = male 2-year-old, m1 = male yearling.

nannies. The top five ranking nannies in herds J and L were designated dominant. Nannies ranked below these were also ranked below other sex-age group goats. Unlike some of their more dominant cohorts, these nannies tended to infringe upon the dominant nannies and be chased away (Fig. 2). The high average for female yearlings in both groups is solely attributable to Ff1 of herd J. Dominant billies also were observed to infringe upon dominant nannies, but totally avoided encounters with the top three nannies.

Nanny-kid Separation

During the course of the study, 73 cases of kids being separated from their nannies were observed. Separation times ranged from 2 minutes to 3 hours. The tendency for lower ranking nannies to interact agonistically with higher ranking nannies suggests an explanation for this high incidence of nanny-kid separation. Such interactions occurred when lower ranking nannies infringed on nannies of higher rank or were chased from a lick. After being displaced, the low ranking nanny moved around the salt lick searching for a lick hole which could more easily be acquired. During this search, a kid often became "lost" due to the kid's inattentiveness, sleeping, playing, or too many mountain goats blocking the view, or because the nanny moved out of the salt lick area. When the kid "discovered" loss of visual contact (i.e. when it awoke or finished play activities) it was considered separated when it could not immediately find its nanny and then initiated "abandoned kid" behavior. Behavior of abandoned kids included searching for the nanny, bleating, and the occasional trailing after a juvenile playmate and its nanny only to be rejected by the playmate's nanny. With one exception each lost kid was eventually found by its nanny. In the one event where I did not observe the kid reuniting with its nanny, the nanny had left the salt lick area alone and vocalized twice. The kid had moved down the mountain side and was apparently out of hearing range. Two hours after the separation, the remaining herd (n=21) left the salt lick together. The kid remained with this group and repeatedly vocalized while moving out of observation range. Reunions typically were marked by nose to nose contact with the nanny smelling her kid along the length of its body.

Separations per hour increased with increasing lower rank among nannies (Fig. 3 and 4). The relationship between lower normalized herd rank and average nanny-kid separations per hour are correlated and significant(K-W $P<0.01$).

The second cause of separation is walk-aways (Fig. 5 and 6). Walk-aways occur when lower ranking nannies searched for a lick hole, or departed from the salt lick area without being chased by another nanny. The parting of the nanny-kid pair under these circumstances is not as sudden as those of the chase. The walk-away separation relationship also was correlated and suggested that, at the salt lick, separations between nannies and kids occurred more frequently among lower ranking nannies(K-W $P<0.01$).

Lower ranks appeared to have a steady increase in average separations as the ranks decreased. The average separation result at the lowest ranks appeared to be nearly linear with the trend that began at the highest ranks. The exceptions in the middle may have been due to the sparseness of the data relative to the higher ranks (See Fig. 4 and 6). High ranking nannies were abundantly observed, being present in all herds. Only the largest herds provided opportunities to observe nannies of middle and low herd normalized ranks.

DISCUSSION

The level of aggression for nannies was lower than the average for all other goats in the herd (Fig. 1). The conditioning induced by repeated wins would tend to place the more experienced and dominant nannies into an increasingly linear hierarchy and reduce aggression (Jackson 1987). This would allow energy otherwise spent in intraspecific competition to be spent on rearing young.

Subordinate aggression may have been increased by crowding which reduced access to salt lick holes and encouraged lower ranking goats to approach the high ranking nannies more frequently. Male yearlings appeared to form peer groups.

It is possible that Ff1 of herd J may be the offspring of one of the dominant nannies. Chadwick (1983) reported that yearlings and newborn siblings often accompany their mothers onto the salt lick area. As such, the yearling may still be afforded some protection by her mother. The yearling Ff1 may also have been conditioned to winning by the protection of her dominant mother (Ginsburg and Allee 1942). Likewise, lower ranking nannies that frequently challenged higher ranking nannies at the salt licks may be offspring of higher ranking nannies.

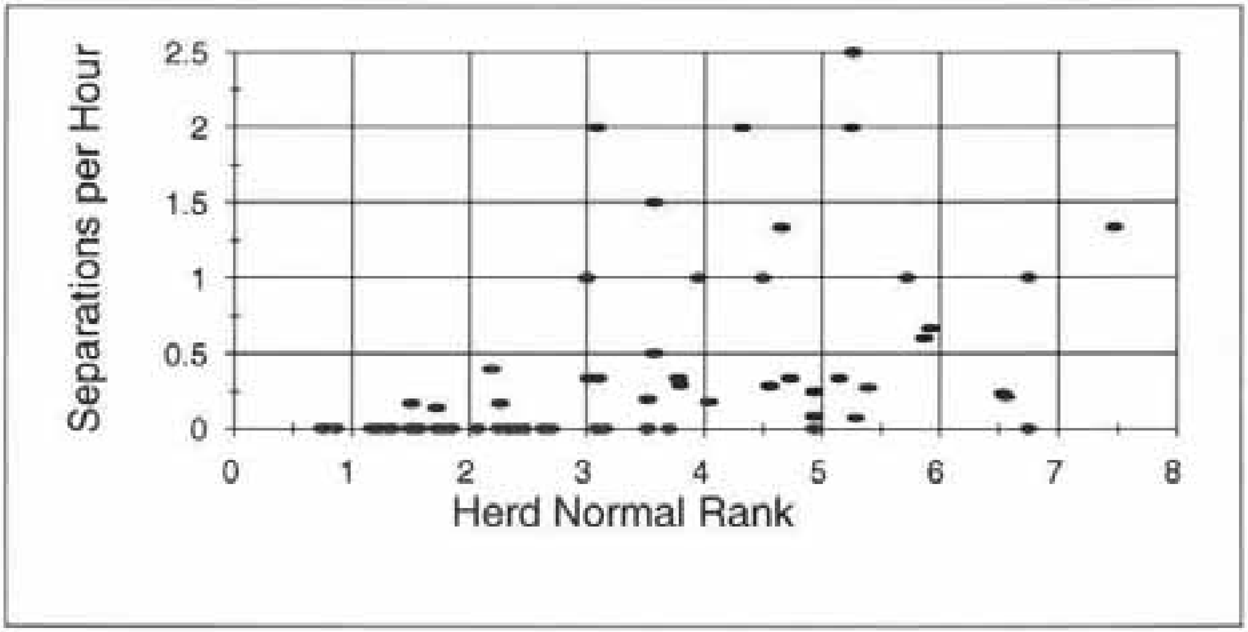

Figure 3. Nanny-kid separations per hour caused by the nanny being chased, in relation to herd normalized rank.

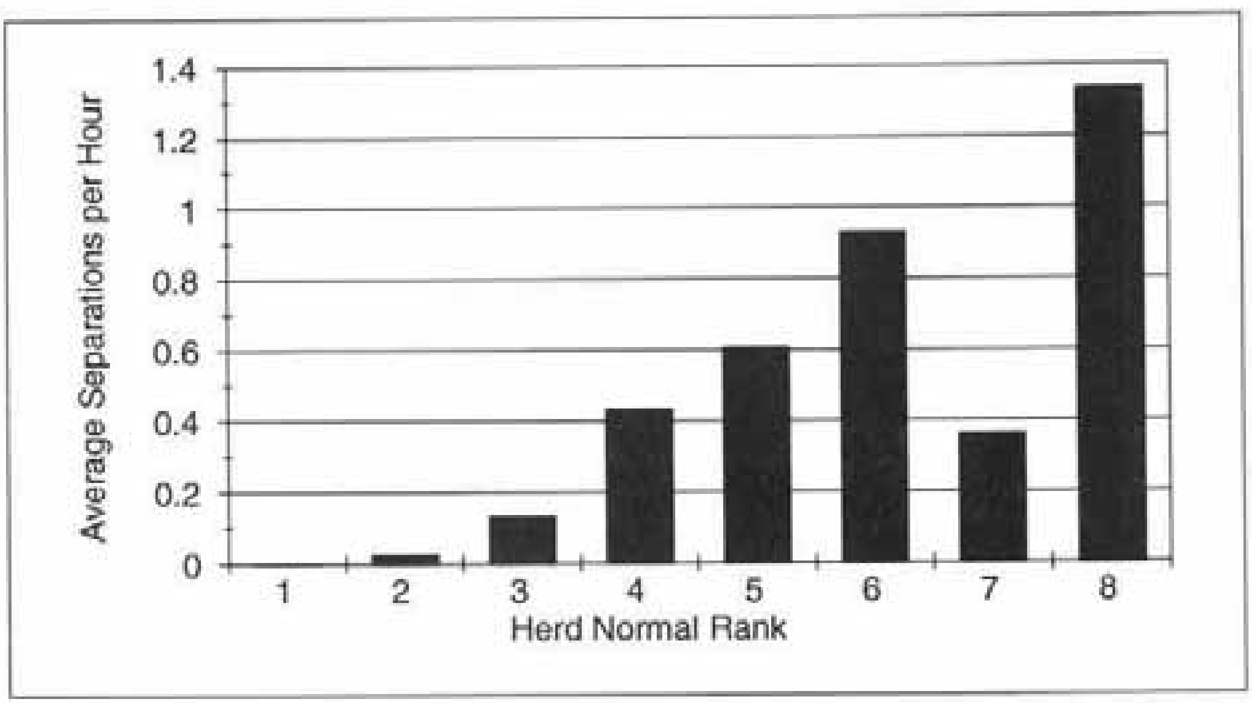

Figure 4. Average nanny-kid separations per hour caused by chases, in relation to herd normalized rank.

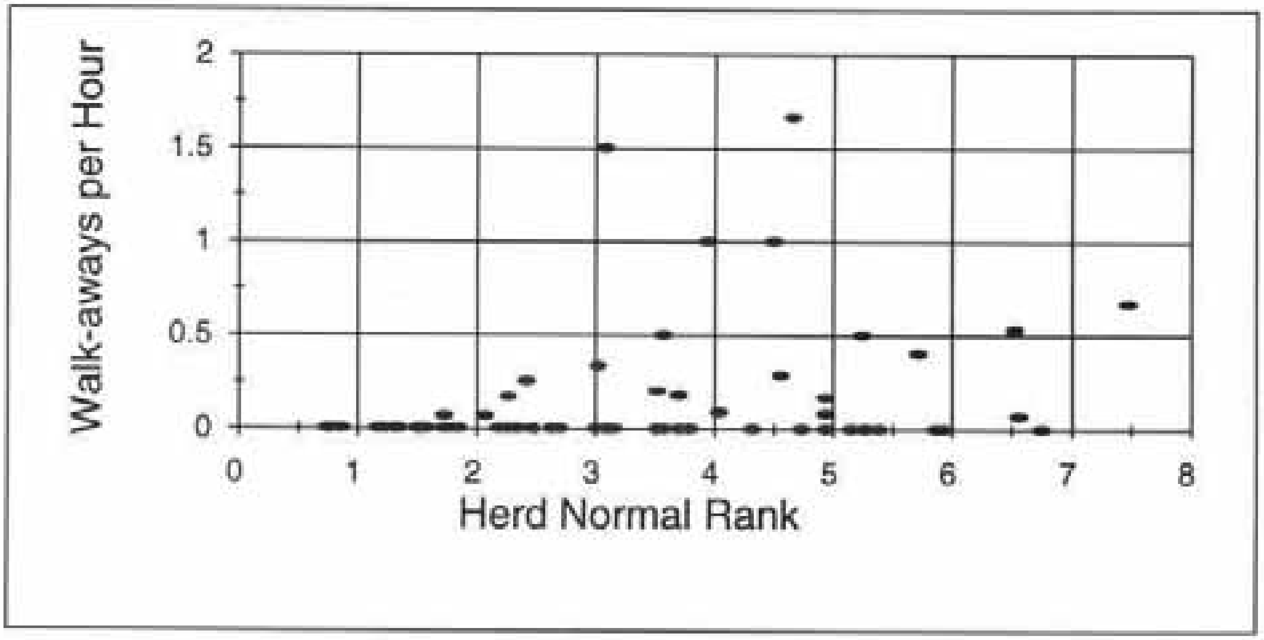

Figure 5. Nanny-kid separations per hour caused by walk-aways, in relation to herd normalized rank.

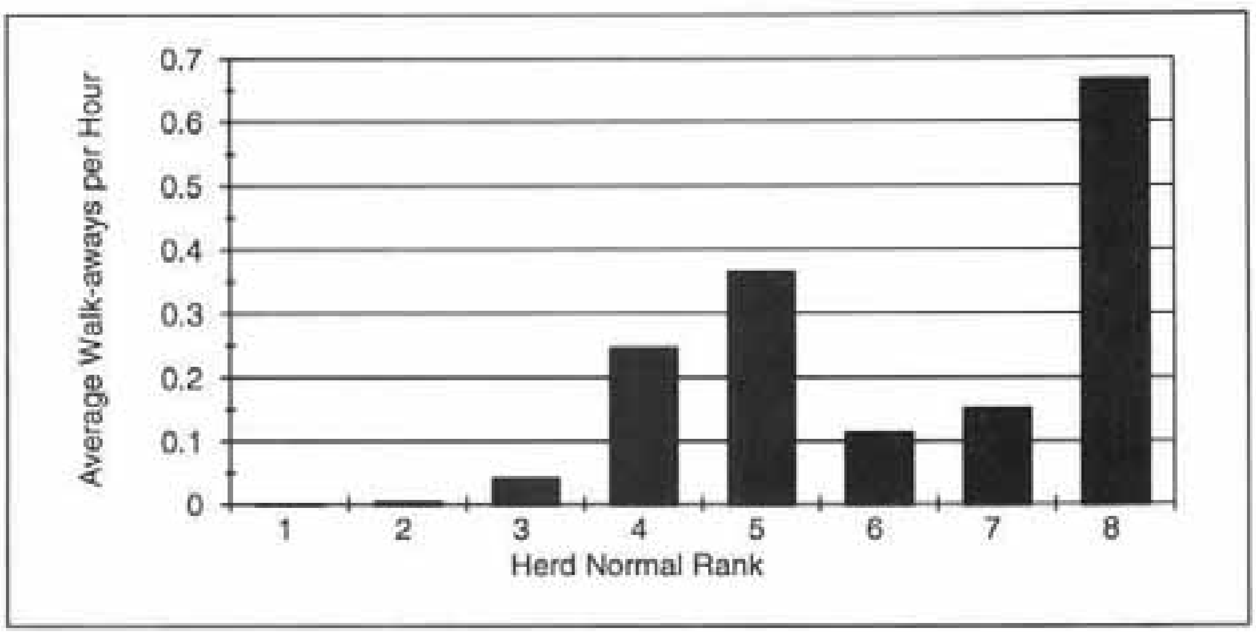

Figure 6. Average nanny-kid separations per hour caused by walk-aways, in relation to herd normalized rank.

Low ranking nannies generally failed to avoid encounters with high ranking nannies. Subadults minimized encounters with high ranking mountain goats by positioning themselves along the outer periphery of the salt lick area. Lower ranking nannies had from two to ten times more encounters with higher ranking nannies than did their non-nanny cohorts. This suggested several possibilities: 1) higher ranking nannies singled out lower ranking nannies and preferentially chased them; 2) some lower ranking nannies were very competitive against the higher ranking nannies; 3) lower ranking nannies had not learned to stay outside the individual space of dominant nannies. The nanny Hk, along with the female yearling Ff1, in Herd J was observed to have more agonistic encounters with higher ranking nannies and actually won several of them. In Herd L, nanny Hk encroached, competed, and won in contests against higher ranking nannies. Let us consider the relative ranking of Hk to higher ranking nannies Ck-Ek using Equation 1. If we remove goats Fk and Gb, then Hk will have a considerable increase in cardinal rank value. The results from Hk against Ck, Dk, and Ek, places Hk as a dominant of rank 3 to 3.6 rather than the 5.29 that results from Hk's losses to the intervening mountain goats. The point is that Hk competed intensively with these higher ranking nannies.

Although other lower ranking nannies did not win against higher ranking nannies, they sometimes encroached upon them only to be repelled. Encroachment by lower ranking nannies and preferential attack of lower ranking by higher ranking nannies are not mutually exclusive possibilities. Both situations arose during the herds' occupation of the salt lick.

Nannies with an ordinal rank of 1 were never separated from their kids either by being chased or by walking away. Rank 1 nanny dominance over the rest of the herd may allow her to remain in one place for long periods, reducing chance separations. Nannies with kids were the highest ranking mountain goats in the Gore-Range Rocky Mountain herd. Nannies with kids interacted two to ten times more among themselves than they did with other non-nanny mountain goats. It is likely that nannies without kids were younger. If so, much of the social hierarchy could be explained by age and might also be correlated with experience in rearing young. When separated, kids may be exposed to greater risk of predation, increased frequency of aggressive encounters with older mountain goats, and longer periods of time without access to milk.

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SUMMER-FALL HABITAT USE AND FALL DIETS OF MOUNTAIN GOATS AND BIGHORN SHEEP IN THE ABSAROKA RANGE, MONTANA

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Abstract: A three year study (1991 to 1993) of mountain goat (*Oreamnos americanus*) ecology was conducted in the Absaroka Range of Montana, Wyoming, and Yellowstone National Park. Data on habitat-use and food habits of goats and bighorn sheep (*Ovis canadensis canadensis*) are presented here. Summer and early fall habitat use by mountain goats and bighorn sheep were dissimilar. Feeding sites for goats tended to be rocky, steep, and sparsely vegetated while sheep feeding sites tended to be open, moderately sloping, and continuously vegetated. Behavioral feeding strategies for the two species also differed. Six observations of interspecific interactions were made during the study. Diets of mountain goats and bighorn sheep were similar and consisted primarily of grasses and sedges. Forage taxa contributed to fall food habits in approximate proportion to their abundance as estimated from taxa frequency and canopy coverage data collected at representative habitat-types.

Mountain goats have been introduced successfully into several mountain ranges in western North America (Johnson 1977). In the Absaroka range of southwest Montana, mountain goats were successfully introduced in 1956 (Swenson 1985). Emigrants from this expanding population have been sighted recently in the Absarokas of northeastern Yellowstone N. P. and Wyoming. Evidence for goats being a member of Yellowstone's Holocene faunal community is lacking; therefore, they are considered exotic by the National Park Service. Determining the ecological effects of mountain goats in Yellowstone is important to their management.

Exotic species may cause impact to native communities (Berger 1991). For instance, mountain goats in Olympic National Park had a detrimental affect on vegetation communities and endemic plants (Pike 1981, Pfitsch and Bliss 1985). Despite being sympatric during their evolution, the introduction of goats to native sheep habitats in western states has evoked questions about potential competition between the two species (Adams et al. 1982).

This study describes summer/fall ecological relationships of mountain goats and bighorn sheep in the Absaroka Range. The data presented include: (1) terrain and vegetation characteristics of goat and sheep feeding sites, (2) fall goat diet for comparison with sheep diet, (3) feeding behavioral strategies of both species, and (4) interspecific interactions observed.

STUDY AREA

The 260 km^2 study area is located in the northern Absaroka Range of southwest Montana and northwest Wyoming. Elevations range from timberline at 2,550 m to 3,313 m, the highest point, on Amphitheater Mountain. Lacking large plateaus, the range is characterized by narrow, abrupt ridges separated by forested drainages. Parent material is primarily the Eocene Absaroka Volcanic Supergroup (Decker 1990). Bedrock is of two primary types: volcanic breccia and lava flows. Steep cliffs and scree slopes are common on northern and eastern exposures. Gradually-sloping northern and western aspects accumulate more soil and support alpine turf communities. Dry, southern slopes have shallow soils and are sparsely vegetated.

METHODS

Ground surveys of the study area were conducted during five 30-day periods from May 15 through October 15, 1991-1993 to document habitat-use by goats and sheep. Prospective goat feeding sites were searched by research teams and observations were made with the aid of 7 x binoculars and a 20x-60x spotting scope.

Habitat-type occupied, time spent in each type, and distance traveled were recorded for feeding goats and sheep. Habitat-types were classified based on terrain, vegetation, and soil characteristics within a 10-meter radius of the subject animal. Four physical characteristics of feeding site selection also were recorded from 7.5" U.S.G.S. topographic maps: slope, aspect, elevation, and distance to escape terrain. Vegetation in three habitat-types used frequently by feeding mountain goats was examined. Percent canopy coverage and frequency were estimated visually for plant species in 2 X 5 decimeter plot frames spaced at one meter intervals along a 20-40 meter line transect (Daubenmire 1959).

In 1992, 22 goat hunters successful in drawing permits in the study area were asked to provide one-quart rumen samples from their harvested animal. Rumen sample analysis (Korschgen 1980) was used to determine fall food habits. No adjustments for differential digestibility were made. Mean percent occurrence of forage taxa in rumen samples and mean percent canopy coverage of forage taxa from plot transects were compared using Spearman's rank-correlation.

Four distinct bighorn sheep herds migrate to summer ranges in the Absarokas from winter ranges in the Beartooth Range and Yellowstone Park. Sheep arrived on the Absaroka summer range in mid-June having already lambed in transitional ranges (Stewart 1975, Martin 1985). Data for groups of ewes, lambs, and juveniles were collected (few adult rams were encountered).

Interspecific interactions were recorded when sheep and goats were observed within 20 m of each other. Each interaction fit into one of four descriptive categories based on whether or not interference competition (Miller 1967) was observed: sheep-dominated, goat-dominated, mutual tolerance, or ambiguous outcome.

RESULTS

Mountain Goats

Goats primarily fed on young plant tissue which grew throughout the summer following receding snow. Goats were observed using various habitats on all aspects depending on snow-melt and plant growth stages (Tables 1 and 2). In the spring, goats fed in snow-free habitats on south aspects. As the summer progressed, goats pursued receding snow lines and the emergence of young, succulent vegetation to habitats on west aspects. By late summer and early fall goats used north and east aspects where steep, shaded ledges harbored melting snow.

Goats fed individually or in small groups ($\bar{x}$ = 5.6±8, 1-47) within or nearby steep, rocky escape cover during all periods (Figure 1). Forty-six percent of all observations of feeding mountain goats were within escape terrain (Figure 2). Mean slope and mean elevation of feeding habitats was 33 degrees (19-63) and 3562 (2925-3836) m, respectively.

While feeding, goats often traveled substantial distances before arriving at bedding sites. They typically traversed a variety of habitats pausing no more than a few minutes to graze any particular site. A mean of 2.9±1.9 habitat-types were used per hour of uninterrupted feeding.

Seven of 15 successful hunters returned rumen samples. Analysis of rumen samples collected from 9-15-92 to 10-6-92 indicated predominant use of graminoid species (76%) in the fall (Table 3). Forbs were second in importance (20%), while a combination of browse and lichens made up the remaining portion of the diet. Spearman's rank-correlation between mean canopy coverage of forage taxa in the three habitat types examined and mean percent occurrence in rumen samples was 0.45 ($P < 0.05$) suggesting forage selection is proportional to abundance. Spearman's rank-correlation between graminoid species canopy coverage and mean percent occurrence of those species in rumen samples was 0.83 ($P<0.01$) suggesting graminoid use in the fall diet is proportional to abundance. No discernible association between use of forb taxa and their availability was detected using the rank-correlation test statistic (-0.09 ($p < 0.80$)).

Bighorn Sheep

From mid-June through September, sheep fed in large groups ($\bar{x}$ = 11.5 ±9, 2-42) in open alpine and timberline meadows. By late September, smaller groups fed in timberline meadows and patches of sparsely vegetated dirt-scree and talus. Bighorn sheep and mountain goats were observed using different aspects ($P<0.0001$) and habitats ($P<0.001$) during all five periods (Tables 1 and 2).

Distance to escape terrain was greater for feeding sheep than goats ($P<0.001$). The average slope of sheep feeding sites was 24 degrees (12-39). The mean elevation of sheep feeding sites was 3429 meters (2960-3868), 133 meters less than goats ($t=4.34$, $P<0.001$).

In contrast to goats, sheep tended to concentrate feeding on one site per feeding period.

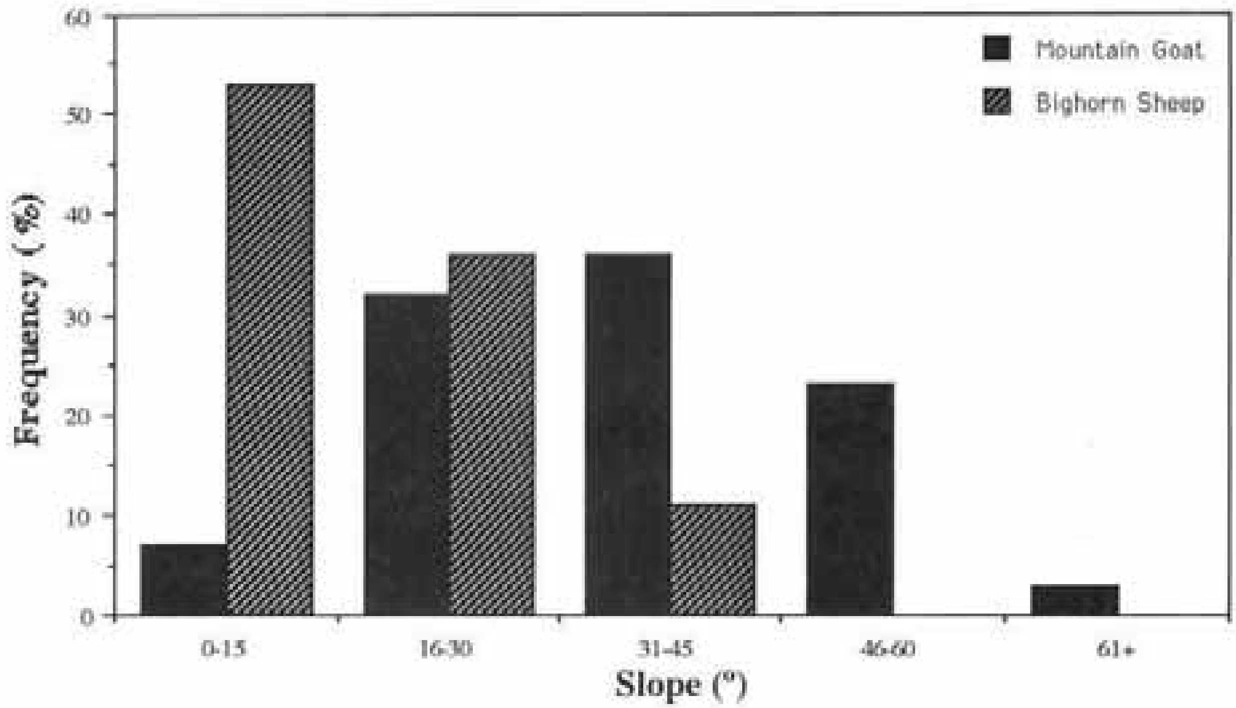

Figure 1. Use of slope by feeding mountain goats and sheep in the Absarokas, 1991-1993.

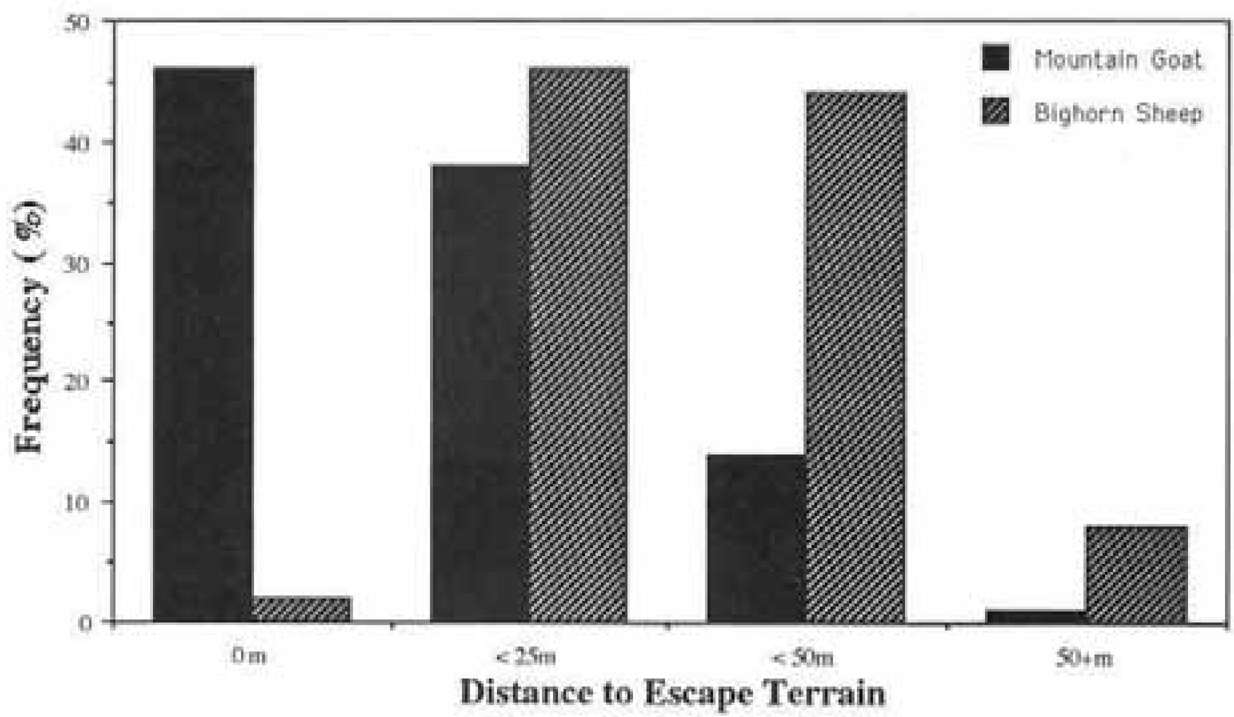

Figure 2. Association with escape terrain by feeding mountain goats and sheep in the Absarokas, 1991-1993.

Table 1. Habitat use[a] by feeding mountain goats and sheep in the Absarokas, 1991-1993.

	n	Ledge	R. scree	S. scree	T. scree	Turf	S.alpine	Talus
May-June								
Goats	48	12 (20)[b]	9 (19)	7 (15)	4 (8)	7 (15)	7 (15)	1 (2)
June-July								
Goats	40	10 (25)	10 (25)	7 (18)	5 (12)	5 (12)	2 (6)	1 (2)
Sheep	36	0 (0)	3 (8)	5 (14)	6 (17)	15 (42)	7 (19)	0 (0)
July-Aug.								
Goats	74	23 (32)	20 (27)	6 (8)	9 (12)	9 (12)	6 (8)	1 (1)
Sheep	34	0 (0)	2 (6)	2 (6)	5 (22)	14 (40)	8 (22)	0 (0)
Aug.-Sept.								
Goats	68	25 (37)	17 (25)	6 (9)	8 (12)	6 (9)	5 (7)	1 (1)
Sheep	28	1 (3)	2 (7)	3 (10)	5 (18)	10 (36)	7 (26)	0 (0)
Sept.-Oct.								
Goats	62	19 (31)	14 (22)	7 (12)	5 (8)	6 (10)	9 (14)	2 (3)
Sheep	29	0 (0)	1 (4)	4 (14)	7 (24)	10 (34)	7 (24)	0 (0)

[a] Types include ledge, rocky scree, sandy scree, turf scree, turf, subalpine, and talus.

[b] Number of observations (percent of total).

Table 2. Aspect use by feeding mountain goats and sheep in the Absarokas, 1991-1993.

	n	N	NE	E	NW	W	SW	SE	S
May-June									
Goats	48	5(10)[a]	2 (4)	2 (4)	5 (10)	6 (13)	8 (16)	9 (18)	11(23)
June-July									
Goats	40	8 (21)	3 (7)	3 (7)	6 (15)	5 (13)	5 (13)	4 (11)	6 (15)
Sheep	36	2 (7)	0 (0)	0 (0)	1 (2)	8 (27)	9 (32)	2 (7)	7 (25)
July-Aug.									
Goats	73	19(26)	10(14)	15(20)	9 (13)	8(11)	5(7)	4(5)	3(4)
Sheep	36	1 (2)	1(2)	0(0)	2 (5)	8 (22)	7 (19)	3 (10)	14(40)
Aug.-Sept.									
Goats	68	23(34)	11(16)	16(23)	11(16)	4 (6)	1 (2)	0 (0)	2 (4)
Sheep	28	3 (12)	1 (3)	1 (3)	4 (13)	10(35)	3 (12)	1 (3)	5 (19)
Sept.-Oct.									
Goats	62	15(24)	11(18)	12(20)	15(24)	7 (12)	0 (0)	1 (2)	0 (0)
Sheep	29	2 (5)	0 (0)	0 (0)	1 (2)	8 (27)	9 (32)	2 (7)	7 (25)

[a] Number of observations (percent of total).

Mean number of habitat-types per hour of feeding was 1.5 ± 0.7 and less than for goats ($t=3.29$, $P<0.01$). Sheep herds intensively grazed one site per feeding bout and directional movements were not observed to the same extent as goats.

Interspecific Interactions

Only six observations of goat-sheep interactions were made, and of these five were neutral. The sixth concerned a group of 11 sheep feeding within 20 m of 7 bedded goats. When the author appeared, ten sheep fled leaving one adult ewe and the goats who appeared unconcerned. Attempting to escape to ledge areas, the ewe was blocked by the bedded goats. The ewe approached to within 10 meters of the author in order to access an alternate escape route. Although goats seemed to prevent use of the escape route, this observation was influenced by the observer and was ambiguous.

DISCUSSION

Feeding site selection and behavioral strategies for the two species were dissimilar. Mountain goats fed on steep, sparsely vegetated sites during all observation periods. Feeding sites were often rocky and closely associated with melting snow. Generally, goats fed individually or in small groups and traveled substantial distances before stopping. Chadwick (1974) described this behavior as "trail feeding" and noted it was greatest in the summer and did not vary until winter when snow prevented long movements and thus, restricted feeding to particular sites.

Bighorn sheep generally fed in large groups in open, moderately sloping, alpine or timberline meadows. While sheep were observed in ledge habitats, they rarely fed at these sites. Sheep seemed to be attracted by the relatively high biomass of turf communities, where they relied on large group size and the visual radius of their feeding sites to detect predators (Shannon et al. 1975, Adams et al. 1982). In contrast to goats, sheep tended to concentrate their feeding on one site.

Seasonal changes in aspect, elevation, and habitat use in response to early growth has been reported in other mountain goat studies (Hjeljord 1973, Smith 1976). In this study, goats consistently used sites with early-growth vegetation. By closely following receding snows and foraging on the subsequent "green-up", goats used all habitat types on all aspects during the five observation periods. Phenologically similar sites were available throughout the growing season because snow melted more slowly on steep, northern and eastern aspects. In contrast, sheep used drier sites where vegetation was more abundant and mature relative to that selected by goats. By using wet sites predominantly, goats avoided temporal overlap with sheep that, in some instances, used the same sites later in the season.

Martin (1985) determined fall diet for sheep on Absaroka summer range by microhistological analysis of fecal droppings (Table 3). Sheep used grasses predominantly (74%) while forbs were second in importance (16%). Sheep also used browse (10%), mainly willow (*Salix* spp). Sheep diets were similar to those found for mountain goats in this study. Both species' diet primarily consisted of common graminoids, particularly sedges (*Carex* spp.). The 5 forage taxa with the highest mean canopy-coverage composed greater than half of both species' fall diets suggesting both species are generalists and feed on the most abundant forage available during the fall. The use of uncommon forage taxa was not detected in either species' diet.

With few exceptions, sheep and goats foraged on different forbs. Sheep used more browse and less lichen than goats. Dissimilarities in the two diets may reflect feeding site selection differences. For instance, goats fed on rushes (*Juncus* spp.) which were abundant in wet, shaded areas like ledges and steep avalanche chutes. Also, sheep browsed willow which primarily grew along drainages in gently-sloping meadows.

Neither species was observed using mineral licks. Martin (1985) did not observe sheep using mineral licks on the Absarokas summer range as well. The alkaline rock types of the Absarokas are characterized by relatively high potassium and/or sodium content (Decker 1990); therefore, mineral sources may be abundantly dispersed throughout the range, rather than concentrated in particular sites. Forage growing in the volcanic soils may also provide minerals.

Competition would occur if the two species were utilizing some environmental resource in short supply; however, feeding behavioral strategies and site selection differences minimized this possibility during the growing season. The contrasting patterns described here are indicative of niche divergence that would be expected given the two species' extensively overlapping distribution and evolutionary history in North America.

The potential for competition between sympatric sheep and goats is likely greater during winter when resources are more limited (Adams et al. 1982). Mountain goats do not occupy sheep winter ranges in Yellowstone Park at present. However, wintering areas for the Beartooth Mountains' goat population overlap with those for some sheep herds that migrate from the Absaroka summer range. Investigating the relationship between the two species on this winter range would be valuable in further addressing the question of competition between native bighorn sheep and introduced mountain goats.

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Table 3. Canopy coverage and frequency in threee habitat types and fall diets of mountain goats and bighorn sheep.

Taxa	Habitat types						Fall diets			
	Ledge n = 6		Rocky scree n = 12		Turf n = 11		Mountain goat n = 7		Bighorn sheep[a] n = 17	
GRAMINOIDS	30.0	94[b]	26.0	88	26.0	98	75.6	75.5[c]	74	17[d]
Agropyron spp.	0.1	2	2.2	68	0.2	4	5.3	7	-	-
Agrostis scabra	-	-	-	-	0.3	4	tr.[e]	Tr.	-	-
Alopecurus alpinus	-	-	-	-	0.2	4	-	-	-	-
Bromus spp.	-	-	-	-	-	-	-	-	1	2
Carex spp.	9.9	94	8.5	54	4.0	24	20.1	19	51	17
Deschampsia caespitosa	2.1	43	0.4	24	7.3	82	6.1	6	6	14
Elymus spp.	-	-	0.1	4	0.4	5	1.6	1.5	-	-
Festuca ovina	2.1	36	2.4	48	2.5	33	8.4	7	11	15
Juncus spp.	7.3	62	7.0	85	1.9	18	15.2	15	2	6
Koeleria cristata	0.1	2	0.4	8	1.4	16	1.0	1	-	-
Luzula spp.	1.5	60	1.0	13	1.1	5	6.5	6	1	1
Oryzopsis spp.	-	-	-	-	-	-	-	-	1	3
Phleum alpinum	-	-	0.7	8	0.8	10	-	-	-	-
Poa spp.	6.6	97	2.9	81	5.3	85	10.4	11	2	8
Trisetum spicatum	0.7	22	1.1	32	1.1	7	2.5	2	-	-
FORBS	22.0	91	37.0	90	59	100	19.6	22	16	15
Achillea millefolium	0.5	12	0.9	16	2.2	26	tr.	tr.	-	-
Androsace spp.	-	-	-	-	0.8	32	-	-	-	-
Antennaria spp.	0.8	36	1.3	7	0.3	4	1.7	1.3	-	-
Areneria obtusiloba	0.8	30	1.5	55	6.4	53	1.7	1.6	-	-
Arnica spp.	0.3	14	3.1	17	1.1	13	1.1	1.7	-	-
Artemisia spp.	1.4	18	0.8	12	0.5	8	tr.	tr.	1	2
Astragalus spp.	1.2	40	3.5	51	5.4	37	tr.	tr.	2	3
Castilleja spp.	-	-	-	-	1.5	12	-	-	-	-
Cerastium arvense	0.7	21	1.4	28	3.2	41	1.5	1.6	-	-
Cirsium foliosum	1.5	48	1.5	40	0.4	5	tr.	tr.	-	-
Draba spp.	-	-	0.1	2	-	-	-	-	-	-
Descurainia spp.	-	-	-	-	-	-	-	-	2	4
Epilobium angustifolium	-	-	-	-	0.5	12	-	-	-	-
Erigeron spp.	2.5	62	1.7	38	3.2	43	tr.	tr.	1	4
Lupinus argenteus	0.1	4	0.8	8	2.6	16	3.1	4	5	4
Mertensia alpina	0.1	4	0.4	6	4.3	20	1.8	1.7	-	-
Phlox multiflora	0.2	8	0.2	4	7.8	58	tr.	tr.	-	-
Plantago spp.	-	-	-	-	0.4	19	-	-	1	1

Taxa	Ledge n = 6		Rocky scree n = 12		Turf n = 11		Mountain goat n = 7		Bighorn sheep[a] n = 17	
Polemolium pulcherum	0.4	20	0.2	12	0.8	6	-	-	-	-
P. viscosum	1.4	32	3.2	41	-	-	-	-	-	-
Polygonum bistortoides	0.1	2	0.1	1	1.9	31	tr.	tr.	-	-
Potentilla spp..	1.2	19	1.1	39	8.2	57	tr.	tr.	1	2
Ranunculus spp.	0.1	14	0.5	14	0.1	1	-	-	-	-
Rumex spp.	0.1	2	0.1	1	-	-	tr.	tr.	-	-
Saxifraga spp.	5.4	76	4.5	32	0.9	26	tr.	tr.	-	-
Sedum lanceolata	2.1	42	4.4	62	3.8	37	4.3	5.4	-	-
Senecio spp.	0.8	18	1.3	20	-	-	1.3	1.3	-	-
Sibbaldia procumbens	-	-	-	-	-	-	-	-	4	7
Silene acaulis	-	-	2.2	38	2.2	17	tr.	tr.	-	-
Smelowskia calcyna	0.5	38	0.7	13	0.2	2	-	-	-	-
Taraxacum spp.	-	-	0.2	4	0.4	6	-	-	-	-
Trifolium haydenii	1.2	20	1.4	40	1.5	16	1.1	1.5	-	-
BROWSE	0.3	5	1.1	15	1.0	5	0.4	0.5	10	10
Pinus spp.	0.3	5	0.8	8	0.2	1	tr.	tr.	1	2
Rosa spp.	-	-	0.2	5	-	-	-	-	1	4
Rubus spp.	-	-	-	-	-	-	-	-	1	2
Salix spp.	-	-	0.1	2	0.8	4	0.1	0.5	5	8
Shepherdia canadensis	-	-	-	-	-	-	-	-	2	2
Vaccinium scoparium	-	-	-	-	-	-	0.1	0.5	-	-
MOSS	16.0	92	5.0	87	3.0	44	tr.	tr.	-	-
LICHEN	5.0	88	3.0	73	1.0	10	2.3	2.5	-	-
ROCK AND SOIL	22.0	100	29.0	100	11.0	85	-	-	-	-

[a] From Martin (1985).
[b] Percent canopy coverage, followed by frequency of occurrence.
[c] Percent of diet, followed by mean percent volume.
[d] Percent of diet, followed by constancy of samples.
[e] Trace amount (<1 ml or 1%).

Bienn. Symp. North. Wild Sheep
and Goat Counc. 9:139-143.

MOUNTAIN GOATS ON MOUNT EVANS, COLORADO - CONFLICTS AND THE IMPORTANCE OF ACCURATE POPULATION ESTIMATES

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Abstract: Translocation of mountain goats (*Oreamnos americanus*) to Mount Evans Colorado has led to perplexing management challenges. From 15 animals released in 1961, the population increased to at least 168 by 1983. Concern regarding interspecific competition between mountain goats and mountain sheep (*Ovis canadensis canadensis*) was addressed by a research project conducted from 1980 to 1986. Coordinated multi-route ground counts have been conducted since 1978. Discovery of an error in estimating the minimum population after the 1991 harvest and a subsequent effort by members of the public to eliminate hunting of mountain goats, led the Wildlife Commission to reduce the number of permits from 44 to 8 in 1992. A resolution proclaiming the Rocky Mountain goat native to Colorado was passed by the Wildlife Commission. A mountain goat population goal of 100 was set tentatively for providing watchable wildlife, hunting, and for keeping mountain goats at a population level which would reduce the possibility of competition and disease transmission with bighorn sheep.

Mountain goats were not known to occur in Colorado when the Game, Fish and Parks Department began releasing them in 1948. Fifteen goats were released in the Mount Evans area of central Colorado in 1961, with the population increasing to at least 168 by 1983. Concern about interspecific competition between mountain goats and mountain sheep (Hobbs et al. 1990) was addressed by a research project conducted from 1980 to 1986. Upon project completion, hunting permits for mountain goats were increased from 15 (1982-86) to 20 (1987), 22 (1988), 30 (1989), and 44 (1990-92). Discovery of an error in determining the minimum population of mountain goats (140 vs 88 in 1991, calculated by eliminating duplicate sightings from a total ground count) led to reduction of 1992 hunting permits from 44 to 8, and to 3 hunting permits for 1993 and 1994.

A simultaneous and ongoing effort by members of the public to stop mountain goat hunting on Mount Evans highlighted the conflict between hunters and recreationists, and the need for better knowledge of user needs and attitudes. The Colorado Division of Wildlife contracted the Human Dimensions in Natural Resources Unit at Colorado State University to cinduct a survey of public attitudes in summer and fall, 1993. Results provided managers with a better understanding of the sociological factors considered in determining wildlife objectives.

In 1993, the International Order of Rocky Mountain Goats proposed that mountain goats be declared a "native" species in Colorado. The Colorado Wildlife Commission passed this resolution on 11 March 1993 (Colorado Division of Wildlife, 1993).

This paper provides a case study of the events on Mount Evans, showing how critical census accuracy can be. Errors can become the focus of public conflict about wildlife management and misinterpretation of agency management objectives. Numerous people participated in the Mount Evans counts over the years including personnel from the U.S. Forest Service and Colorado Division of Wildlife, and members of the Rocky Mountain Bighorn Society. R. A. Larson, D. J. Todd, R. B. Gill, K. A. Green, G. Hain, R. D. Hernbrode, R. R. Oehlkers, S. M. Werner, J. J. Vaske, and K. A. Wittmann were members of the Mount Evans wildlife-associated recreation analysis team. J. L. George analyzed and re-analyzed count data and reviewed the manuscript.

BACKGROUND AND STATUS

Population Estimation and Harvest

Ground counts of mountain goats and mountain sheep were used to estimate populations in the Mount Evans area, about 100 km^2 of mountainous terrain east of Guanella Pass. Coordinated multi-route ground counts were initiated in 1978, and have been conducted annually since, yielding 16 years of population estimates. Annually, 25-35 people were divided into 12-15 teams covering 12-15 routes in one day. The counts were made during late July, starting at first light. The methodology involved counting and classifying groups of animals, noting their location on maps and recording the time of observation. Afterward, count data were summarized and probable duplicate sightings were eliminated to produce a minimum population size.

Mountain goat and bighorn sheep population minima ranged from 44-168 and 60-210, respectively, during 1978-1993 (Fig. 1). The mountain goat population may have been relatively stable (1981-1989) with a harvest of 10.8 percent (i.e. mean harvest = 14.9 ±0.9 SE animals and mean minimum population = 137.1 ±6.6 SE). The bighorn sheep population may have been stable only during 1981-1984 (mean ram harvest = 3.6 ±0.8 SE, mean minimum population = 120.3 ±12.9 SE). Mountain goat harvest objectives were increased in 1989 to bring the goat population closer to 100. Harvest was 28 in 1989, 41 in 1990, 44 in 1991, 7 in 1992, and 3 in 1993. A decreased harvest quota in 1992 and 1993 was set following a July 1992 count of only 68 goats and evidence of a miscalculation in 1991 (88 vs 140, resulting from failure to exclude all duplicate sightings). In subsequent counts, data were rechecked to prevent recurrence of such errors.

Upon Division request, the Wildlife Commission took emergency action and reduced the 44 licenses issued for 1992 to 8. A new drawing was held for the 8 licenses. The remaining 36 license holders were offered a license in another goat unit, first priority for Mount Evans in 1993 if licenses were issued, a license in 1993 with one unit to be offered, or given a refund.

Hunter - Recreationists Conflicts

Two conflicts between hunters and other recreationists resulted in a public outcry and media coverage in the Denver newspapers. The first occurred on 9 September 1984 when a licensed hunter took a mountain goat above Summit Lake and brought the animal through the parking lot on a busy Sunday afternoon. The second incident occurred on 26 August 1990 when a licensed hunter shot a sheep in full view of a number of other visitors. The sheep was shot too close to the Mount Evans Highway to be in regulatory compliance and the hunter was prosecuted.

Regardless of the legality of hunters' actions, the public questions the compatibility of hunting in an area of high general recreational use. Temporal separation of users was implemented in 1985, 1986, and 1987. The goat season was moved from September to October when the road was closed to vehicles because of potentially dangerous driving conditions. However, in 1985 and 1986, early winter storms during the first week of October made hunting conditions and access difficult. The season was then returned to September-early October but split into two periods, with weekday openings. In addition, letters were sent to all hunters asking their assistance in preventing conflict in this area of extreme sensitivity. In 1990 and 1991, there were four 5-day seasons with no weekend hunting. In 1994, the area within a half-mile of the highway was closed to hunting.

Based on the surveys conducted in 1993, about 75 percent of the people who visited Mount Evans had no conflicts with other users. Conflict resulting from individual visitor behavior interfering with other visitors was rare, and was primarily related to viewing and wildlife feeding.

Population Objectives

The intent of increasing the number of permits during 1989-1991 was to reduce goat numbers. We believe that failure to crop the mountain goat population results in increased interspecific competition and transmission of Johne's disease (*Mycobacterium paratuberculosis*). Opposing the effort to reduce goats was a group that espoused making the Mount Evans area into a "preserve" and terminating hunting. These citizens favored a mountain goat population that was disposed primarily to "watchable wildlife." In an effort to balance these opposing objectives, a minimum population objective of 100 (based on ground count minima) was established.

DISCUSSION

Minimum Viable Population

Small populations may not maintain genetic variability or persist over time. They are subject to stochastic extirpation events or slow extinction due to accumulation of deleterious alleles through inbreeding (Lacava and Hughes 1984, Reed et al. 1986). Thomas (1990) suggested, based on empirical evidence, that 10 is far too small (genetic

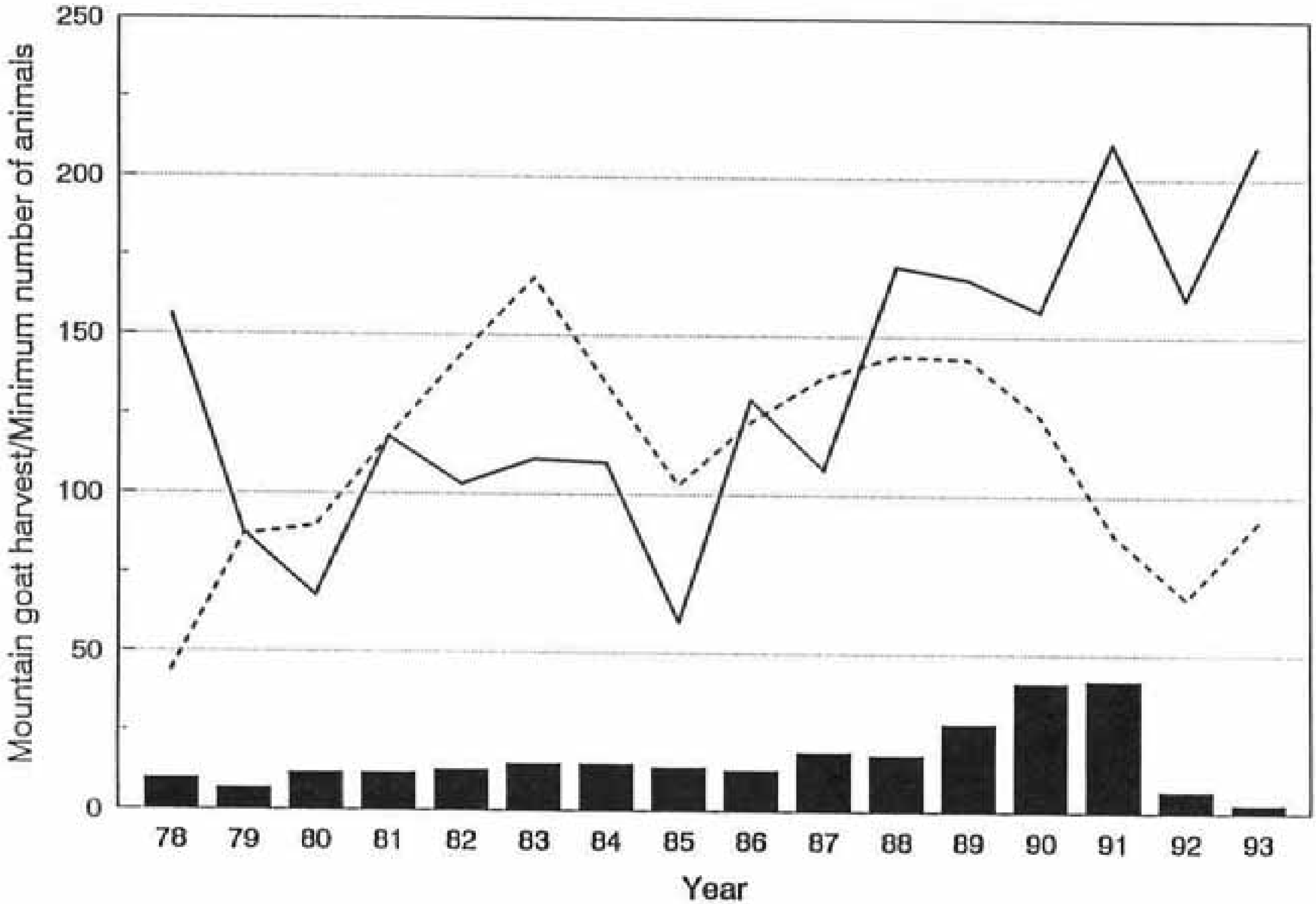

Fig. 1. Minimum number of mountain goats (dashed line) and bighorn sheep (solid line) based on annual ground counts, and number of mountain goats harvested (solid bar), 1978-1993.

variability will be lost rapidly and extinction will likely be swift) and that 100 usually is inadequate. For example, a simulated grizzly bear (*Ursus arctos*) population of 50 has a 0.06 probability of remaining extant for 300 years with an expected time to extinction of 114 yrs (Shaffer 1978, Shaffer and Samson 1985). An effective breeding population of 50 may be sufficient to avoid loss of variability, but a larger population may be required to neutralize the effects of genetic drift (Franklin 1980).

Berger (1990) found that all sheep populations of fewer than 50 animals went extinct within 50 years and that populations with more than 100 persisted for 70 or more years. He concluded that herd objectives should be >100. It has been suggested that a "best estimate" minimum viable population (MVP) for mountain sheep is 125 (Smith et al. 1991). Presuming that mountain goats fit a similar paradigm and that the population may not be isolated (about 200 mountain goats occupy Grays-Torreys Peaks, 11 km northwest of Mount Evans), a herd objective of 100 for Mount Evans may be an acceptable MVP.

Population Estimate Accuracy

Most counts of large wild ungulates approximate two-thirds of the real population (Neal et al. 1993). To what extent variables diminish the accuracy of the ground counts for Mount Evans is unknown. In an attempt to describe the variability, three ground counts (using methods described) were conducted in 1987 (D. F. Reed, pers. obs.). Unfortunately with a small sample size (n =3; i.e., 11 Jul = 132, 25 Jul = 137, and 30 Jul = 113), the standard error was large and 95 percent confidence limits were wide (mean = 127 ±7.3 SE, 95% CI = 96-159). Furthermore, this only described the population minima. How many were missed when the 137 were counted? This is unknown. Similarly, it is unknown for the other 15 years of population minima (Fig. 1). Hence, an independent test of ground count methodology is needed.

Probably the most practical method to independently test the ground count method would be a mark-resight study involving a prescribed number of "telemetry marks" and "helicopter counts." Assumptions involving mark-resight methodology were tested for mountain sheep and a computer program (NOREMARK) developed (Neal et al. 1993; G. C. White, per. comm.). Applying the design feature of NOREMARK to an estimated mountain goat population of 100 and 5 resighting occasions (helicopter counts), the following confidence intervals (CI) were generated:

if number of animals with telemetry marks = 40
then, CI = ±13.7% or ±13.7 animals.

if number of animals with telemetry marks = 50
then, CI = ±10.6% or ±10.6 animals.

To manage for a population of 100 mountain goats, the latter probably represents the CI needed.

MANAGEMENT LIMITATIONS

The "Wilderness" designation (U.S. Forest Service) of the Mount Evans area (excluding the highway and Summit Lake) may constrain approaches to test the ground count methodology. The "mark-resight" method assumes that all animals have an equal chance of capture (and being marked). Capture via helicopter rather than trapping in randomly selected sites may be a reasonable way to accomplish equal accessibility. Secondly, if ground counts were substituted for the 5 helicopter resighting occasions, this would entail organizing and training up to 150 people -- a labor intensive effort. An exemption for helicopter operation in the wilderness is unlikely, hence, the "mark-resight" test will likely not go forward.

Contraceptives may provide future options for controlling wildlife populations. New technologies to regulate the reproductive rates of wild animals may be operational by the end of the 1990s (D. L. Baker, pers. comm.). However, in most wildlife management situations, the promise of controlling the growth of populations with contraceptive technologies may be more symbolic than real. Computer simulations that compare the efficacy of hunting versus contraception to control wildlife populations suggest that fertility control will be feasible only with small populations of large animals (N. T. Hobbs, pers. comm.). On this basis, fertility control of mountain goats on Mount Evans may prove useful. Fertility control technology is so new that we are unable to forecast either its effectiveness or its costs. Furthermore, we have not engaged our publics in debate over the ethical and policy issues that will constrain the use of fertility controls. In any case, public hunting is economically superior to other population control options.

Results of the surveys suggest that conflict over wildlife management policy, is rooted in the fundamental differences in values that characterize contemporary American society (whether or how people ought to use and enjoy wildlife). It is unlikely that such value conflicts can be managed. However, management strategies, like spatial and/or temporal zoning of uses, can reduce conflicts between people whose values are similar, even if they engage in different forms of wildlife-associated recreation. More specifically, 8 alternative management scenarios were suggested by the public for the Mount Evans corridor (Colorado Division of Wildlife, 1994). Some scenarios do not meet current Division mandates and are incompatible with the U.S. Forest Service mandates. Ultimately the wildlife commission will determine the scenario by which Mount Evans wildlife will be managed.

CONCLUSION

An error in census, although discovered and corrected before negative impact occurred, caused a serious credibility problem for wildlife managers. Opponents of hunting used this error to capitalize on media coverage and public sentiment to further question the Division's ability to manage the outcome for the public trust. Current census methodology has been reviewed. Comparative tests of methodology should be conducted so that census accuracy is ensured.

The wildlife management and wildlife recreation activities which occur in the Mount Evans area must meet the needs of a large and diverse public possessing different and sometimes opposing values. If conflicts are not managed, widespread public support for diverse recreational activities will be jeopardized. This could have long lasting wildlife management consequences.

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Bienn. Symp. North. Wild Sheep
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THE EFFECTS OF PHYSICAL GEOGRAPHY ON DALL SHEEP HABITAT QUALITY AND HOME RANGE SIZE

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Abstract: Physical geography and prevailing macro-climatic factors determine habitat suitability for Dall sheep (*Ovis dalli*). Dall sheep habitats, which support high densities of sheep, are found on the lee (or snow-shadowed) sides of linearly arrayed mountain ranges which lie across the routes of prevailing bulk air flow. The higher density sheep habitats within these mountains are characterized by long, straight drainages paralleling bulk air flow. These drainages channel cold, heavy, dry air masses downhill after the air masses have cooled and lost the ability to carry water while being forced up and over the mountains. Wind speed increases as gravity accelerates the dense air masses downhill, producing catabatic winds in the absence of (or within) barometric pressure cells. These predictable winds prevent snow accumulation on ridges between tributaries that flow into larger drainages and produce stable wintering habitats for Dall sheep. Habitable but suboptimal ranges are found where one or more of these ideal physiographic conditions is absent and average winter snow accumulation is less than 175 cm (70 in). Winter ranges are less stable in the suboptimal habitats. Preliminary analysis of existing data on Dall sheep movements and home range sizes suggests an inverse relationship between habitat climatic stability and winter home range size. Less stable winter habitats demand greater flexibility in use of available microhabitats by the sheep which occupy these ranges. This demand results in larger home ranges with generally less stable populations of sheep than higher quality (more climatically stable) habitats.

It has been long observed and previously noted (Heimer and Smith 1975, Nichols 1978) that Dall sheep distribution in Alaska is limited by snow accumulation. Dall sheep are not found in areas with mean snow accumulations of greater than 175 cm (70 in) (Heimer and Smith 1975). Heimer and Smith (1975) also speculated that rams harvested from rugged portions of the southern Wrangell Mountains had the highest horn quality index in Alaska because their habitats, unique among Alaska sheep ranges, have southern exposure and are in the snow shadow created by the coastal Chugach Mountains.

It also has been axiomatic that winter winds, along with light, dry snows, are important components of ideal Dall sheep winter range (Nichols 1974, 1978; Heimer 1984). Heimer (1992) argued that, from Dall sheep adaptations, their apparent tendency toward a stable population strategy was an evolutionary result of habitat stability. In this paper we integrate the well-accepted factors of snowfall and wind to form a hypothesis defining habitat quality in terms of the physical geography determining these factors.

BACKGROUND

Why Integrate Prevailing Storm Movement and Geomorphology?

Our interest in the idea that prevailing bulk air (storm) movement is related to Dall sheep ecology through geomorphology resulted from 2 serendipitous events:

Prevailing storm movement. After spending portions of more than 20 winters in classic, high-density Dall sheep habitat in the central Alaska Range, Heimer had the opportunity to work with colleagues from the Bureau of Land Management in a helicopter-supported sheep capture operation in the Tanana/Yukon uplands. Several sheep were to be marked with radiocollars for a movement study. Preliminary studies (Gross 1963) suggested these Dall sheep moved considerably more than those in other areas (Heimer 1973).

The Tanana/Yukon uplands lie between the Tanana and Yukon Rivers in Interior Alaska. These uplands cannot be accurately defined as mountainous, being primarily rounded hills completely enveloped by boreal forest. Still there are a few scattered hills of montane which support alpine plant communities and reach altitudes of about 2000 m (6000 ft). These mountains are not arrayed as a typical "range of mountains" but scattered discontinuously through-out the lower hills. The Tanana/Yukon uplands are considered the logical refugia of thinhorn sheep during the most recent (Illinoian) glaciation because this area was not glaciated while other current Alaskan sheep habitats were covered by ice (Coulter et al. 1962). As a result of not having been "recently" glaciated, the Tanana/Yukon uplands are atypical of modern Dall sheep country, and call to mind the habitats postulated for mountain sheep as they colonized the new world (Geist 1971, Valdez 1982). The Tanana/Yukon uplands support viable but low-density and disjunct Dall sheep populations which exploit limited "islands" of alpine tundra surrounded by boreal forests. Storm movement through the Tanana/Yukon uplands generally is from south to north, but there is no geographic barrier to eastward (onshore) storm movement into the uplands from the Bering Sea via Norton Sound or the Chukchi Sea via Kotzebue Sound.

In the course of the Tanana/Yukon uplands sheep capture work, Heimer was let out of the helicopter on a mountain top so the helicopter could be maneuvered more safely in pursuit of a sheep. He was told to walk to a more suitable landing area where he would be picked up after the sheep had been caught. In the course of looking for a suitable landing site, Heimer walked eastward along a ridge and noticed that unlike other east-west ridges in the Alaska Range, snow cornices were found on both sides of the ridge. This, of course, meant that snowstorms "blew in" from both sides of that ridge, indicating the absence of a prevailing "windward/leeward" situation.

This situation was strikingly different from the central Alaska Range where an immutable "windward/leeward" snow deposition dominates. There, prevailing bulk air flow is northward up the south slopes, over the top of the Alaska Range, and down the northward drainages into Alaska's Interior region. Thus, air movement results in the "lee" side of east-west ridges being unfailingly on the north side of each ridge. The presence of snow cornices on both the north and south sides of an east-west ridge in the Tanana/Yukon uplands showed that not all sheep habitats are subject to identical climatic influences with respect to snow and wind direction, and resulted in consideration of differing geomorphic arrangements of high and low density sheep habitats with respect to prevailing bulk air flow.

<u>Geomorphology</u>. The second event was a flight Heimer made from Fairbanks, Alaska to Whitehorse, Yukon in a single-engine Cessna. The flight route was a transect chosen along sheep ranges on the north faces of the Alaska and north slope of the Wrangell Mountains in Alaska, and the south side of the Muskwa trench to Whitehorse in the Yukon. These sheep ranges lie in the precipitation shadows created by the Alaska Range and Wrangell-St Elias Mountains.

Sheep abundance along this transect varies from high in the central Alaska Range and northern Wrangell Mountains to relatively low in the adjacent northern reaches of the St. Elias Mountains of the Yukon. In the course of covering this expanse of sheep habitat along a major sheep population density gradient, it became apparent the high density areas had differing geomorphology than the areas with lower density.

Where Dall sheep populations are at high density, the major drainages are typically oriented north-south (parallel to prevailing bulk air flow), and were generally long and straight. In areas of the Yukon, where sheep density was less, drainages were shorter, more crooked, and flowed "around" the high ridge which forms the southern side of the Muskwa trench. Thus, it seemed unlikely that density driven (catabatic) wind velocity in the Yukon would be as great as in the Alaskan portion of the transect.

<u>Integration and hypothesis</u>. In Dall sheep country, high-density sheep habitats are found along long, straight drainages which lie on the lee sides of linear mountain ranges arrayed perpendicularly to prevailing bulk air flow. In these situations, warm moist air is forced up the windward sides of the mountain ranges where it cools adiabatically causing the water it carries to be deposited as snow. On the south side of the Alaska Range, the ice fields of the West Fork of the Susitna, the Susitna, McLaren, and Black Rapids glaciers attest to this phenomenon.

Once air reaches the crest of the Alaska Range, it is cold, dense, and dry. As this heavy air cascades catabatically down the long, straight drainages characteristic of "classic" Dall sheep habitat, it removes the typically light, dry snow which accumulates on the lower east-west ridges. These wind-blown ridges support plant communities which form ideal Dall sheep wintering habitats once the snow is removed. In these ideal habitats home ranges are small, and documented fidelity to seasonal ranges is 100% (Heimer 1973, Heimer and Watson 1982, Spiers and Heimer 1990). Stable, high-density populations may be expected in these areas (Heimer 1992).

Our hypothesis predicts where prevailing air flow does not consist of air masses adiabatically cooled to the point of dryness, where the direction of storm front movement is inconsistent, or where geomorphology does not favor acceleration of catabatic winds down relatively long, straight drainage channels to promote wind-scouring of snow from lower elevation vegetated ridges, sheep habitats will be less than ideal. In these marginal habitats, sheep survival should require more adaptive exploitation of micro-habitats. Our hypothesis also predicts a natural consequence of this forced adaptability should be larger home ranges (with increased difficulty for researchers to establish range fidelity) and lower density populations more prone to fluctuation.

METHODS

Optimal ranges with known sheep densities and winter home ranges were identified by the criteria listed above. Optimal ranges in the Alaska (Heimer and Watson 1986) and Brooks Ranges were located on the lee sides of linearly arrayed mountain ranges lying across prevailing bulk air flow routes and having long straight drainages for catabatic air flow.

Two differing types of suboptimal range where density and winter home range data were available also were identified. One range in the Tanana/Yukon uplands was considered suboptimal because it is not arrayed across the path of consistent bulk air flow, and lacks long straight catabatic wind channels. The other suboptimal range was located on the windward (snow depositing) south slope of the Brooks Range. In this area, habitat geomorphology was not unfavorable (the Brooks Range lies across the prevailing south to north bulk air movement). However, snow accumulation approaches the Dall sheep habitability threshold on these ranges because they lie on the south slope of the Brooks Range where snow is deposited.

Overall densities of sheep on each range were determined by dividing population size (from summer aerial count data) by the area counted.

Winter range sizes were determined by monitoring the movements of collared sheep. The greatest linear distance between winter radio-locations was defined as an index of the maximum home range size for each identified winter range. A mean winter range size index for each habitat type was then calculated. In the Alaska Range, 9 optimal winter ranges were identified over the course of 20 years using more than 400 sheep marked with visible neckbands. Range identity and fidelity were then confirmed using radio-marked sheep over separate 3-year periods (Heimer 1973, Heimer and Watson 1986, Spiers and Heimer 1990). In the Brooks Range, 11 optimal ranges were identified by 268 radio locations of 38 sheep over a 5-year sampling period. In the suboptimal ranges of the Tanana/Yukon uplands, 3 winter ranges were delineated by 566 radio locations of 15 marked sheep over a 5-year period (Durtsche et al. 1990). Suboptimal ranges on the south side of the Brooks Range were defined by 82 radiolocations of 12 sheep over a 3-year period.

Fidelity to winter ranges was determined by consistency of range use from year to year. Fidelity was expressed as the percentage of consistent use of winter ranges for marked sheep of each area.

RESULTS

Sheep populations from the "classic" habitats had smaller home ranges and higher population densities than those from "marginal" habitats (Table 1).

DISCUSSION

This paper reports observations which provide a rationalization for long-apparent distributional and population density parameters relating to Dall sheep. It is not a chronicle of experimental science. We have placed our observations in the construct of hypothesis development and testing as a vehicle for their presentation more than as a rigorous hypothesis test. Still, the construct of hypothesis testing provides preliminary assurance that a satisfactory explanation for variations in Dall sheep home range size may be found.

Table 1. Density, winter range size, and observed winter range fidelity by optimal or suboptimal range designation.

Type/Location	Density (sheep/mi²)	Index of maximum winter range diameter	Fidelity (%)
Optimal:			
Brooks Range (north)	2.4 - 5.1	4.0 mi (6.4 km) (n = 11 ranges)	100
Alaska Range[a]	3.0 - 6.0	5.6 mi (9.0 km) (n = 9 ranges)	100
Suboptimal:			
Tanana/Yukon uplands[b]	0.2 - 0.5	21.3 mi (34.1 km) (n = 3 ranges)	100
Brooks Range (south)	0.2 - 0.5	5.2 mi (8.3 km) (n = 5 ranges)	81

[a] Heimer and Watson (1986)
[b] Durtsche et al. (1990)

As suggested by the hypothesis, population densities were higher (approximately 10 times) in optimal habitats than in suboptimal habitats. While no data relating winter forage production per unit of range to Dall sheep density are available, the "optimal" ranges have sustained higher density populations of Dall sheep over time than the "suboptimal" ranges. We suggest prevailing wind and precipitation shadowing are major factors contributing to these sustained high densities because of the consistently greater area of suitable winter range available to sheep.

The hypothesis also predicted correctly with respect to winter range size. Weighted averages of both optimal areas produced a mean maximal winter range index dimension of 7.5 km (4.7 mi) while the weighted average of both suboptimal areas produced a mean maximal winter range index dimension of 17.9 km (11.2 mi).

It is possible this latter dimension could be inflated by data from the Tanana/Yukon uplands. The long time span of data gathering in that area (5 years) and the large number of relocations (566) could have obscured occupancy of smaller discrete ranges if Durtsche et al. (1990) used all locations to define large composite home ranges. If this were the case, actual range fidelity may be lower than the 100% reported from the Tanana/Yukon uplands (Table 1).

Fidelity to defined winter ranges was low in the suboptimal Brooks Range area. Three of 19 marked ewes definitely changed home ranges over the 3 years of the study. These different winter ranges were separated by an average distance of 21.9 km (13.7 mi). It is notable there has been no suggestion of winter range shifting in the optimal areas in either the Brooks Range (n = 38 radio-collared sheep monitored intermittently over 5 years) or Alaska Range (n = more than 400 neckbanded sheep monitored intermittently over 20 years). Still, suboptimal area winter range shifts in the Brooks Range are relatively common. Also in the Brooks Range, Ayers (1986) reported 1 of 10 radio-marked ewes in the Western Brooks Range (which would be classified as suboptimal habitat according to our hypothesis criteria) changed winter ranges between 1983 and 1985. The distance between the centers of her winter ranges was 17.7 km (11.1 mi).

The suggestion that home range size is larger in areas with less-than-ideal geomorphology may be relevant in some management situations. For example, residents of Arctic Village have maintained throughout the last decade that their October subsistence sheep hunting success in the upper East Fork of the Chandalar River (the suboptimal Brooks Range area) has been compromised by aircraft disturbance. The villagers assert that aircraft used by recreational hunters during the August season drove sheep from winter ranges where sheep were successfully harvested during the years before the overflights. This claimed link between presumed aircraft harassment of sheep on their summer ranges and absence of sheep from winter ranges where they were successfully harvested in the past is not credible.

The finding that Dall sheep in this area have large home ranges (particularly if linked to near-threshold snow accumulation because of their range locations on the windward side of the Brooks Range) may explain why sheep have been inconsistently found on the same winter ranges year after year. Similarly, the finding that some Dall sheep home ranges vary tremendously in size obviates concerns that arise when sheep appear to be inconsistent in movements over the short term where habitat geomorphology is not ideal.

Finally, consideration of the geographic or geomorphic correlates of population density and home range size for Dall sheep may be of some benefit to bighorn managers planning transplants. The bighorn literature is replete with accounts of transplants to apparently suitable vegetative communities in suitable proximity to escape terrain, yet the transplants did not thrive. Perhaps a simple overview of prevailing air flow and physiography could serve profitably as a first screen of habitat suitability prior to applying more sophisticated habitat suitability models typically applied in evaluating proposed transplant programs.

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CONSEQUENCES OF HABITAT FRAGMENTATION ON WILD SHEEP METAPOPULATION MANAGEMENT WITHIN USA

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Abstract: Comparisons of current and historical wild sheep habitat information with wild sheep distribution data gathered for the Bureau of Land Management's Bureauwide Mountain Sheep Ecosystem Strategy Plan indicate continuing fragmentation of metapopulation habitat. Implications of this fragmentation include a potential permanent loss of viable wild sheep habitat with a subsequent loss of metapopulation viability. The data illustrate that actual and potential habitat fragmentation occurs throughout the western United States rather than being confined to just a few locations. Habitat that links populations can be overlooked because it is not viewed as typical wild sheep habitat. The paper discusses how fragmentation has impacted some metapopulations and provides recommendations for achieving metapopulation management.

Prior to settlement, wild sheep were widely distributed in most mountain ranges and badlands of western North America. Since that time apparent large scale habitat fragmentation has taken place (Wishart 1978) (Fig. 1). Fragmentation occurs when a large expanse of habitat is transformed into a number of smaller patches which are isolated from each other thus forming a matrix of habitats unlike the original. Using Hanski and Gilpin's (1991) definition of fragmentation, we believe wild sheep, as one of many species with formerly continuous spatial distributions, are experiencing habitat fragmentation. Fragmentation of habitat remains the principal threat to most species in the temperate zone (Wilcove et al. 1986).

The key to management of all races of wild sheep is habitat protection, maintenance, and enhancement (Nichols 1978, Wishart 1978). Until recently the predominate approach to habitat management has been at the local scale (Bleich et al. 1990). Local scale is defined as the scale at which individuals move and interact with each other in the course of their routine feeding and breeding activities (Hanski and Gilpin 1991). A metapopulation is defined as a set of local populations which interact via individuals moving among local populations. A species restricted to a newly fragmented habitat does not necessarily function as a metapopulation. It may have such a restricted ability to disperse that a local population, once extinct, will remain extinct. We must understand the dynamics of these fragmented populations so that proper management remedies can be attempted to prevent total extinction (Hanski and Gilpin 1991). Metapopulation scale in relation to local scale has been defined by Hanski and Gilpin (1991) as the scale at which individuals infrequently move from one place (population) to another, typically across habitat types which are not suitable for their feeding and breeding activities, and often with substantial risk of failing to locate another suitable habitat patch in which to settle. The importance of metapopulations to bighorn sheep (*Ovis canadensis*) and the adverse impacts of fragmentation have been addressed (Schwartz et al. 1986, Bleich et al. 1990, Berger and Wehausen 1991, Ramey 1991).

The Bureau of Land Management (BLM), as well as other habitat management agencies has begun managing for biodiversity over broad ecosystems, resulting in a focus on landscape ecology and metapopulation management. Forman and Godron (1986), in defining landscape ecology, pointed out that landscape ecology has many similarities with metapopulation studies, including survival of species, communities, and ecosystems in fragmented habitats; how to distinguish the matrix, or the distinction between habitat patches and their surroundings; origin, size and shape of habitat patches; and the role of habitat corridors in

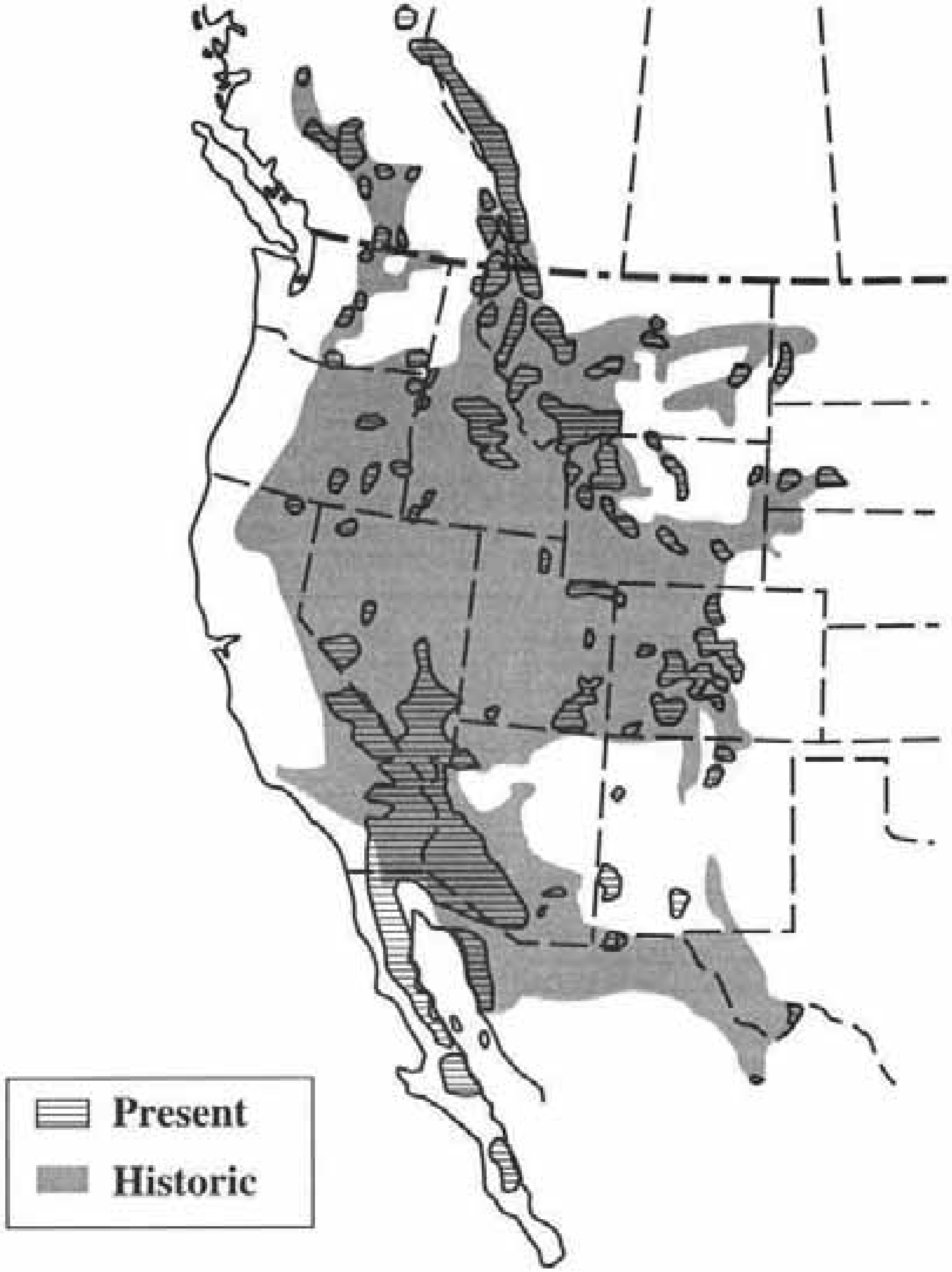

Fig. 1 - Present and Historic Distribution of Mountain Sheep in the Western United States (after Wishart 1978).

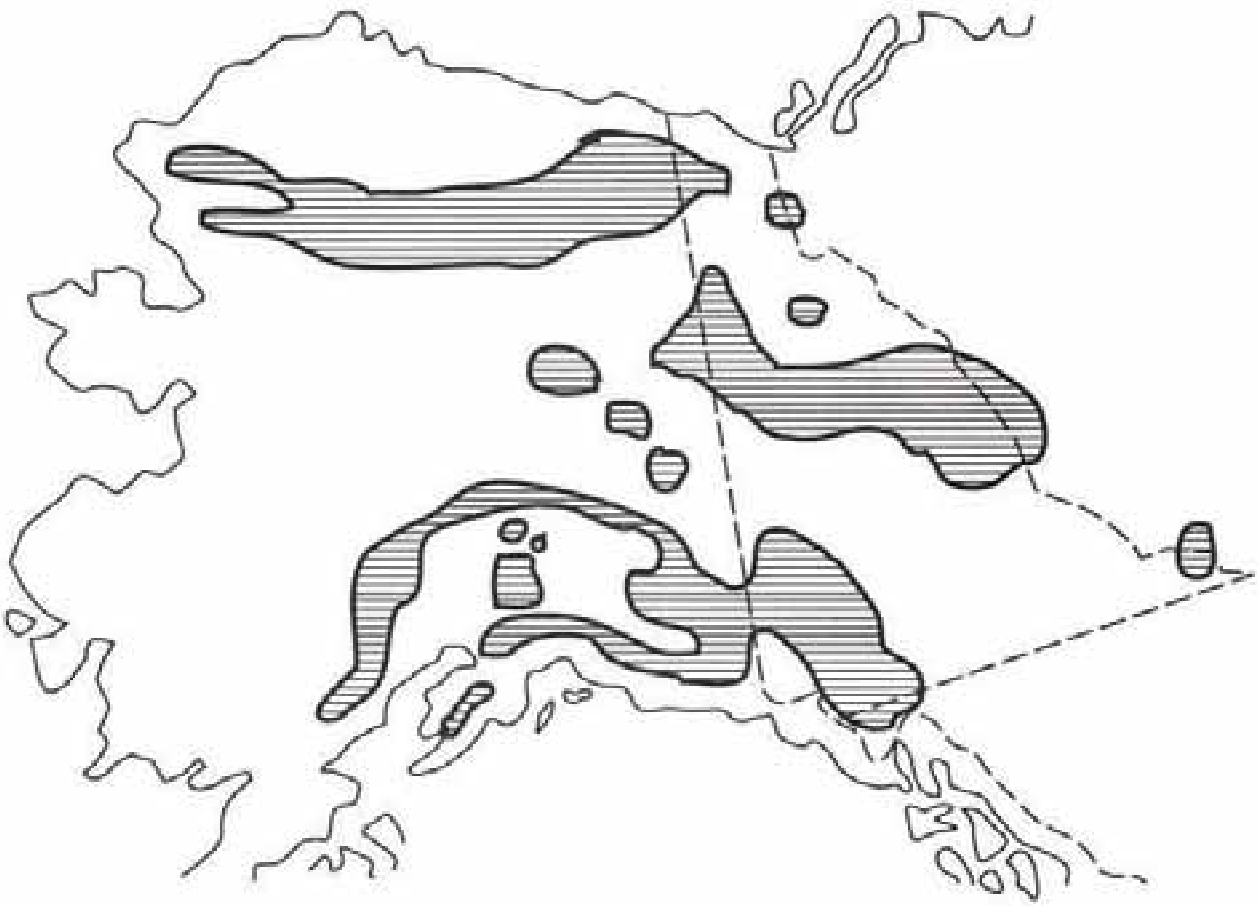

Fig. 2 - Present Distribution of Dall Sheep in Alaska and Canada (after Nichols 1978).

Fig. 3 - Present and Historic Distribution of Desert Bighorn Sheep in the Western United States.

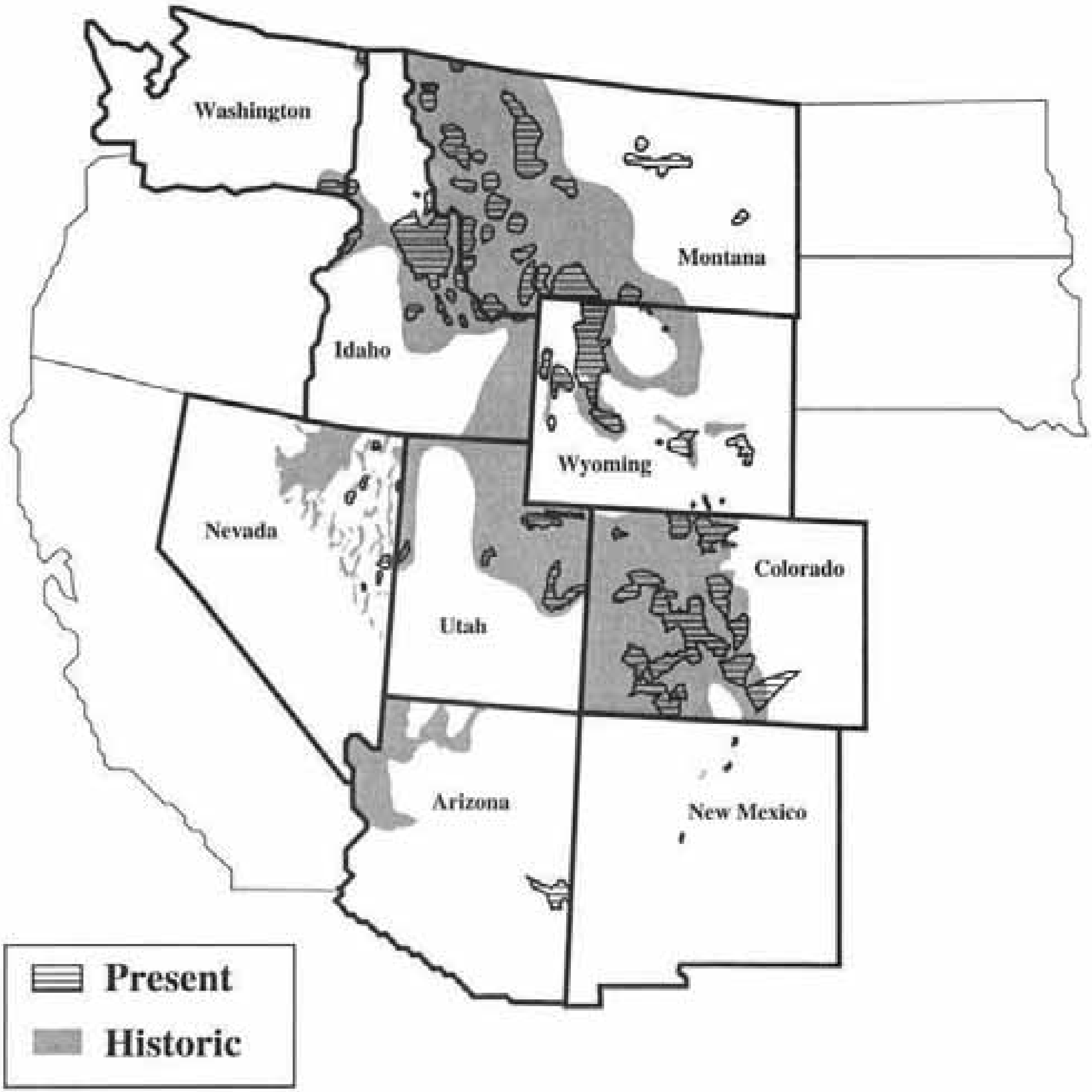

Fig. 4 - Present and Historic Distribution of Rocky Mountain Bighorn Sheep in the Western United States.

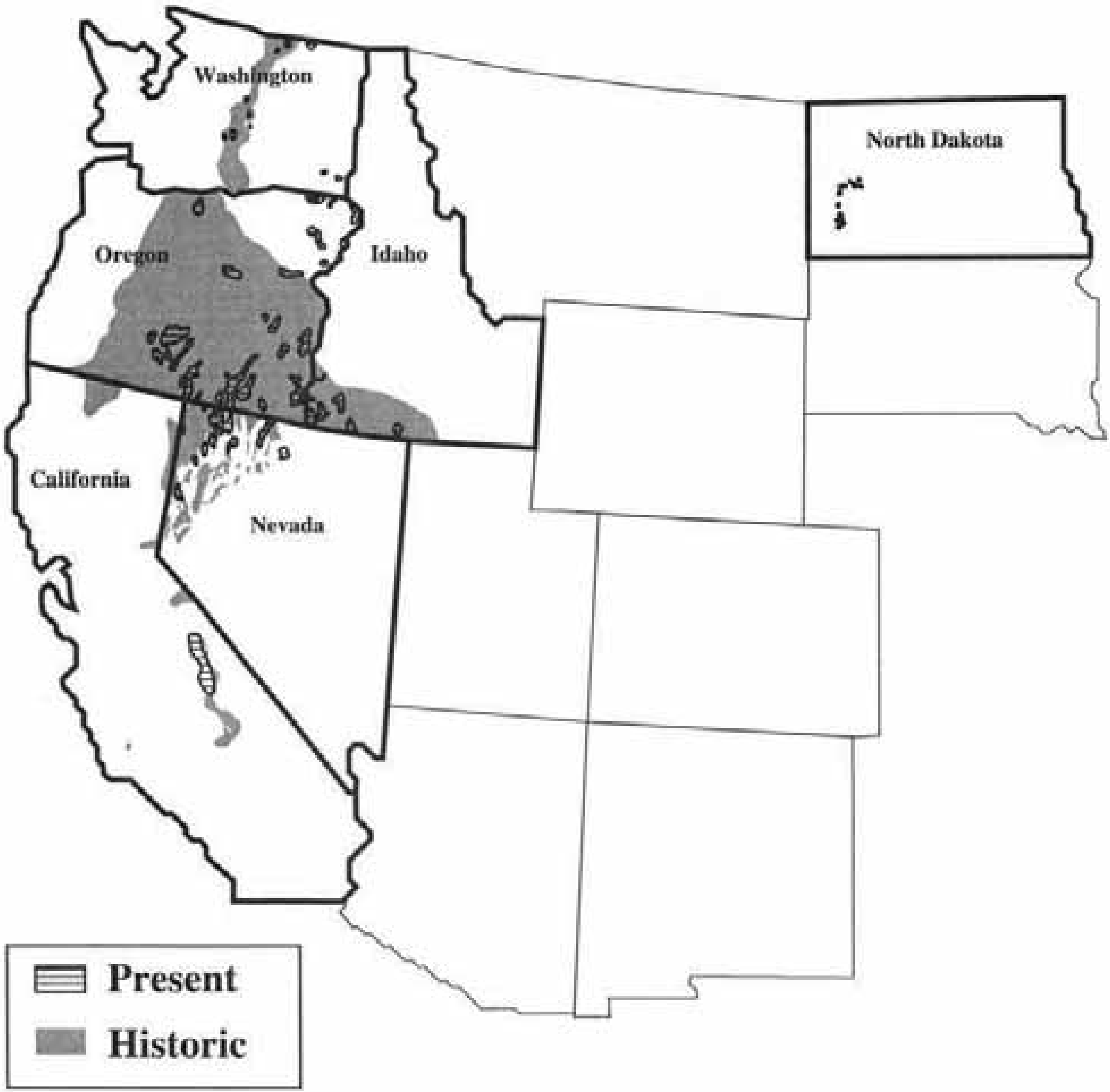

Fig. 5 - Present and Historic Distribution of California Bighorn Sheep in the Western United States

facilitating dispersal and hence maintaining viable populations. Metapopulation studies developed deductively, with extensive use of mathematical models and, with extensive testing of any advances against observational data and experimental systems. On the other hand, landscape ecology is holistic in its approach and focuses on the entire landscape. Merging of the 2 disciplines should make for exciting scientific synthesis.

One of the first strategy plans based on landscape ecology being prepared by the BLM through interagency cooperation is entitled, *Mountain Sheep Ecosystem Management on Public Lands*. This planning effort will establish Bureau-wide goals for managing the thinhorn sheep and 3 bighorn sheep subspecies which occur on public land. These wild sheep are Dall sheep (*Ovis dalli dalli*) (Fig. 2), desert bighorn sheep (*O. c. nelsoni*) (Fig. 3), Rocky Mountain bighorn (*O. c. canadensis*) (Fig. 4), and California bighorn (*O. c. californiana*) (Fig. 5). In order to prepare such a plan we need to understand as much as possible about current management practices, wild sheep distribution, population numbers, population and habitat limiting factors, and several management support items including habitat manipulation projects, land acquisition exchange needs, and right-of-way acquisition. One of our first steps was to quantify and document these items. We will limit the discussion in this paper to those responses pertinent to metapopulation management.

We thank all the state wildlife agencies, BLM, USDA Forest Service, and private members of the interagency team who developed the questionnaire used to gather the needed information and who will continue to be involved in the task of completing the plan.

METHODS

A compiled dBASE IV data base in the form of a questionnaire was sent to all 138 BLM field offices. Although the BLM biologists were to respond directly to the questionnaire, all responses were to be coordinated with state wildlife agencies and other federal agencies. To date, 134 (97%) of those contacted have responded. Questions tied directly to analyzing the state of metapopulation management included total number of habitat acres currently occupied, total number of acres that are suitable habitat but unoccupied, total acres of historic habitat which are no longer suitable for habitation, and factors which limit habitat use. Suitability is determined from habitat inventory results. The questions were to be applied to a biological unit or bioregion by species or sub-species. A biological unit/bioregion is defined as a territory having a combination of biological, social, and geographic criteria, rather than geopolitical considerations; generally, a system of related, interconnected ecosystems. In most cases, this formerly was called a herd unit. Because Canada is not presently included in this planning effort, we are reporting only on sheep populations within USA.

RESULTS

The 134 respondents provided information for 252 biological units/bioregions. From a total of 57,743,704, acres, 81% (46,576,169 acres) are occupied habitat, 6% (3,611,274 acres) are unoccupied suitable habitat and 13% (7,556,261 acres) are historic unsuitable habitat. Within the 252 total biological units/bioregions, 24% are unoccupied, 24% have a population of 50 or less individuals, 25% have a population between 51 and 100, and 27% support populations of >100 individuals. Analysis of the habitat information was completed for individual species and sub-species.

Dall Sheep

Dall sheep in Alaska. Alaska contains 29,475,300 acres of Dall sheep habitat (Fig.2). Dall sheep currently occupy 96% (28,339,300 acres) of the total with unoccupied suitable and historic unsuitable each being 2% or 468,000 acres and 668,000 acres respectively.

Desert Bighorn Sheep

Six of the 11 western states provide a total of 17,501,022 acres of habitat (Fig. 3). Desert bighorn sheep occupy 75% (13,143,340 acres) of this area with 9% (1,531,672 acres) suitable but unoccupied and 16% (2,826,010 acres) unsuitable historic habitat.

Rocky Mountain Bighorn Sheep

Ten of the 11 western states provide a total of 7,430,439 acres of habitat (Fig. 4). Rocky Mountain bighorn sheep occupy 52% (3,842,056 acres) of this area while 13% (951,964 acres) is unoccupied but suitable and 35% (2,636,419 acres) is unsuitable historic habitat.

California Bighorn Sheep

Five of the 11 western states provide a total of 3,336,943 acres of habitat (Fig.5). California bighorn sheep occupy 37% (1,251.473 acres) with 20% (659,638 acres) unoccupied but suitable and 43% (1,425,832 acres) unsuitable historic habitat.

DISCUSSION

With 134 respondents listing a total of 252 biological units, it is not clear if the metapopulation management approach has become a working concept. A review of Figures 2 through 5 indicates the application of metapopulation management principles are being applied unequally throughout the 11 western states and Alaska. Several of the respondents have mapped and reported on individual local populations rather than displaying and discussing existing metapopulations.

With a 1993 total estimated population of 72,396 wild sheep in the western United States and Alaska we have made some progress in increasing sheep numbers from the estimated population of 65,725 in 1974 (Trefethen 1975). Of the 252 biological units reported, 60 (24%) have a "0" population. Eighteen of the 60 biological units with "0" populations are predicted to be populated by the year 2000 through transplants and dispersal. We presume these 18 represent the suitable unoccupied habitat. The remaining 42 "0" population biological units should represent the 7,556,261 acres of unsuitable historic habitat which indicates continued fragmentation of habitat. Discarding the 60 "0" populations we are left with 192 occupied biological units. Taking the conservative approach and following Berger (1990) we conclude that sheep in 32% (61) of the remaining 192 biological units will likely go extinct within 50 years. Wehausen (1995) reviewed Berger's work and has raised doubt concerning the likelihood of these populations actually going extinct. Careful population monitoring will be necessary to determine which view is correct. This amount of time, taken in the context of biodiversity and ecosystem management, is not adequate to state there would be a viable population or metapopulation in those biological units. A worst case scenario for the 61 populations which could go extinct within 50 years is that an additional 3,705,263 acres of presently occupied habitat would be lost.

The majority of occupied habitat is found in those areas where the human influence is least felt. Fifty one percent of occupied wild sheep habitat occurs in Alaska with the remaining 49% spread through the 11 western states. At the other end of the spectrum, 50% of the unsuitable historic habitat is found in 4 states, including California (18%), Nevada (13%), and Wyoming and Idaho (10% each). This finding is consistent with the thrust of landscape ecology which is particularly concerned with the human role in landscape development (Hanski and Gilpin 1991). California has not only undergone tremendous urbanization during the 20th century, it joins the other 3 states in having widespread, intensive livestock grazing. Livestock grazing was the primary habitat limiting factor cited by the majority of those responding. Other habitat limiting factors included habitat fragmentation and timber management. Habitat fragmentation can be a cause for population decline or extinction as a result of land use practices. Aggressive reintroduction programs, where appropriate, could raise the total occupied habitat by 6%.

Review of the questionnaire results on a species and subspecies basis supports the general consensus that increased habitat fragmentation leads to populations and habitats that are in jeopardy.

Dall Sheep

Dall sheep habitat is the least fragmented of all the species and subspecies addressed in this paper. Its 7 biological units range in size from over 21,000,000 acres to 690,400 acres. Population figures for Dall sheep appear to have remained basically stable over the last 20 years. Alaska is extremely low in human population for its size, with limited access to many parts of the state. Livestock grazing is not an issue in Alaska at this time. Once the land selection issues associated with the Native Claims Act have been resolved, the metapopulation situation may change.

Desert Bighorn Sheep

Three of the 20 biological units identified with "0" population are suitable unoccupied habitat. The remaining 17 represent the 2,636,419 acres of unsuitable historic habitat. A review of Figure 7 illustrates the habitat fragmentation that has taken place to date. Fifteen of the remaining 70 biological units support population levels of less than 50 individuals, potentially predisposing desert bighorn habitat to a loss of approximately 1,701,056 acres (a 10% increase in habitat loss in the next 50 years). A continued aggressive reintroduction and augmentation program into appropriate locations could perhaps recover 9% of the habitat available.

decrease the potential for extinction of low population habitats, and increase metapopulation potential by lowering habitat fragmentation. Livestock grazing, habitat loss and habitat fragmentation are identified as habitat limiting factors. In states where livestock grazing has been identified as a major habitat limiting factor, disease could be carried from population to population by individuals who have had nose to nose contact with domestic sheep. Livestock grazing in this context is in itself a habitat fragmenting activity. In California, what should be one extraordinarily large metapopulation is fragmented into 5 smaller metapopulations by fenced, multiple-lane highways and, two open aqueducts.

Desert bighorn sheep populations appear to have increased over the past 20 years from approximately 11,115 individuals in 1974 (Trefethen 1975) to 15,858 in 1993. Livestock grazing and disease are the top 2 population limiting factors.

Rocky Mountain Bighorn Sheep

Three of the 16 biological units identified with "0" population are suitable unoccupied. The remaining 13 biological units represent unsuitable historic habitat areas which indicates a loss of 35% of the total habitat for these sheep. A review of Figure 4 illustrates the habitat fragmentation that has taken place to date. Fifteen of the remaining 55 biological units support population levels of less than 50 individuals, predisposing Rocky Mountain sheep habitat to a loss of approximately 1,433,161 acres of habitat (a 19% increase in habitat loss in the next 50 years). An aggressive reintroduction program into appropriate locations could perhaps recover 13% of the habitat available and increase metapopulation potential by lowering fragmentation. Livestock grazing, timber management practices and habitat fragmentation are identified as habitat limiting factors. Rocky Mountain bighorn sheep populations appear to have decreased over the past 20 years from approximately 13,110 individuals in 1974 (Trefethen 1975) to 9,163 in 1993. Livestock grazing and disease are the top 2 population limiting factors.

California Bighorn Sheep

Eleven of the 24 biological units with "0" population are suitable unoccupied. The remaining 13 biological units represent unsuitable historic habitat areas which account for the 43% loss of total California bighorn sheep habitat. Thirty of the remaining 60 biological units support populations of less than 50 individuals, which raises the potential for the loss of 727,126 acres or 22% more habitat. An aggressive appropriately designed reintroduction program could increase the occupied portion of total habitat by 20% which may lower the high level of habitat fragmentation which is evident (Fig. 9). Livestock grazing, and habitat fragmentation are 2 of the top habitat limiting factors.

California bighorn sheep populations have increased over the last 20 years from approximately 1,500 in 1974 (Trefethen 1975) to an estimated 4,995 individuals. This apparent paradox demonstrates a "semi-feast or famine" population situation. Sixty percent of the occupied biological units with populations greater than 50 individuals contain populations in excess of 100 individuals. Most of the remaining populations are close to a 100 individuals per area level. A review of the amount of acres contained within the occupied areas results in a determination of high density populations. If, as reported, livestock grazing and disease are the primary population limiting factors, these high density fragmented populations could quite easily become endangered. This has been demonstrated in 4 populations in California.

RECOMMENDATIONS

The largest single road block to adequate ecosystem management is the ability to change attitudes and agency thought processes. For a highly vagile species such as bighorn sheep, large areas must be managed for wide-ranging metapopulations. With these points in mind, we offer recommendations for implementing and maintaining the metapopulation/landscape ecology approach needed to insure the continuation of viable bighorn sheep populations.

1. All agencies involved in management of bighorn sheep must move from territorialism to mutualism. We are all working to perpetuate a species which is wide ranging and has no ability to recognize jurisdictional boundaries. We, therefore, are acting imprudently if we ignore natural laws in favor of "territorial imperative."
2. Using the interagency plan being prepared for BLM as a starting point, bighorn sheep biologists and managers should form interagency advisory groups. There should be a group for each separate species and sub-species. Each interagency group should undertake the following tasks.

a. Determine the current geographical distribution of the target wild sheep.

b. Determine where the geographical distribution has been fragmented into metapopulations and local scale populations.

c. Establish the functionality of these metapopulations and local populations in terms of their viability through population demographic studies and habitat trends.

d. Establish where within the geographical distribution there is potential for recovery of "lost" habitat and put a strategy in place to accomplish the recovery.

e. Implement a strategy which will maintain viable metapopulations far into the future.

3. Develop ecosystem based guidelines for continual successful management of wild sheep on a metapopulation basis and provide to all agencies and private organizations involved with bighorn sheep management

The Northern Wild Sheep and Goat Council and the Desert Bighorn Council may be the appropriate organizations to work with agencies and other organizations in forming the interagency groups.

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EVALUATION OF A MULTIVARIATE MODEL OF MOUNTAIN GOAT WINTER HABITAT SELECTION

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Abstract: A predictive model of winter habitat selection by mountain goats (*Oreamnos americanus*) in south coastal Alaska was developed using discriminant function analysis (DFA). Thirty-two individual goats on the Upper Cleveland Peninsula (UCP) were radio-collared and monitored on a biweekly basis for 1-3 years to provide information on winter habitat selection. DFA was used to separate winter habitat areas from randomly selected areas on the UCP. Distance to cliffs, aspect, and timber volume provided the greatest discrimination power. The model was tested by placing radiocollars on 13 resident goats in a subpopulation located 75 km south of the UCP and on 15 goats transplanted to previously unoccupied habitat on an island 35 km south of the UCP. Relocation flights over 2 winters in the first test area and over 1 winter in the second revealed that the model correctly predicted winter use areas in 81 and 82 percent of the cases, respectively. Accuracy of predictions was significant at the $\underline{P} < 0.05$ level.

Human habitation and development continue to expand in the range of northern wild sheep and goat populations. Wildlife management strategies designed to maintain populations of these species hinge, to a large degree, on protecting critical habitats to minimize the impact of land use or resource extraction. The potential impacts to mountain goats from logging coastal old growth forest is of particular concern in southeast Alaska where several studies of habitat selection have demonstrated that some low to mid-elevation, south-facing slopes with commercial timber are used heavily by mountain goats for winter habitat (Schoen and Kirchhoff 1982, Smith and Raedeke 1982, Fox 1983, Smith 1986). However, simply knowing the attributes of critical habitat is not enough. To be effective in influencing land use decisions, biologists must be able to identify critical habitats in a timely fashion over relatively large areas using tools commonly available to resource managers. The use of habitat models is often chosen to fill this need (O'Neil et al. 1988, Hobbs and Hanley 1990, Allen et al. 1991).

Several investigators have developed models of habitat selection for goats in southeast Alaska using discriminant function analysis (DFA) (Schoen and Kirchhoff 1982, Fox 1983). These studies demonstrated that DFA could be used to differentiate between goat habitat and random locations in a given study area. Anderson (1990) similarly applied DFA to distinguish between resting sites used by bobcats (*Felis rufus*) and random sites. Dubuc et al. (1990) used DFA to differentiate between watersheds used, or not used, by river otters (*Lutra canadensis*) in Maine. However, none of these studies provided independent tests of the accuracy of this modelling approach.

This study applied a habitat selection model using DFA generated in 1 study area to predict habitat selection in 2 other areas in south coastal Alaska. The objective was to determine whether biophysical information available on standard forest inventory and topographic maps could be used to accurately predict the location of winter habitat for coastal mountain goat populations. If successful, the model would give forest and wildlife managers a quantitative tool for use in designing timber sales, roads, or habitat retention areas.

Funding for this project was provided by Federal Aid in Wildlife Restoration Projects W-22-1, W-22-2, and W-22-3. Additional funding was provided by Region 10 of the U.S. Department of Agriculture (USDA) Forest Service. Alaska Department of Fish and Game biologists John Schoen, Matthew Kirchhoff, biometricians Michael Thomas and Jay Ver Hoef, and technicians Kent Bovee and Scott Brainerd provided assistance in the field and support during analysis.

STUDY AREAS

Three separate study areas were used in this analysis (Fig. 1). The Upper Cleveland Peninsula

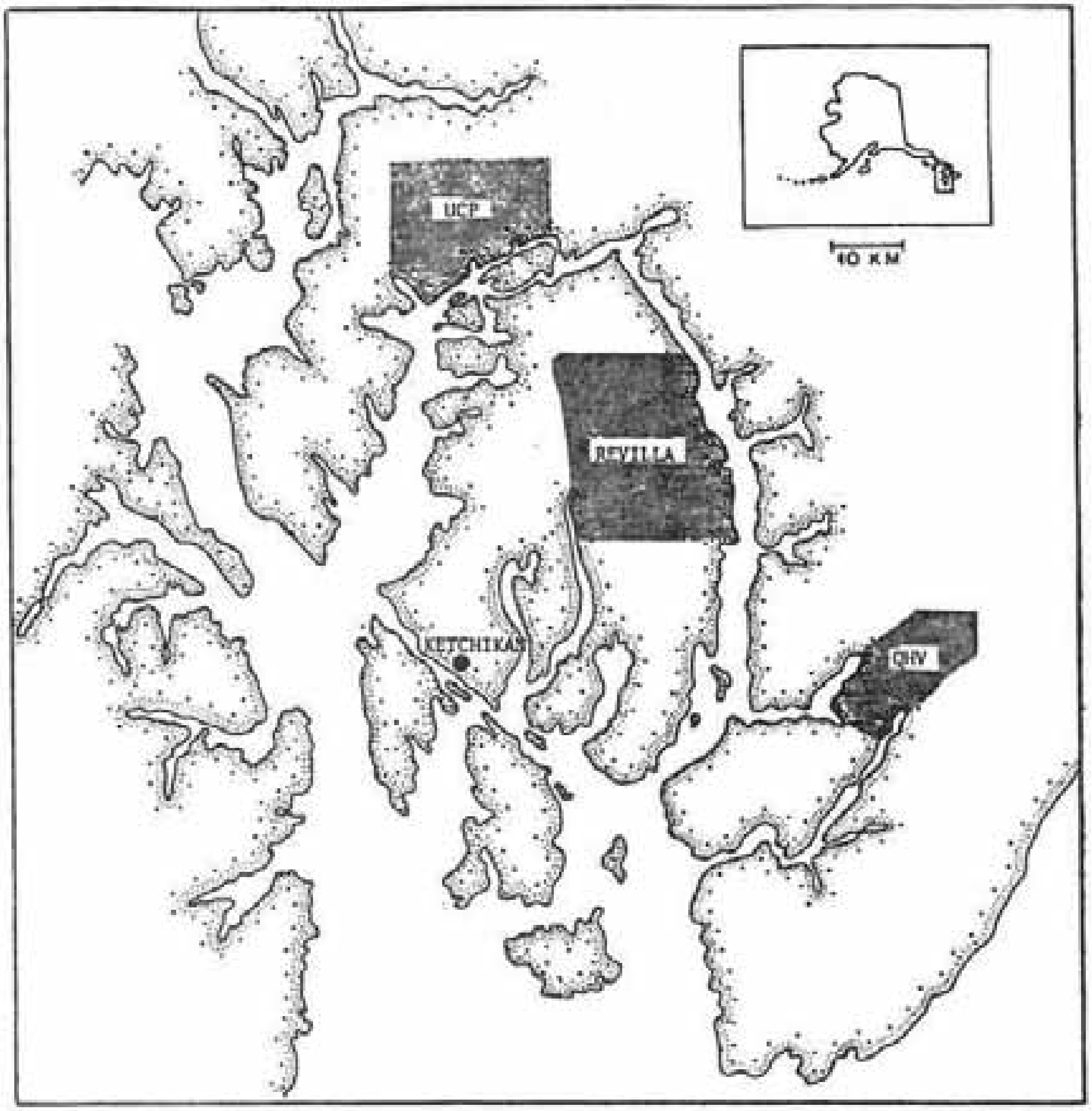

Fig. 1. Location of Upper Cleveland Peninsula (UCP), Quartz Hill vicinity (QHV), and Revillagigedo Island (Revilla) study areas near Ketchikan, Alaska.

(UCP) is located approximately 80 km north of Ketchikan, Alaska. The UCP is typical of coastal goat habitat with elevations ranging from sea level to over 1,500 m. This area is described in detail in Smith (1986). The UCP was selected as the "base" area for development of the habitat selection model.

The Quartz Hill vicinity (QHV) area is located on the coastal mainland approximately 70 km east of Ketchikan and 80 km southeast of the UCP. This area is biophysically similar to the UCP and sustained goat populations of comparable density to the UCP (Smith 1984a). The Revillagigedo Island study area (Revilla) is on the northeast third of Revillagigedo Island approximately 50 km northeast of Ketchikan, midway between the UCP and QHV. Although biophysically similar to the UCP and QHV, this area was not occupied by goats until they were transplanted to the area in 1983 (Smith and Nichols 1984). The QHV and Revilla areas are described in detail in Smith (1984b).

METHODS

Standard U.S. Geological Survey topographic maps, overprinted with USDA Forest Service timber types and expanded to 1:31,680 scale, were used for development and testing of the model. Independent grid overlay systems similar to those used by Schoen (1977) were developed for each study area by overlaying a 10 x 10 matrix with 100 grid cells per section, on the topographic maps. Each cell contained approximately 2.6 ha of land. This size was considered large enough to permit accurate mapping of goat relocations, yet fine enough to permit a single point sample of habitat parameters to describe the cell.

Habitat variables used for the predictive model included elevation, aspect, slope, distance to the nearest cliff (i.e., area of measurable slope >50°), and timber volume. These parameters have the most influence on goat habitat use in Southeast Alaska (Fox et al. 1982, Schoen and Kirchhoff 1982, Fox 1983, Smith 1986).

Habitat variables were scaled or converted to numeric values as follows. Elevations were scaled in 36 m (100 ft) increments. Aspects were grouped as flats, N (including NW and NE), E and W, and S (including SE and SW). Slope categories were 0-15°, 16-20°, 21-25°, 26-30°, 31-37°, 38-50°, 51-65° and >66°. Distance to cliffs was in 0.4 km units. Standard USDA Forest Service timber volume classes (0, <8, 8-20, 21-30 and >30 thousand board feet per acre [mbf/a]) were used (No metric equivalent exists for these classes [Schoen and Kirchhoff 1990]). Additional details of methodology for parameter measurement are provided in Smith (1986).

A predictive model of goat winter habitat was developed using stepwise DFA to separate cells used by a sample of goats in winter from randomly selected cells in the same area as previously reported for goats by Schoen and Kirchhoff (1982) and Fox (1983). For this analysis, the 1,526 grid cells randomly selected and sampled by Smith (1986) to determine habitat availability on the UCP were divided into 2 groups. The first group consisted of those cells used by goats on the UCP during the winter (Nov 1-Mar 31). Additional UCP cells used by goats as reported in Smith (1986), but not included in the random sample, were added to the first group. This was called "winter habitat." The remaining random cells, which were unused by the collared goats, were considered "other" habitat.

The discriminant function derived with the UCP data base was used to predict the location of winter habitat on the QHV and Revilla study areas. Systematic samples of 25% of the grid cells on the QHV and Revilla study areas, consisting of all cells with even x and y coordinate values, were sampled for elevation, aspect, slope, distance to cliffs, and timber volume as was done for the UCP cells. Each of the cells was then classified by the DFA as most likely belonging in the "winter habitat" or "other" group.

Maps of "winter habitat" were developed using a 2-step process. First, cells identified by the DFA as being in the "winter habitat" group were mapped on the study area grid overlays. Second, lines were drawn around these "winter habitat" cells and any nonsampled cells that shared at least 3 corners with sampled cells that were classified as "winter habitat."

This "3-corner" rule for classifying nonsampled cells on the QHV and Revilla study areas was tested by randomly sampling 250 additional cells on the QHV, not included in the systematic sample. These cells were chosen so that 50 cells with 0, 1, 2, 3 and 4 corners, respectively, contacted systematically sampled cells classified by the DFA as "winter habitat." When these 250 cells were then processed by the DFA, 4% of those with 0 corners in contact with systematically sampled "winter habitat" cells were also classified as "winter habitat." This percentage increased to 29% for cells with 1 corner in contact with "winter habitat," 54% for cells with 2 corners, 79% for cells with 3 corners and 80% for cells with all 4 corners in contact with "winter habitat." Thus the "3-corner" rule appears to be a conservative approach to completing mapping from the 25% systematic sample.

To test the accuracy of the predictions of "winter habitat," goats were radio-collared and monitored in the QHV and Revilla study areas. In the QHV area, 13 goats, distributed over all major ridge complexes in the study area, were radio-collared in summer 1982. Winter relocations were obtained for these goats on a biweekly basis during winters 1982-83 and 1983-84. In the Revilla, 15 of 17 goats transplanted to the Revilla as described by Smith and Nichols (1984) were fitted with radiocollars and released in the center of the study area in 1983. These goats were also located on a biweekly basis during the winter of 1983-84.

Winter relocations for goats collared on the QHV and Revilla study areas were mapped to determine whether they fell within the predicted "winter habitat" areas. Chi-squared goodness-of-fit tests were used to assess the level of significance of the goats' selection for the predicted "winter habitat" (Sokal and Rohlf 1969).

RESULTS

The DFA of UCP cells used by radio-collared goats during winter (n = 313) versus unused, random UCP cells (n = 1,436) identified slope category as the most powerful discriminating variable for separating the 2 cell groups. The standardized canonical coefficients (Table 1) indicate that slope angle contributed nearly twice as much to the separation of the groups in multivariate space as did distance to cliffs, and more than twice as much as timber volume. The latter 2 variables were relatively close in terms of their discriminating power. Aspect and elevation contributed less to the discrimination, but were, nevertheless, significant in terms of overall separation.

From the signs of the coefficients it is evident that slope, aspect, and timber volume make positive contributions to the function (i.e., steeper slopes, more southerly aspects, and higher timber volumes are characteristic of habitat cells) while elevation and distance to cliffs make negative ones (i.e., higher elevations and greater distances from cliffs are more characteristic of random cells).

Table 1. Standardized canonical coefficient of the discriminant function analysis of "winter habitat" versus "other" cells on the Upper Cleveland Peninsula (UCP), Alaska study area, 1981-84.

Variable	Constant
Elevation	-0.12220
Aspect	0.15548
Slope	0.70545
Distance to cliff	-0.40808
Timber volume	0.31803

The derived discriminant function had relatively large Wilks λ (0.81) and relatively small separation of group centroids in multivariate space (1.05 for "winter habitat" cells versus 0.23 for "other" cells), which indicates there is substantial overlap of the groups. This is not surprising, inasmuch as many of the "other" cells are, in fact, biophysically identical to the cells used by goats during the winter. In fact, many of the "other" cells were probably used by radio-collared goats during times between location, or by unmarked goats throughout the winter.

Nevertheless, the canonical correlation of the equation (0.44) is high enough to suggest that this function can adequately discriminate among the cell groups. This conclusion is also supported by the results of the classification table which indicates that the function correctly classified 84% of the "winter habitat" cells and 71% of the "other" cells when the cells were reprocessed through the function (Table 2). The most important test of the DFA, however, is how well it predicts areas that will be used by goats during winter.

Of the 1,906 cells systematically sampled on the QHV study area, the DFA classified 808 (42%)

Table 2. Results of classification of "winter habitat" and "other" cells on the Upper Cleveland Peninsula, Alaska (UCP) study area when reprocessed through the discriminant function analysis.

		Predicted group	
Actual group	(n)	Winter habitat	Other
Winter habitat	313	264 (84%)	49 (16%)
Other	1436	411 (29%)	1025 (71%)

Table 3. Variable scales and codes for use with classification coefficients for predicting winter goat habitat based on discriminant function analysis of "Habitat" vs. "Random" cells on the Upper Cleveland Peninsula, Alaska (UCP) study area, 1981-84.

Variable	Scale	Code
Elevation	100 ft (36m) contours	100 = 1
		200 = 2
		300 = 3
		...
Aspect	n/a	flat = 1
		N, NE, & NW = 2
		E & W = 3
		S, SE, & SW = 4
Slope	degrees	0-15 = 1
		16-20 = 2
		21-25 = 3
		26-30 = 4
		31-37 = 5
		38-50 = 6
		51-65 = 7
		66+ = 8
Distance to cliff	miles (0.4km intervals)	0 = 0
		< 0.25 = 1
		0.25 < X < 0.50 = 2
		0.51 < X < 0.75 = 3
		...
Timber volume	mbf/acre	0 = 0
		< 8 = 1
		8-20 = 2
		21-30 = 3
		30+ = 4

as habitat cells. Of the 5,690 cells sampled on the on the Revilla, the DFA classified 2,362 (42%) as habitat. After drawing lines around groups of cells, the total proportion of each area predicted to be "winter habitat" was approximately 40%.

In the QHV area, 81% of all winter relocations of radio-collared mountain goats (n = 280) occurred within the borders of the predicted habitat. An additional 17% of the QHV relocations occurred in cells adjacent to the border. In the Revilla, 82% of all winter relocations (n = 60) were within the borders and another 8% occurred in cells adjacent to the border. Chi-squared analysis of goodness-of-fit indicates that in both the QHV and Revilla study areas, goats made significant (P < 0.001) selection for the predicted habitat cells.

Table 4. Classification coefficients for use in predicting goat winter range based on discriminant function analysis of habitat selection patterns of 20 Upper Cleveland Peninsula (UCP) goats from 1981-84.

	Classification coefficient	
Variable	"Habitat"	"Random"
Elevation (C_e)	0.3792435	0.3967944
Aspect (C_a)	1.2069100	1.0750910
Slope (C_s)	1.2243040	0.7473263
Distance to cliff (C_d)	1.8619730	2.2229880
Timber volume (C_t)	2.1358060	1.7548600
Constant	-12.9007500	-10.4777900

DISCUSSION

Although the underlying assumptions of DFA were strained in this application, DFA is an extremely robust procedure and violation of some assumptions is not fatal to the results. The most serious criticisms of using DFA in habitat analysis are that authors attempt to infer cause-and-effect relationships (Williams 1983) or that DFA may invent erroneous statistical relationships with no possible biological significance (Rextad et al. 1988). This study avoided these problems by simply applying DFA to make predictions which were then tested using an independent procedure. Thus as a management tool, this approach appears logically sound, practical, and easily applied.

Based on the degree of accuracy of predictions, the function derived from the UCP could be used with confidence to predict the location of winter habitat in other areas that are biophysically similar to the UCP. This may include much of the coastal goat range in southern Southeast Alaska and north coastal British Columbia. To apply the function, topographic and timber type maps like those used in this analysis should be overlaid with a similar grid system. Then the elevation, aspect, slope, distance to cliffs, and timber volume should be determined for all or a systematic sample of cells. All values must be scaled as indicated in Table 3. The values for each cell would then be entered into the equation:

$$SCORE_i = \text{Elevation} * (Ce_i) + \text{Aspect} * (Ca_i) + \text{Slope} * (Cs_i) + \text{Distance to cliff} * (Cd_i) + \text{Timber Volume} * (Ct_i) + (\text{Constant}_i)$$

for both the "Habitat" and "Random" coefficients given in Table 4. The resulting scores would be compared and the cell would be classified as belonging in the group for which it has the higher score. Predicted "Habitat" cells can then be mapped for use in decision-making.

With the increasing availability of GIS technology, it may now be possible to conduct similar analyses much faster and more thoroughly than presented here. A wider range of multivariate techniques is also being developed and applied to habitat modelling. Other methods of discriminant analysis use Kernal density estimation (Hand 1982) and new methods of spacial data analysis and image analysis (Ripley 1988, Cressie 1991) can also be used. Regardless of the statistical approach used, additional efforts should be made to test the accuracy of habitat selection models with the empirical approach used in this study to avoid the problems identified by Rextad et al. (1988).

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SPATIAL SEGREGATION OF BIGHORN SHEEP, MULE DEER, AND FERAL HORSES

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Abstract: We examined population size, spatial distribution, and behavioral interactions of Rocky Mountain bighorn sheep (*Ovis canadensis*), mule deer (*Odocoileus hemionus*), and feral horses on the Pryor Mountain Wild Horse Range (PMWHR) and the Bighorn Canyon National Recreation Area (BCNRA) of Montana and Wyoming. The BCNRA winter range is one of the driest, if not the driest, sites occupied by the 3 species in Montana, and the summer range is one of the most heavily forested and rugged areas occupied by feral horses in the northwest. During 1993, we estimated 159 (S.E. 61) sheep, 516 (S.E. 121) deer, and 95 (S.E. 22) horses on the winter range in the study area. Potential for competitive interactions between deer and horses or sheep were low due to habitat segregation in winter and habitat and spatial separation in summer. Horses and sheep used similar cover types in summer and winter and exhibited clumped distributions that could have exacerbated competition for forage if forage were limiting. Spatial segregation reduced the potential for competition at current population levels. The consequences of population increases should be considered by managers in the area. The mule deer population is apparently stable, but the sheep population has increased by approximately 17% annually since 1989, and interest groups supporting feral horses are capable of blocking population reductions in the horse population.

Ecologically similar species co-occur through one or a combination of strategies. These include competition, resource partitioning, and coexistence (Begon and Mortimer 1987). Behavioral domination, one form of interference competition, has been documented for a number of potentially competitive species, such as mule deer and cattle (Kie et al. 1991), burros and bighorn sheep (Seegmiller and Ohmart 1981), and red fox (*Vulpes vulpes*) and coyotes (*Canis latrans*)(Dekker 1983). Resource partitioning allows for coexistence and avoids competition by separating species by habitat or forage use. Moose (*Alces alces*), elk (*Cervus elaphus*) and white-tailed deer (*Odocoileus virginianus*) in northwestern Montana were found to spatially segregate to reduce competition (Singer 1979) and Wydeven and Dahlgren (1985) found competition to be reduced between pronghorn antelope (*Antilocapra americana*) and bison (*Bison bison*) by differences in forages consumed. Coexistence, unlike the other strategies, occurs in landscapes containing unlimited resources supporting sympatric populations. Habitat preferences and preferred food items are utilized without regard to the presence of another species. Kissell and Kennedy (1992) found this to be the case for two generalists, raccoons (*Procyon lotor*) and opossums (*Didelphis virginiana*).

Most co-occurring ungulates possess great opportunity for overlap in habitat use and food habits. Bighorn sheep, mule deer, and horse populations have been shown to compete, partition resources, or coexist (Wishart 1978, Seegmiller and Ohmart 1981, Kie et al. 1991) with another ungulate population when present.

A community of potentially competitive species exists on and around the Pryor Mountain Wild Horse Range (Boyce et al. 1992). The PMWHR was established in 1968 to manage and protect the resident feral horse population (BLM 1984). PMWHR historically supported both mule deer and bighorn sheep. Bighorn sheep were extirpated prior to the turn of the 20th century but recently have recolonized a portion of the PMWHR. During the past decade, the sheep population has been increasing rapidly (Coates and Schemnitz 1989). The horse population has been maintained at approximately 120 through capture and removal since 1971 (BLM 1984), and the mule deer population has varied about the historical mean (500-600).

Ungulate populations occupying small restricted ranges, such as on the PMWHR, may require intensive management (Wydeven and Dahlgren 1985). Boyce et al. (1992) implied a need to evaluate potential competition between bighorn sheep, feral horses, and mule deer on the PMWHR as a factor in management. Studies directed toward feral horse behavior (Feist 1971), feral horse reproduction (Feist and McCullough 1975), feral horse population dynamics (Garrot and Taylor 1990), and bighorn sheep ecological relationships (Coates and Schemnitz 1989) have been completed; however, no attempt has been made to differentiate use of resources of the area by the three ungulates relative to their ecological requirements. Our objectives were to determine population estimates for mule deer, bighorn sheep, and feral horses, ascertain distributional patterns, and describe behavior regarding the potential for competitive interaction.

We wish to acknowledge J. T. Peters, of the Bighorn Canyon National Recreation Area (BCNRA), for his dedicated support and logistical assistance and J. Lindsey (BCNRA) for computer and field assistance. We would also like to acknowledge the assistance of R. Hawkins in conducting population surveys and K. Iverson, of the Montana Department of Fish, Wildlife, and Parks (MDFWP), R. Hawkins, and R. Schwartz for their excellent flying. Our appreciation is extended to T. Easterly and the Wyoming Game and Fish Commission for use of equipment during aerial relocation of radio-collared animals. We also wish to thank J. Parks, of the Bureau of Land Management (BLM), A. Wood, J. Watson (MDFWP), and C. Eustace (MDFWP) for assistance in capturing and collaring animals. We thank F. Schwieger for assistance concerning the horse population. We thank the Bassit, Schwend, Snell, and Tillet families for use of their land throughout this study. This study has been funded by the Montana Department of Fish, Wildlife, and Parks, the National Park Service, the Bureau of Land Management, and the National Forest Service.

STUDY AREA

The study area is located approximately 75 km south of Billings, MT (45°00' N, 108°20' W). The study area encompasses approximately 350 km^2 and includes the Pryor Mountain Wild Horse Range, portions of the Bighorn Canyon National Recreation Area, and lands managed by the Bureau of Land Management, the Custer National Forest, and the Crow Indian Tribe.

Soils are relatively raw, composed typically of sandstone, limestone, shale, dolomite, and alluvial deposits (Richards 1955, Blackstone 1975). Topographic features consist of vertical canyon walls, steep talus slopes, and gently rolling hills and meadows intersected by canyons. Several spring-fed and some intermittent creeks traverse the area.

Habitat on the BCNRA and surrounding area has been classified into 6 principal types (Knight et al. 1987). Juniper/mountain mahogany woodlands are dominated by Utah juniper (*Juniperus osteosperma*) and mountain mahogany (*Cercocarpus ledifolius*). This type is further broken down into juniper woodland, mountain mahogany shrubland, and juniper/mountain mahogany woodland, depending upon the dominant species. Riparian habitat is dominated by cottonwoods (*Populus* spp.). Desert shrubland is dominated by saltbrush (*Atriplex* spp.), greasewood (*Sarcobatus vermiculatus*), big sagebrush (*Artemisia tridentata*), and mixed desert shrubland communities. Rubber rabbitbrush (*Chrysothamnus nauseosus*), shadscale (*Atriplex confertifolia*), big sagebrush, broom snakeweed (*Gutierrezia sarothrae*), bluebunch wheatgrass (*Agropyron spicatum*), Fendler three-awn (*Aristida fendleriana*), and needle-and-thread (*Stipa comata*) comprise the major components of mixed desert shrubland. Sagebrush steppe includes both big sagebrush and black sagebrush (*Artemisia nova*) communities. Basin grasslands are dominated by bluebunch wheatgrass, blue grama (*Bouteloua gracilis*), needle-and-thread, broom snakeweed, Hooker sandwort (*Arenaria hookeri*), fringed sagewort (*Artemisia frigida*), and Hoods phlox (*Phlox hoodii*). Coniferous woodlands are characterized by limber pine (*Pinus flexilis*), ponderosa pine (*P. ponderosa*), douglas fir (*Psuedotsuga menziesii*), and a spruce-fir (*Picea-Abies* spp.) mix.

Climate varies from near desert to subalpine with the elevation ranging from 1109 m to 2675 m. Mean summer temperature at the lower elevation in Lovell, WY, is 21.1 C and mean summer precipitation is 2.13 cm. Mean winter temperature is -6.3 C and mean winter precipitation is 0.74 cm (Western Sugar Company, recorded since 1920).

Adjacent land uses include cattle ranching and agriculture. Cattle are maintained on portions of the study area throughout spring and summer. Agricultural crops primarily consist of alfalfa. Hunting is allowed on the study area. Deer are harvested through regular season regulations in Wyoming and Montana and two bighorn sheep permits have been issued annually by Montana since 1991.

METHODS

Population Estimation

Bighorn sheep and mule deer were captured and marked 21-22 September 1992 and 14-15 January 1993 using a net gun fired from a Hughes 500-C helicopter (Barrett et al. 1982, Andryk et al. 1983). Age was estimated for bighorn sheep and mule deer using tooth wear and replacement (Cowan 1940; Deming 1952; Robinette et al. 1957). Each animal was fitted with an uniquely marked radio collar (150.000-151.999 MHz). Horses were not radio-collared, but 20 readily recognizable horses distributed among various bands were used as "marked" animals. Sixteen female and 4 male bighorn sheep, 14 female and 3 male mule deer were radio-collared, and 14 female and 6 male horses were used as "marked" animals.

To estimate population size, approximately 30 aerial transects were flown in a Hiller 12-E at approximately 1-week intervals from 10 February to 8 March 1993, with each transect replicated 5 times. Transects were separated by approximately 0.5 km and typically were flown during the morning (0700-1200 hrs). Transects were flown 20 - 40 m above the terrain at 40 - 50 km/hr. The date, time, location, species, number of animals, sex, age category (adult or juvenile) when possible, and the number of marked animals in the group were noted. Chapman's (1951) estimator and Lincoln-Peterson index techniques were used to estimate population size. Chapman's estimate corrects for surveys in which no marked animals of a species were observed. Each estimate derived was used to determine a mean population estimate. Mean estimates were compared with results of previous studies by Coates and Schemnitz (1989) using a t-test to evaluate population growth rates between 1985-1988 and 1988-1993.

Distribution

Distribution was determined by radio locations and casual observations during ground and aerial surveys. Locations were determined for 3 time periods: morning (0500-0959 hrs); midday (1000 - 1559 hrs); and evening (1600-2300) hrs. Aerial locations were obtained using a portable receiver and 2, 2-element directional antennas attached to the wing struts of a Super Cub or 1 pivotal 3-element directional antenna mounted beneath the fuselage. Aerial locations were made typically during the morning time block. Ground locations were obtained using a portable receiver and hand-held, 2-element, directional antenna. Additional locations were obtained by chance observations. To obtain independence of observations, days and time blocks were randomly assigned to species and individual animals, respectively. Feral horses were located by a weekly ground search. All locations were plotted on 1:24000 USGS topographic maps and Universal Transverse Mercator (UTM) coordinates were obtained. Overall distribution of marked animals was determined by lumping all the locations of one species for a season. Distributional ranges were overlayed to determine common areas of use.

Behavior

An attempt was made to observe each marked animal and the group associated with it twice/season; once during the morning and once during afternoon hours. An observation consisted of an 1-hour session during which behavior type (feeding, bedded, standing, moving) was recorded every 5 minutes for both the focal animal and the majority of the animals present in a group. Observations were made using a 15-60 X spotting scope. Days and individual radio-collared animals to be observed were determined randomly. Observations of horses were conducted by chance. At each session, we noted the number of hetero- and conspecifics visible in the area, the estimated distance from the focal group, estimated distances moved at 15-minute intervals by the focal group, and aggressive or submissive behaviors observed during the session. Homogeneity of behavior across seasons for each species was examined using chi-square. Due to small sample sizes, sexes were lumped.

RESULTS AND DISCUSSION

Population Estimation

Table 1. Population estimation for bighorn sheep, mule deer, and feral horses, on the Pryor Mountain Wild Horse Range during winter, 1993.

	Bighorn sheep				Mule deer				Feral horses			
Date	n_i[a]	m_i[b]	N_1[c]	N_2[d]	n_i	m_i	N_1	N_2	n_i	m_i	N_1	N_2
11 February	39	3	260	209	244	7	593	550	54	14	77	75
17 February	44	3	293	235	155	5	527	467	48	10	96	93
22 February	6	0	0	146	142	4	604	514	42	6	140	128
1 March	20	3	133	109	191	4	812	690	39	10	78	75
8 March	22	4	110	96	139	6	394	359	48	9	107	10
Total N_1	199 ± 91				586 ± 151				100 ± 26			
Total N_2	159 ± 61				516 ± 121				95 ± 22			

[a] Total number of animals observed.
[b] Total number of marked animals observed.
[c] Lincoln-Peterson population estimator.
[d] Chapman's population estimator.

Population estimates for 1993 are given in Table 1. Coates and Schemnitz (1989) reported the bighorn sheep population to be increasing at an exponential rate of $r = 0.18$ during 1985-88. We found the population increased at the same exponential rate ($r = 0.172$; $p > 0.05$) since 1988. This high growth rate is characteristic of colonizing populations of other ungulates (Eberhardt 1987, Gogan and Barret 1987).

Estimated mule deer population size was in the range typical of the study area during 1986-1990 (MDFWP 1990) when the population generally increased. Our estimates suggest the population size may have stabilized during 1990-1993. The minimum number of mule deer known to be alive following the hunting season of 1990 (MDFWP 1990), 565, was similar to our estimate.

The horse population was estimated to be approximately 100 based on helicopter surveys during winter 1993. Another, possibly more accurate, estimate based on sightings of uniquely marked individuals during spring and summer 1993 indicated approximately 180 feral horses, including 1993 foals. Garrot and Taylor (1990) reported the population to be this high only twice during an 11-year period from 1976 to 1986. If foals were deleted from the summer ground population estimate, a downward adjustment of 17%, our helicopter surveys estimated approximately 50% of the actual population size. Stoll et al. (1991) briefly reviewed studies in which ungulate populations are underestimated 33% - 66%. Given the terrain, vegetative cover, and the nature of the technique, our estimates are much more likely to underestimate than overestimate population size.

Distribution

The 3 species were spatially segregated throughout the year (Fig. 1a-b). Through winter and early spring, bighorn sheep were distributed primarily along the edge of Bighorn Canyon. Rams and ewes remained together until mid-late winter. Thereafter, rams moved to a portion of the study area inaccessible to horses and seldom frequented by ewes. Horses ranging in close proximity to the sheep population showed very strong fidelity to the southern and east-central portions of the PMWHR. Distribution of these horses was similar in each season, probably as a result of limited water sources. Other bands of horses used the southern portions of the study area for winter range. Deer were distributed along the southern portion of the study area during winter and early spring.

In spring, sheep were distributed similar to late winter while horses occupying the south-central and southwestern portions of the study area began a migration northward on the East Pryor Mountain. Deer also began migrating northward during the spring.

Summer distributions provided extreme examples of spatial segregation. During lambing, ewes spent considerable time near or in the Bighorn Canyon. Two ewes were observed lambing in Crooked Creek Canyon, approximately

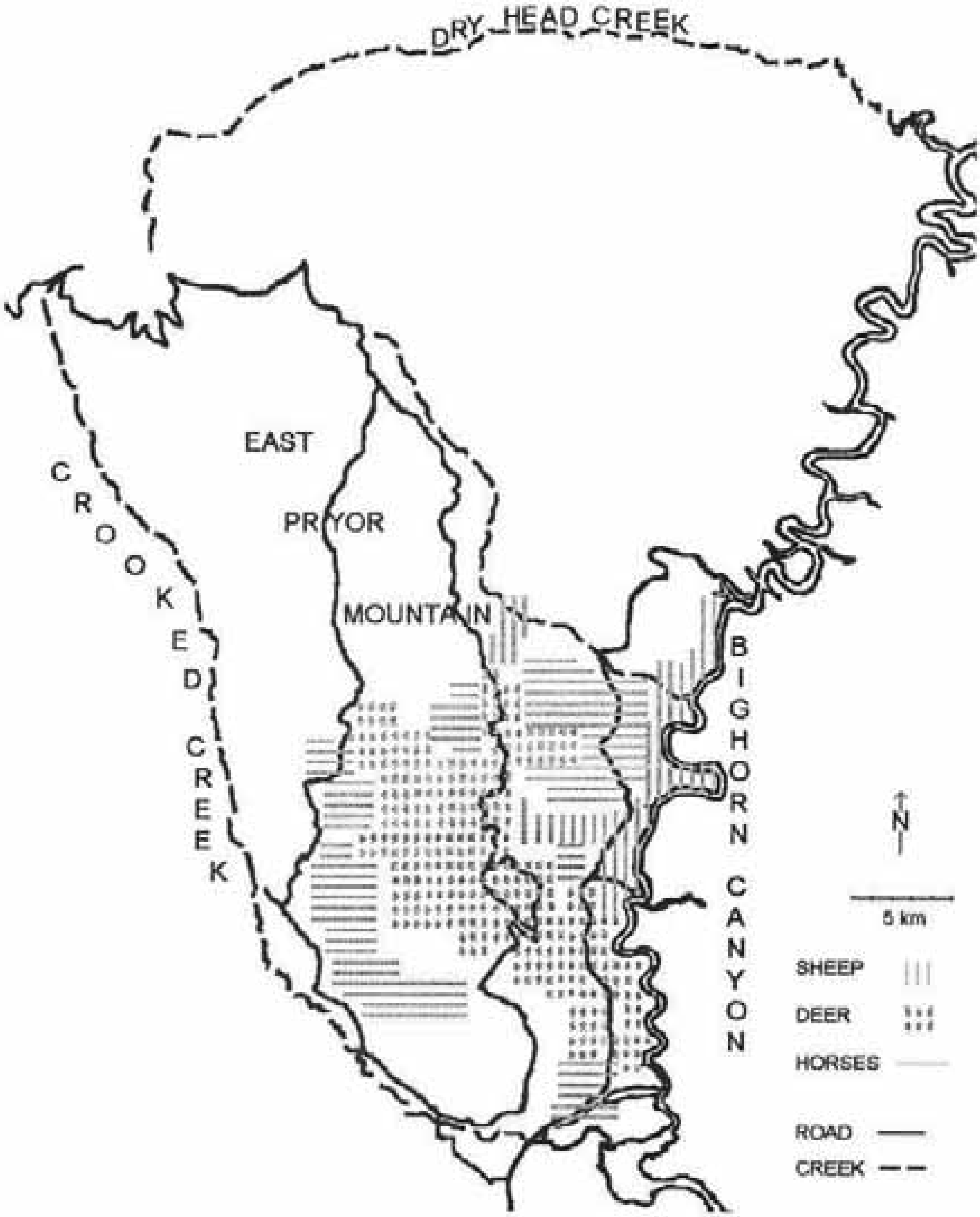

Figure 1a. Distribution of bighorn sheep, mule deer, and feral horses on and surrounding the Pryor Mountain Wild Horse Range during winter 1993.

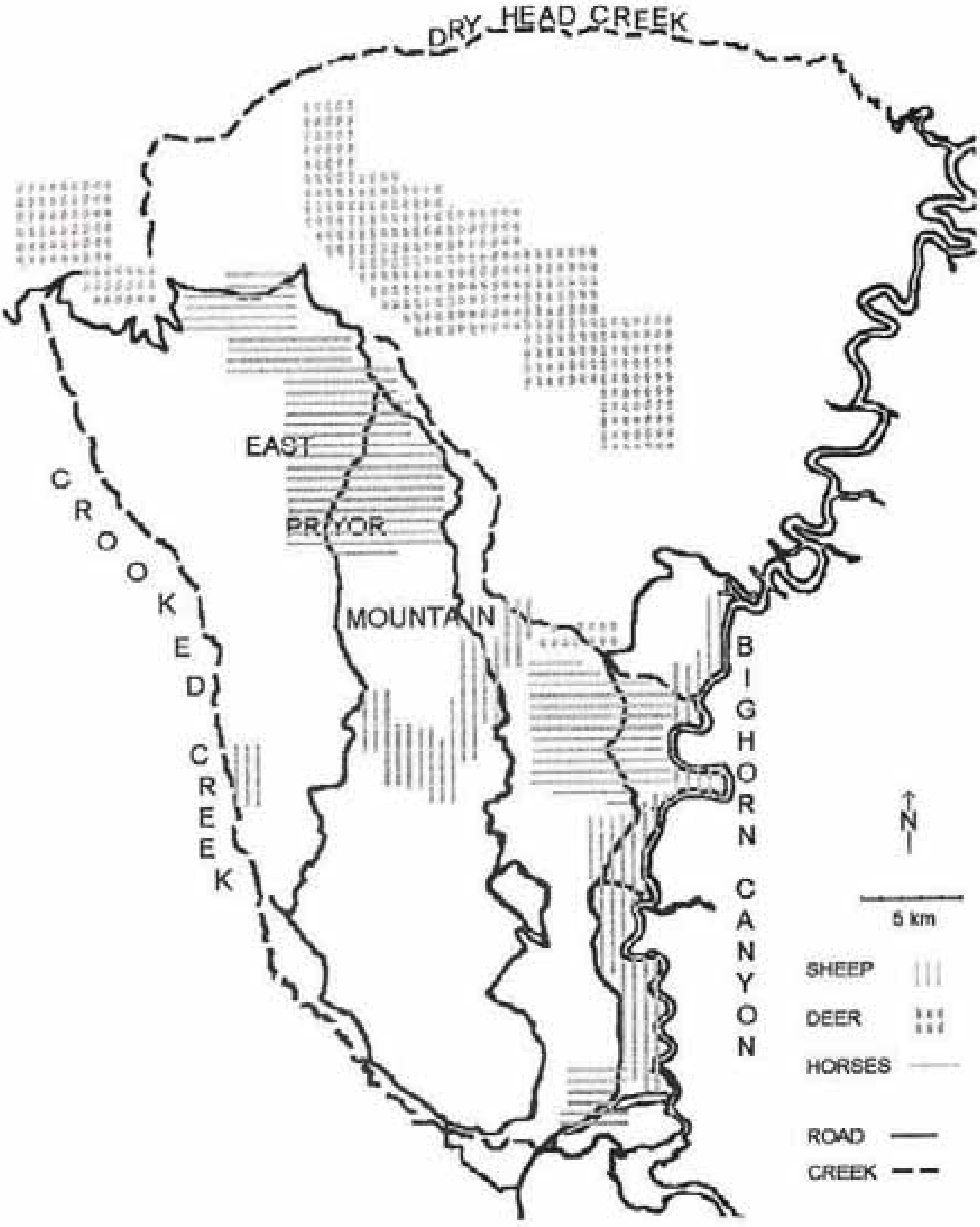

Figure 1b. Distribution of bighorn sheep, mule deer, and feral horses on and surrounding the Pryor Mountain Wild Horse Range during summer 1993.

10 km west of the primary lambing area. These ewes returned to the primary lambing area, the Bighorn Canyon, within 6 weeks. Rams occupied a large area of little topographic relief and a considerable distance (>3 km) from permanent water in the center of the study area during the summer and fall. Leslie and Douglass (1979) also reported that ewes occupied areas of greater topographic relief and closer to water than areas used by rams. The majority of the horse herd spent the summer and fall seasons at the top of East Pryor Mountain. Most deer summered along the base of the mountain on the northern and northeastern sides. Only one radio-collared deer summered on top of the East Pryor Mountain. Additionally, very few deer were seen on top, or on the southern aspect, of the East Pryor Mountain during summer and most of fall.

Rams returned to the lower elevations of the study area during late fall and early winter where ewes spent summer and fall. Horses and deer also returned to the winter range during this time. Snow and the onset of more severe winter conditions appeared to be factors initiating fall/winter migration.

Ungulates typically separate spatially or temporally to avoid competition (Hirst 1975). Though there was insufficient evidence to support the existence of competition between feral horses, bighorn sheep, and antelope, Berger (1986) invoked habitat separation and food habit preferences as the strategies used in the Great Basin to avoid competition. Seasonal distributions of the 3 species on our study area were indicative of spatial segregation suggesting that it is at least one tactic being used to avoid competition.

Behavior

No difference in frequency of behavior (feeding, moving, standing, bedded) between seasons was observed for mule deer (X^2 = 15.4, p > 0.5). Differences between fall and summer (X^2 = 14.4, p < 0.005), fall and spring (X^2 = 14.85, p < 0.005), and fall and winter (X^2 = 10.06, p < 0.05) for frequency of behaviors were indicated for bighorn sheep. Differences in frequency of behaviors were observed for feral horses between fall and summer (X^2 = 9.7, p < 0.05), and fall and spring (X^2 = 14.1, p < 0.005).

Very few (N < 6) interspecific interactions were observed during 1993. All *occurred* in the winter or early spring, when the three species were on winter ranges and all included horses as the dominant species when horses were present. Like Berger (1986), we found that encounters between species were rare as a result of different habitat preferences and seasonal use patterns. Coates and Schemnitz (1989) also reported few interactions (n = 9) between sheep and horses; where they occurred, horses were the dominant species.

MANAGEMENT RECOMMENDATIONS

Greatest opportunity for competition existed during winter when the three species were in close proximity. However, given present population sizes, distributions, movements, and the infrequent encounters between species, little or no interspecific interaction of population consequence appears to be occurring. Therefore, we recommend that the three species be managed independently at this time. Berger (1986) noted that interspecific conflicts between feral horses and native species almost always resulted in submission of the native species. With this in mind, we suggest that these ungulate populations be monitored closely to determine if the increasing sheep population is influenced by the feral horse herd or if the sheep population expands its range further to maintain the reduced potential for competition with horses.

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FOREWORD TO THE WORKSHOP REPORTS ON SHEEP MANAGEMENT PROGRAMS, NORTHERN WILD SHEEP AND GOAT COUNCIL, CRANBROOK, BRITISH COLUMBIA 2-6 MAY, 1994

WAYNE E. HEIMER, Executive Director, Northern Wild Sheep and Goat Council, Alaska Department of Fish and Game, 1300 College Road, Fairbanks, AK 99701

Originally, management of northern wild sheep throughout their ranges in the United States and Canada was done by simply opening or closing the hunting season to allow harvest of presumably surplus sheep, typically assumed to be mature rams. Later on, managers (with autonomy that is unthinkable today) began to "do what they thought was best" for the sheep and the hunters who wanted to use them. In more recent times, selective pressures for recognition of other uses and greater public involvement have driven the evolution toward a system of formally defined management programs.

These management programs are presumably guided by management policies that drive management plans which, in turn, determine effort (measured in time and money) to gather biological information which may affect the regulations by which management is practiced. Although the formal system is presumed to function in this fashion, there is considerable variability in philosophy, policy, plans, and effort expended in managing sheep among management agencies.

The purpose of this workshop was to generate reports on the sheep management program from each member state or province in the Northern Wild Sheep and Goat Council. These reports were generated by response to a questionnaire sent to the recognized sheep managers in each state or province. Questions relating to the presence of a recognized or formal program, its origin, its funding, effort expended, and a discussion of program effectiveness were asked of all participants. All member states and provinces where bighorn, Stone, and Dall sheep are present responded.

The symposium organizers, the executive board of the Northern Wild Sheep and Goat Council, the workshop participants, and I hope that these abbreviated reports will be useful. We anticipate these reports will be useful as histories of how things got the way they are as well as information on how management is currently proceeding. We also hope that the agencies which prepared the reports saw them as an internal review of their own programs. The discussion sections should be particularly helpful in understanding the operation of each program because participants were asked to be particularly frank in evaluating program effectiveness.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 9:175.

1994 NWS&GC MANAGEMENT WORKSHOP QUESTIONNAIRE RESPONSE: THE FOUNDATION FOR NORTH AMERICAN WILD SHEEP - PUTTING WILD SHEEP ON THE MOUNTAIN

DUNCAN GILCHRIST, Director, Foundation for North American Wild Sheep, 720 Allen Ave, Cody, WY 82414, (307) 527-6261

The Foundation for North American Wild Sheep (FNAWS) may be the world's most successful hunting-oriented wildlife conservation organization. It is composed of over 5,000 members that are dedicated to the concept of putting wild sheep on the mountain. Each year the group holds an annual convention during a four-day period in February or March with some 2,000 attending members. All states having a sheep auction permit have chosen this group to auction a ram permit to the highest bidder. In all cases, the funds are earmarked by the state for sheep projects. In addition, FNAWS itself funds up to $500,000 for wild sheep and associated projects each year.

This group, headquartered at Cody, Wyoming, is very cost effective as there are only 6 paid employees. This number is far lower than any of the other major organizations. The overhead of the organization is held to a minimum. The 11 elected officers and directors are unpaid except for expenses. Some directors even pay their own expenses. In addition, there are other members that contribute much time in their respective fields of expertise to the organization at no cost.

I am proud to say that I am an elected director of FNAWS. As a director, I am spending approximately 50 nights away from home on FNAWS business in 1994. This includes attending board meetings and functions to which FNAWS normally sends a representative. In addition, I spend many days in the field talking over sheep management projects with biologists and others. There is so much that needs to be done.

Article III of the bylaws states:

"To promote and enhance increasing populations of indigenous wild sheep on the North American continent, to safeguard against the decline or extinction of such species, and to fund programs for professional management of these populations, keeping all administrative cost to a minimum."

The organization publishes a quarterly magazine titled WILD SHEEP. It is a quality publication filled with information on wild sheep, FNAWS activities, as well as hunting reports from members.

There are many FNAWS Chapters throughout the country who are likewise working towards the same or similar goals. Monies raised by the chapters are their own to spend. I have attended several chapter fundraisers and have been most impressed by the people that I have met.

Bidding at the convention is spirited with a close ratio of value to bid price, and bids are 80% of value or higher overall. Most bidders have a genuine dedication to the organization because of the high percentage of money that returns to the ground in the form of funded projects compared to the other major hunting organizations. About 80% of FNAWS net income is spent on grant-in-aid funding.

The national headquarters in Cody, Wyoming, are located almost next door to the Buffalo Bill Museum. This building houses a fine collection of Boone and Crockett trophies, western and wildlife art, the Winchester gun collection, the museum of the Plains Indians, and the Buffalo Bill collection. It takes time to visit this museum.

The FNAWS headquarters is beginning to house a respectable collection of wild rams and ram literature.

The annual membership dues are $45.00 (1994)

Bienn. Symp. North. Wild Sheep
and Goat Counc. 9:176-179.

1994 NWS&GC MANAGEMENT WORKSHOP QUESTIONNAIRE RESPONSE: ALASKA'S DALL SHEEP MANAGEMENT PROGRAM

WAYNE E. HEIMER, Alaska Department of Fish and Game, 1300 College Road, Fairbanks, Alaska 99701

QUESTION: Does your state or province have an identifiable sheep management program?

Yes.

QUESTION: What is your guiding policy statement?

The Alaska Department of Fish and Game (ADF&G) Dall sheep management policy (most recently revised in 1980) says:

1. The department recognizes the constitutional mandate of the state of Alaska to manage Dall sheep on the sustained yield principle for the benefit of the resource and the people of the state, and also recognizes that national and international interests must be considered.

2. The department recognizes that responsible Dall sheep management must be based on scientific knowledge. An active department program will be maintained to increase knowledge of the population status and the biological and ecological requirements of sheep.

3. Maintenance of suitable habitat is of foremost importance in Dall sheep management. The department will seek land-use designations and controls that will maintain sheep habitat. Introduction of domestic animals which may compete with Dall sheep for available forage or which may introduce diseases or parasites will be opposed.

4. It is recognized that management techniques for sheep may change with future advances in knowledge of sheep biology.

5. Transplanting Dall sheep for restocking former ranges or stocking vacant habitat may be a useful management tool. However, because transplants often have unforeseen detrimental effects, introductions of sheep will be generally opposed.

6. Dall sheep will be managed to provide sustained yields of animals for humans and for wild carnivore populations that depend on them for food.

QUESTION: How do/did you do management planning?

Early management planning efforts (1976) consisted of species teams composed of area management biologists, regional managers, and regional researchers agreeing on the biological capacities, limitations, and existing uses of Dall sheep in each management unit of the state, and selecting appropriate management goals for each population.

QUESTION: What are your management goals?

These planning teams identified 2 types of goals relating to uses of Dall sheep.

1. Hunting was the dominant use of Dall sheep when statewide management plans were drafted. Consequently, Dall sheep management plans centered primarily on hunting management. Three types of hunting experiences were identified.

1A. Maximum opportunity to participate in Dall sheep hunting: In some areas, providing the opportunity to go sheep hunting was the primary goal. Harvest success rate, size of animals harvested, commonality of transportation type used, and hunter density were secondary considerations. Hunters were advised that these conditions may be less than desirable under some circumstances, but consistent opportunity to participate without requirements beyond purchase of a hunting license was assured. An unlimited number of resident licenses are available at $25. An unlimited number of nonresident licenses are available at $85, and an unlimited number of nonresident sheep tags are available at $425. Harvest is limited to 1 full-curl ram per year.

1B. Opportunity to hunt under aesthetic conditions: In areas with this goal, plans were made to provide high quality hunting experiences in terms of uncrowded opportunities where a hunter could reasonably:

1) Expect an increased measure of solitude with freedom from constant involvement with alternate transportation types other than he or she used.

2) Anticipate a higher harvest success from a less-intensively harvested resource.

3) Enjoy an enhanced opportunity to be selective in ram harvest.

Hunters have been given many chances to understand that providing the opportunity to hunt under aesthetically-pleasing conditions may require limiting participation through lottery permit systems. In areas not limited by permit requirement, any appropriately licensed hunter may participate. Aesthetic quality goals are most often achieved because the areas where these goals apply are remote.

1C. Opportunity to harvest trophy rams: In a few select areas, the goal was to provide a hunting experience where each hunter has the opportunity to take an unusually large, trophy ram. Hunters understand this requires limiting participation by lottery permit and submaximal ram harvests. Originally, legal standards in trophy management areas were higher than in other areas. With passage of the statewide full-curl minimum for ram harvests, the legal definition for harvest is now uniform. The full curls are just larger in trophy management areas. Anyone may apply for a permit in trophy management areas except in the Tok Management Area, where successful hunters may not reapply for 4 years.

1D. When subsistence hunting was institutionalized, providing the opportunity to participate in subsistence harvest of Dall sheep became a further hunting management goal.

2. Although hunting was the dominant use of sheep when management plans were drafted, recognition of other types of sheep use was formally institutionalized. These uses included viewing, photography, and scientific study of Dall sheep. They were provided for by special areas reserved for them throughout the year, and by restricting hunting activities to a 42-day fall season statewide.

QUESTION: What methods do you use to reach them?

1. A research program was established to increase knowledge.

2. Once knowledge was available, capacities and abilities of sheep in each area were matched with the appropriate management goal. High-density populations with well-developed access, a history of high human harvest, and production of small-to-average rams were designated for "maximum opportunity." Areas where it was reasonable to expect low hunter effort were designated "aesthetic," and only a couple areas where rams typically produced large horns were established for "trophy management."

3. As knowledge increased, regulations were changed appropriately as needed.

4. A statewide harvest monitoring system was developed using Pittman-Robertson money under the Survey and Inventory program. Population monitoring programs were developed by each area management biologist consistent with his or her interest in, or ability to monitor, sheep population size, composition, and productivity.

5. Area management biologists were encouraged to be vigilant with respect to habitat concerns in their assigned areas and coordinate responses to land-use planning efforts with habitat specialists.

QUESTION: How much effort is devoted to reaching them?

There are 12 area management biologists who have sheep in their assigned management districts. These biologists are generalists who are expected to perform data gathering and management functions for all wildlife populations and habitats in their respective areas. It is reasonable to suggest that each of these "journeyman-level" management biologists spends 1 month per year involved with sheep management. This translates into roughly $75,000 in salary and benefits for management biologists.

In addition, the harvest monitoring function requires about 4.5 months of "technician-level" work. This comes to approximately $17,000 in salary and benefits.

Finally, approximately 4 months per year of additional time has typically been devoted to sheep management by a regional management specialist in the most "sheep-rich" region (the Interior) of Alaska. At the same pay grade as for area management biologists, this requires an additional $19,000 in salary and benefits.

Thus, the total person-months allotted by ADF&G to sheep management comes to an average of about 20.5 person-months per year. Sixteen of these are at the management biologist level for a total of $94,000 in salary and benefits. The remaining 4.5 person-months are associated with harvest statistics compilation and analysis at the technician level for about $17,000 and benefits. The total expenditure for personnel is approximately $111,000.

QUESTION: What is your operating budget for sheep management?

Over the last 5 years, ADF&G's operating budget for sheep management (including research) has been approximately $6,000 for harvest reporting and up to $10,000 for survey-inventory work throughout the state. Plans for the next fiscal year call for an increase of 85 to 100 thousand dollars in sheep operational funds. It appears unlikely that this increase will be sustained.

Other Agency Participation in Sheep Management in Alaska

The National Park Service (NPS), the U. S. Fish and Wildlife Service (USFWS), the Bureau of Land Management (BLM), and the U. S. Forest Service (USFS) are also active in sheep research and habitat management in Alaska. NPS activities center in the Noatak National Preserve, Gates of the Arctic National Preserve, and the Wrangell-St. Elias National Park and Preserve. NPS expends approximately $70,000 annually ($30,000 on about 6 person-months per year and $40,000 on field operations).

USFWS activities are primarily centered on the Arctic National Wildlife Refuge; in a cooperative program with the state, USFWS has expended approximately $100,000 per year there, averaged over the last 5 years. Expenditures on the Kenai National Wildlife Refuge were high last year with $36,000 disbursed to conduct a bounded population estimate of Dall sheep numbers.

BLM sheep interests are focused on the Tanana/Yukon uplands where about $10,000 are spent annually on survey work and habitat research, assessment, and manipulation in areas used by Dall sheep.

USFS activities are limited to the Kenai Peninsula where interpretive programs and some habitat research studies are underway. Costs to USFS are not known at this time.

Total other agency expenditures over the last 5 years have probably averaged $160,000 to $190,000.

Additional Funding and Foundation for North American Wild Sheep Participation

The state of Alaska does not consistently ask the Foundation for North American Wild Sheep (FNAWS) for funding. Grants to ADF&G from FNAWS have been primarily from the Alaska FNAWS Chapter, and have averaged about $4,000 per year over the last 5 years (including a fairly large grant of approximately $12,000). The national FNAWS organization reports spending almost $400,000 in Alaska since its organization. Less than 10% of this money has gone toward biological management of Dall sheep. More than 90% of it has gone to political action.

The state of Alaska has yet to participate in donation of a governor's permit to FNAWS to raise funding for sheep management. Legislation which would make this possible has been submitted.

DISCUSSION

While the Alaska Department of Fish and Game has a well-structured management program which is currently in a state of flux there are 3 factors which influence the program.

The first is critical need. The biology of Dall sheep in Alaska allows adequate management of this species with less effort than other Alaskan species. Dall sheep in Alaska exist in stable, climax habitats which are still in pristine condition. Consequently, habitat protection is the priority, and enhancement projects are considered of little utility. In Alaska, land ownership patterns and mandated review render habitat protection relatively inexpensive. Also, limiting harvest of Dall sheep in Alaska to fully mature rams is currently understood to have no deleterious effects on Dall sheep population performance. Simply put, in the past, managers inferred that harvest of truly surplus animals required minimal monitoring and management. Consequently, commitment of funding to this species, which has required little "conventional management" to meet human demands, made it a lower funding priority than other species which are more labile as a result of their biology, habitats, and harvest management. With recent declines in Dall sheep abundance, increased funding is being committed to Dall sheep.

A second complicating factor is Alaska's legislatively-mandated provision for subsistence use and the conflicting federal subsistence priority on federal public land. Subsistence use as it is presently defined in terms of historic aboriginal harvest practices may not be sustainable. Still, subsistence harvest of Dall sheep is practiced at variable levels of intensity in remote areas. In addition, most subsistence use of Dall sheep is focused on federal public lands where state management options are limited and in dispute at this time. Finally, the general wildlife curriculum under which managers train makes it difficult for managers to deal with ewe harvests. I think this is because most population management training is based on examples from cervid populations in temperate zone ecosystems where natural predation has been reduced and density-dependent food limitation is demonstrable. Consequently, acceptance of the idea that Dall sheep biology in intact arctic ecosystems may be an exception to the general ungulate case has been slow among Alaskan managers.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 9:180-183.

1994 NWS&GC MANAGEMENT WORKSHOP QUESTIONNAIRE RESPONSE: ALBERTA'S BIGHORN SHEEP MANAGEMENT PROGRAM

JON T. JORGENSON, Alberta Fish and Wildlife Services, #200 5920-1A St. SW., Calgary, Alberta.

QUESTION: Does your state or province have an identifiable sheep management program?

Alberta has a recently-formulated bighorn sheep management plan that is quite comprehensive in nature. It is a publicly available plan that contains information on the evolution of bighorn management in Alberta, the biology of the species, historical and current status, policy framework, management goals and objectives, and plan applications on a regional perspective.

QUESTION: What is your guiding policy statement?

The Fish and Wildlife Policy for Alberta (Fish and Wildlife Division 1982) establishes policy goals for the administration of wildlife resources in Alberta. These policy goals provide a framework for the formation of specific bighorn sheep management plan goals.

Resource Protection

1. "....The primary consideration of the government is to ensure that wildlife populations are protected from severe decline and that viable populations are maintained....

Resource Allocation

2. "...The wildlife resource, as a Crown resource, will be utilized in a manner which contributes the most benefit to the citizens of Alberta.

3. "...Wildlife will be allocated through a defined process whereby specific resources are deployed to specified uses in order to achieve stated public benefits.

4. The Division (Services) may allocate live wildlife for various uses such as game farming, game ranching, education, or science and zoological displays in conformity with other aspects of the wildlife policy.

5. Wildlife must be allocated among different primary users in response to government policy. Until such time as supply and demand can be better rationalized, the following interim allocation guidelines will prevail in order of priority:

   "...resident recreational use of game will have precedence over nonresident use. Wildlife stocks not fully allocated or utilized to higher priority uses may be allocated commercially to nonresidents.

6. The allocation of wildlife stocks to the different primary uses does not imply that other uses cannot occur within areas where such uses are entitled.

Recreational Use

7. A variety of wildlife recreational opportunities, in addition to hunting, will be available for the benefit and enjoyment of Albertans.

8. "A variety of hunting opportunities will be available for the recreational benefit of Albertans...

Commercial Use

9. The division will encourage an environment that promotes the growth of the tourist industry..."

QUESTION: How do/did you do management planning?

The bulk of the management planning was initially done by the species coordinator (we no longer have species coordinators). Input was then solicited from regional biologists to provide more specific information on local herd status, special management issues, land use issues, population goals, and hunting priorities. Draft plans were also reviewed by certain persons with experience in bighorn sheep.

QUESTION: What are your management goals?

Our management goals essentially involve resource protection and resource allocation amongst the various user groups:

Goal 1: To ensure that viable populations of bighorn sheep are maintained.

This will be achieved by protecting all existing wintering populations from overharvest, illegal hunting, disturbance, and disease, and by securing and maintaining all of the known wintering areas. To this end, all known winter ranges have been mapped along with associated summer ranges where these have been identified.

Goal 2: To ensure that populations and habitats are managed to meet the resource requirements of the recreational and economic goals and objectives.

Current population estimates have been identified along with harvest goals (numbers of trophy rams and ewes) for each of our sheep management areas. Population objectives for each area by the year 2000 have also been determined toward which harvest allocation and other management practices will be tuned to achieve. Harvest goals in terms of trophy rams and non-trophy sheep to the year 2000 have also been established.

Goal 3: To maximize the recreational benefits and enjoyment to Albertans from the bighorn sheep resource through the provision of a variety of types and amounts of recreational opportunities.

Two types of sheep hunting opportunities will be made available to residents. Maintain the current opportunity to hunt "trophy" (4/5-curl) rams, and as part of the population management strategy for maximizing the production of trophy rams, provide the maximum opportunity for residents to hunt "non-trophy" (ewes and lambs) bighorn sheep. The harvestable surplus of trophy rams will generally be limited to 50% of the total number of trophy rams available and shall not be allowed to exceed 70%. At least 80% of the harvestable surplus of trophy rams will be allocated to recreational hunting by residents under an unlimited entry season. A 1-year wait-out period will apply to any successful trophy sheep hunter. Non-trophy hunting will generally be restricted to residents under a limited entry regime. The harvest of non-trophy sheep will not exceed 18% of the winter population of yearlings and ewes unless population levels are to be reduced.

Resident trophy seasons will generally open 1 week earlier than that for nonresidents and extend approximately 15 days beyond the closure for nonresidents to October 31.

A provision is made to provide a variety of opportunities to all Albertans for directly-related, nonconsumptive wildlife activities such as viewing, photographing, and scientific and educational activities that will enhance knowledge of bighorn sheep.

Goal 4: To optimize the economic benefit to Alberta from the commercial use of the bighorn sheep resource.

Provide the opportunity for outfitter-guides to contract nonresident trophy sheep hunters.

Provincially, a maximum of 20% of the harvestable surplus of trophy rams may be allocated to the outfitting industry. Nonresident hunting for trophy sheep and, hence, outfitting activities will be directed to more remote areas of the province to reduce conflicts with resident hunters. Nonresidents will be required to hunt with a licensed sheep outfitter who has been allocated a specified number of nonresident/alien sheep licenses which are valid only in specified wildlife management areas. A 4-year waiting period for successful nonresident/alien trophy sheep hunters will apply.

QUESTION: What methods do you use to reach them?

A standardized format has been developed to inventory most of the provincial sheep populations on a 2-year rotational basis. Only populations with well-delineated winter ranges and not widely dispersed, and with consistently more than 20 animals are surveyed. Results from these surveys have been used to establish future population goals as well as to determine annual permit numbers for non-trophy hunting seasons.

A well-established program of compulsory registration has been in effect for many years as a way of monitoring harvests and success rates which in turn are also used in the permit setting process.

Several long-term bighorn sheep research projects have been initiated (and still continue) to gather data on population dynamics. The data collected from these projects have had a direct impact on the current management program. Additionally, more short-term projects on local populations have been conducted primarily in response to some local issue of high priority. These projects have provided better information on population levels, seasonal range use, response to recreational/industrial developments as well as the causes and impacts of disease.

Regional biologists respond to local issues regarding sheep populations in their areas with whatever management programs they see fit and can afford in terms of manpower and budgets. Special habitat protection measures may have to implemented or habitat enhancement projects initiated.

QUESTION: How much effort is devoted to reaching them?

To try and put a manpower and dollar figure on the effort expended on the sheep management program in Alberta is not easy. The level varies from year to year, depends on whether any special projects were initiated in response to some local issue, and more important than all is the ever-changing levels of staff and budgets. Considerably less effort is expended now than what was done 4 or 5 years ago.

The only programs which have not been affected severely by changing economic times and that are maintained each year are the compulsory registration program, annual permit setting process, and population inventory. The division has also maintained its involvement in 2 sheep research programs.

The compulsory registration program involves administration and enforcement staff time to register animals and process forms as well as the time of a technician for computer entry. Bighorn sheep are only a small portion of the harvest statistic program which is maintained for all species in Alberta. Considering the relatively small number of sheep harvested in Alberta (approx. 230/yr), about 1 person-month would be devoted to harvest statistics at an estimated cost of $3,000.

The local management of bighorn sheep falls mostly under the jurisdiction of the 4 area wildlife biologists with sheep in their regions. They are responsible for implementing any sheep management programs required including population inventory, permit setting for non-trophy sheep, any habitat enhancement projects, and any research projects. At present, the actual time involvement varies between individuals, but would probably average 1 person-month per year (probably a bit generous) at a total cost of about $18,000. This puts the total manpower expenditure for sheep management in Alberta at around $21,000.

QUESTION: What is your operating budget for sheep management?

An allotment of about $12,000/year is made toward helicopter time to do population inventory in various parts of the province. This is an indirect expenditure since the aircraft belong to the government and their use (and budget) comes from another department. We are, however, allotted a certain number of hours each year with which to do surveys. The $12,000 is the cost to the government of operating the aircraft for the approximately 30 hours given annually for sheep surveys. It is significantly less than what it would cost us to charter from the private sector.

Additional monies allotted toward sheep management might come to about $5,000 per year and would include general operating expenses related to the harvest statistics, research programs, habitat enhancement programs, or other programs initiated by regional biologists. In 1993 about $16,000 of additional money was contributed by the division (mostly in the form of equipment) to research programs involving sheep. Most of the monies used for research projects come from sources outside of the division.

The Fish and Wildlife Services total budget is $29 million.

Other Agency Participation in Sheep Management in Alberta

The only other agency that devotes time toward bighorn sheep management is the Canadian Parks Service (i.e., federal government). Their primary management effort goes toward population inventory, monitoring of specific populations, and habitat enhancement programs such as prescribed burning. While the primary goal of the burning is not solely to enhance bighorn sheep range, sheep invariably benefit from it. The burning is more related to returning successional vegetative states to a more natural order before fire suppression became vogue. The National Parks Service also maintains a rather intensive branding program of adult rams in an effort to discourage poaching. Since this is more enforcement related, I have not included any manpower costs.

The Canadian Parks Service allots approximately $12,000 annually for aircraft time performing inventory work, although surveys are conducted every 3 years on a rotational basis. Prescribed burning programs vary considerably from year to year in activity levels. About 1,000 hectares has been burned per year for the last several years at a cost of about $20 per hectare. The Canadian Parks Service has also made significant contributions toward various research programs involving sheep both on and off federal lands. In 1992/93, $30,000 was contributed toward sheep research, and another $20,000 was contributed in 1993/94. This contribution consisted of equipment, manpower, and monies.

The manpower commitment from the Canadian Parks Service is equivalent to about 7 or 8 person-months per year, or about $35,000 per year.

Additional Funding and Foundation for North American Wild Sheep Participation

Funding for research projects has generally come from sources other than the Fish and Wildlife Division. For the last 2 years, contributions have amounted to about $83,000 per year. These sources are mostly from other government granting agencies, from private groups (Fish and Game Associations, etc.), from private companies (oil and gas, or coal mining), or from university grants.

The only money received from the Foundation for North American Wild Sheep (FNAWS) was $500 to help finance a research project on Ram Mountain in 1993. Other requests from FNAWS have been turned down.

The Fish and Wildlife Division does not have any special hunting permits for sheep that are donated, auctioned, raffled, or given away in some other manner as a means of raising funds for bighorn management. The idea has been suggested several times and gone through several discussion stages, but nothing is contemplated for the near future.

DISCUSSION

Alberta has a very comprehensive management program for bighorn sheep. It outlines fairly specifically the goals and objectives as to how the sheep resource will be protected (populations and habitat) and how the resource will be allocated among the various user groups. Recreational hunting is clearly defined in terms of harvest goals, allocation between residents and nonresidents, types of hunting opportunities, seasons, and restrictions to that hunting opportunity should the resource be threatened.

Of all the components in the program, however, there are only a few which one could say are consistently delivered including population inventory, compulsory registration, and permit setting. Unfortunately, in this era of declining manpower and resources, even some of the systematic survey programs are taking a back seat to other higher priority programs.

Other aspects of the program such as habitat protection, habitat enhancement, research goals, and non-consumptive objectives are more vaguely outlined. The objectives appear more as guidelines or things that would be good to do if resources were not a limiting factor. Their implementation is left to the local wildlife biologist to initiate depending on their other priorities.

Bienn. Symp. North. Wild Sheep and Goat Counc. 9:184-185.

1994 NWS&GC MANAGEMENT WORKSHOP QUESTIONNAIRE RESPONSE: BRITISH COLUMBIA'S MOUNTAIN SHEEP MANAGEMENT PROGRAM

DAN BLOWER, Ministry of Environment, Lands and Parks, Wildlife Branch, 780 Blanshard St., Victoria, British Columbia V8V 1X5

QUESTION: Does your state or province have an identifiable sheep management program?

The province of British Columbia has an identifiable, but loosely structured sheep management program.

QUESTION: What is your guiding policy statement?

Provincial policy is to retain the existing herds and their supporting habitat.

QUESTION: What are your management goals?

Management goals are:

1. Maintain an optimum abundance of the various species and subspecies.

2. Provide reasonable levels of consumptive and non-consumptive uses of the resource.

QUESTION: What methods do you use to reach them?

Management planning is guided by a Preliminary Mountain Sheep Management Plan for British Columbia.

Regional sheep management plans are developed for each region of the province where sheep occur (all regions except Vancouver Island and Lower Mainland). Provincial program coordination is overseen by the Wildlife Branch in Victoria.

QUESTION: How much effort is devoted to reaching them?

Wildlife managers spend a disproportionate amount of time on mountain sheep management over the management of other wildlife species. However, there are no provincial personnel who are employed exclusively to manage mountain sheep.

QUESTION: What is your operating budget for sheep management?

No specific operational funds are set aside annually for sheep management in the province.

Other Agency Participation in Sheep Management in British Columbia

Other agencies regularly or intermittently involved in sheep management in the province are: Foundation for North American Wild Sheep (FNAWS), B.C. Wildlife Federation; Guide Outfitters Association of B.C.; Habitat Conservation Fund of B.C.; Wild Sheep Society of B.C.; Nature Trust of B.C.; Nature Conservancy of Canada; Canadian Wildlife Service; Okanagan Regional Wildlife Heritage Fund; Kootenay Wildlife Heritage Fund; East Kootenay Hunters Association; and East Kootenay Wildlife Association.

Additional Funding and Foundation for North American Wild Sheep Participation

No tabulation of the monetary or staff time contributions of these agencies toward sheep management in the province is available. FNAWS has been a fairly consistent contributor toward provincial sheep management, with approximately $10,000 received annually. The province has not yet approved the donation of a sheep hunting permit to FNAWS for auction.

DISCUSSION

The Wildlife Branch of B.C., Ministry of Environment, Lands, and Parks coordinates the mountain sheep management program in the province. Two species and four races of mountain sheep occur in British Columbia.

Thinhorn sheep (*Ovis dalli*) are located only in the northern half of the province and numbers are estimated at 12,000. Approximately 11,500 of these are classed as Stone sheep (*Ovis dalli stonei*) and approximately 500 as Dall sheep (*Ovis dalli dalli*).

Bighorn sheep (*Ovis canadensis*) are located in the central and southern portions of the province and numbers are estimated at 8,000. Approximately 4,500 of these are classed as California bighorn sheep (*Ovis canadensis californiana*) and approximately 3,500 as Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*).

Management activities have primarily been devoted to setting sheep hunting regulations and carrying out selective population surveys. Other important activities carried out to varying degrees and/or in various regions include population transplants, range assessments, habitat acquisitions, and habitat enhancements.

Harvest regulations are mainly centered on open season ram hunting, using a curl regulation to limit harvests. Where "limited entry hunting" (draw for permits) occurs, there is a trend toward "any-ram" regulations. Permit ewe hunting also occurs on some bighorn sheep populations. Nonresident hunting is regulated in most areas by the allocation of a quota to licensed guide outfitters.

Some of the mountain sheep management issues of concern in the province of British Columbia are:

1. An up-to-date provincial mountain sheep management plan has not been developed.

2. As the operational management of mountain sheep populations is strongly regionalized, some difficulties occur in developing a fully coordinated provincial management program. To some extent, the personal philosophies/preferences of individual regional wildlife biologists determine the type of program followed in a region.

3. Mountain sheep population inventory/survey data is inadequate (or in some areas virtually non-existent) in all regions of the province.

4. The mortality factors that are controlling the numbers of mountain sheep are not adequately understood in most populations. However, wolf predation on thinhorn sheep and cougar and coyote predation on bighorn sheep are known to be important mortality factors for some populations.

5. Horn-curl regulations continue to be of some administrative concern. Difficulties in handling enforcement and hunter appeals following confiscation of marginal sheep, although not numerous, are time consuming for staff and a traumatic experience for individual hunters.

6. The need to more effectively control/regulate the aboriginal sustenance hunting of ram mountain sheep has been increasingly recognized in recent years.

7. The transmission of diseases to mountain sheep from domestic livestock continues to be of concern. The increasing use of domestic sheep grazing as a forest silviculture brush control measure could result in the exposure of wild sheep to domestic sheep diseases. Also, the importation of exotic sheep (i.e., barbary sheep, mouflon sheep) by some domestic livestock interests have disease transmission and genetic interbreeding implications for indigenous mountain sheep.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 9:186-191.

1994 NWS&GC MANAGEMENT WORKSHOP QUESTIONNAIRE RESPONSE: CALIFORNIA'S MOUNTAIN SHEEP MANAGEMENT PROGRAM

VERNON C. BLEICH, California Department of Fish and Game, 407 West Line Street, Bishop, California 93514

STEVEN G. TORRES, California Department of Fish and Game, 1416 Ninth Street, Sacramento, California 95814

QUESTION: Does your state or province have an identifiable sheep management program?

California has a mountain sheep management program, with a statewide program coordinator located in the Sacramento office, and a regional coordinator located in the Bishop office of the California Department of Fish and Game (CDFG).

QUESTION: What is your guiding policy statement?

General policy for the conservation of wildlife in the state of California is provided in Section 1801 of the California Fish and Game Code, which states:

"...It is hereby declared to be the policy of the state to encourage the preservation, conservation, and maintenance of wildlife resources under the jurisdiction and influence of the state. This policy shall include the following objectives:

a. To maintain sufficient populations of all species of wildlife and the habitat necessary to achieve the objectives stated in subdivisions (b), (c), and (d).

b. To provide for the beneficial use and enjoyment of wildlife by all citizens of the state.

c. To perpetuate all species of wildlife for their intrinsic and ecological values, as well as for their direct benefits to all persons.

d. To provide for aesthetic, educational, and nonappropriative uses of the various wildlife species.

e. To maintain diversified recreational uses of wildlife, including the sport of hunting, as proper uses of certain designated species of wildlife, subject to regulations consistent with the maintenance of healthy, viable wildlife resources, the public safety, and a quality outdoor experience.

f. To provide for economic contributions to the citizens of the state, through the recognition that wildlife is a renewable resource of the land by which economic return can accrue to the citizens of the state, individually and collectively, through regulated management. Such management shall be consistent with the maintenance of healthy and thriving wildlife resources and the public ownership status of the wildlife resources.

g. To alleviate economic losses or public health or safety problems caused by wildlife to the people of the state either individually or collectively. Such resolution shall be in a manner designed to bring the problem within tolerable limits consistent with economic and public health considerations and the objectives stated in subdivisions (a), (b), and (c).

h. It is not intended that this policy shall provide any power to regulate natural resources or commercial or other activities connected therewith, except as specifically provided by the Legislature..."

Policy specific to the conservation of the wild sheep resource is provided in Section 4900 of the California Fish and Game Code, which states:

"...The Legislature declares that bighorn sheep are an important wildlife resource of the state to be managed and maintained at sound biological levels. Therefore, it is hereby declared to be the policy of the state to encourage the preservation, restoration, utilization, and management of California's bighorn sheep population. The management shall be in accordance with the policy set forth in Section 1801 [of the Fish and Game Code]..."

QUESTION: How do/did you do management planning?

The statewide program coordinator annually organizes a meeting for the department's Mountain Sheep Management Program participants. The objectives of this meeting include reviewing and reporting the progress of current research and management efforts, receiving and reviewing proposed research, coordinating survey and capture efforts, and outlining the program budget and fund requests.

The statewide and regional coordinators and contract collaborators are currently preparing an updated "Long-Range Conservation Plan for Mountain Sheep in California." In addition to updating management goals, this plan will serve as a lead reference for management planning, continued population assessment, program priorities, and the economics of our conservation efforts. This plan should be completed in 1994.

Planning mandates are also specified in Section 4901 of the Fish and Game Code. This provides for the preparation of management plans based on defined management units. Management units are defined on geographic and biological criteria, and include information on the following:

1. Data on the numbers, age, sex ratios, and distribution of bighorn sheep within the management unit.
2. A survey of range conditions and a report on the competition that may exist as a result of human, livestock, wild burro, and any other mammal encroachment.
3. An assessment of the need to relocate or reestablish bighorn populations.
4. A statement on the prevalence of diseases or parasites within the population.
5. Recommendations for achieving the policy objective of Section 4900 [of the Fish and Game Code].

These management plans generally are prepared as a collaborative effort that includes input from the local wildlife unit manager, the regional coordinator, and the statewide coordinator. Appropriate goals are selected for each management unit on a case-by-case basis using the best biological information available to the planners.

QUESTION: What are your management goals?

Management goals for mountain sheep, as published in the Statewide Plan for Bighorn Sheep (California Department of Fish and Game 1983:3), are as follows:

1. Maintain, improve and expand bighorn habitat where possible or feasible.
2. Reestablish bighorn populations on historic ranges where feasible.
3. Increase bighorn populations so that all races become numerous enough to no longer require classification as rare or fully protected.
4. Provide for aesthetic, educational, and recreational uses of bighorn sheep.

QUESTION: What methods do you use to reach management goals?

1. Most research and management activities are carried out by the efforts of department biologists and contract collaborators. Given departmental time constraints, most ground-monitoring efforts are conducted by contract staff, while survey, capture, and habitat improvement projects are coordinated and conducted by department staff.
2. Based on the results of the program research, plans were formulated that provided for a variety of uses of sheep occurring in the various management units. In some cases, harvest management was recommended and, in others, recommendations against harvest

until certain criteria defined in the management plans were met specifically were included.

3. Although no detailed statewide objectives exist for monitoring each mountain sheep population, local personnel cooperate with project coordinators to ensure the acquisition of meaningful demographic information on a regular basis. Annual demographic surveys are conducted in those zones subject to harvest management, and recommendations for utilization are formulated based on those surveys.

4. State law (Office of Administrative Law) requires that the department annually provide hunting regulation proposals. These proposed regulation changes are provided to the California Fish and Game Commission, and are submitted for public review and input. Final recommendations and adoption of regulations occur in April.

5. State law (California Environmental Quality Act) provides that an environmental document be prepared to ensure full disclosure of environmental impacts anticipated to result from implementation of any harvest management recommendations. Such a document has been prepared each year since 1987. This document is also circulated for public review and input.

6. Unit biologists review and comment on federal land management proposals that would impact the habitat of mountain sheep, and work to ensure that anticipated impacts are mitigated to the extent possible.

7. Formal working groups that include representatives of CDFG, as well as land management agencies and other appropriate personnel, have been initiated to coordinate management efforts for mountain sheep occurring in the Sierra Nevada (*Ovis canadensis californiana*) and in the peninsular ranges of southwestern California (*Ovis canadensis cremnobates*). Both of these subspecies are listed as "Threatened" by the California Fish and Game Commission.

QUESTION: How much time is devoted to reaching management goals?

There are 9 unit biologists that have sheep in their assigned geographic areas. As in most other states, these biologists are generalists and are expected to accomplish a variety of tasks related to numerous species occurring in their geographic areas. The amount of time spent on mountain sheep by each of these unit biologists varies considerably. In some cases (n=2), less than 1 week per year is spent on activities directly related to wild sheep management, while in others (n=2), as much as 3 months per year may be spent on activities related directly to the management of the wild sheep resource. On average, unit biologists probably spend less than 1 month each year on activities related directly to the management of the mountain sheep resource. The amount of time dedicated to sheep management by unit biologists probably is a function of 3 things: (1) the number of other "urgent" activities, such as environmental review activities, occurring within their geographic area; (2) the size of the sheep population in their geographic area; and (3) the presence of ongoing harvest programs in their geographic area.

Currently, all of the mountain sheep in California occur in a single administrative region that includes the eastern Sierra Nevada, the Mojave Desert, and the Sonoran Desert. The regional coordinator expends approximately 6 months/year on activities related directly to the management of mountain sheep in this broad geographic area. Activities include facilitating and coordinating aerial survey activities, research efforts, and overseeing the harvest program.

The program coordinator at the statewide level expends approximately 10 months/year on administration directly related to the management of mountain sheep in California. Activities include program planning and administration, budgeting, project coordination with regional staff, oversight of survey and research efforts, oversight of contract collaborators, reviewing legislative proposals, preparing hunting recommendations and environmental documents.

The total person-months dedicated to the management of wild sheep by personnel of the California Department of Fish and Game total approximately 25 months/year; 9 of these are accomplished by unit biologists, 6 of these are accomplished by the regional coordinator, and 10 are accomplished by the statewide program coordinator.

QUESTION: What is your operating budget for sheep management?

There is no special operating budget for activities of wildlife unit biologists or the regional coordinator related to the management of mountain sheep. In recent years, operating expenses for each of these personnel have been limited to approximately $5,000/year for all management activities. When operating expenses are exhausted, some augmentation may be provided from funds controlled by the statewide program coordinator.

Since 1986, CDFG has received approximately $200,000/year from the California Environmental License Plate Fund specifically for mountain sheep management. These funds have been made available through a special legislative appropriation on an annual basis. Additionally, CDFG has received funds ranging from $37,000 to $162,000 from the annual sale of special fund-raising hunting permits (Table 1) since 1987. To date, the department has received $734,473.50 from the allocation of 64 mountain sheep tags. These funds are allocated to an account dedicated to mountain sheep management. Section 4903 of the Fish and Game Code stipulates that such funds must be used "...solely for programs and projects to benefit bighorn sheep and for the direct costs and administrative overhead incurred solely in carrying out the department's bighorn sheep activities. Administrative overhead shall be limited to the reasonable costs associated with the direct administration of the program. These funds shall be used to augment, and not to replace, moneys appropriated from existing funds available to the department for the preservation, restoration, utilization, and management of bighorn sheep." The interpretation of these mandates has been open to some question both by persons within and outside CDFG.

Table 1. Summary of Nelson bighorn sheep tag allocations, harvest, applications, and auction tag revenue[a] from 1987-1994 in California.

Year	Allo-cated	Number harvested	Number applicants	Revenue[a]	Tag fees	Total
1987	9	9	4,066	$ 70,000.00	$ 21,930.00	$ 91,930.00
1988	9	7	3,385	$ 59,000.00	$ 18,525.00	$ 77,525.00
1989	9	9	3,185	$ 40,000.00	$ 17,525.00	$ 57,525.00
1990	6	6	2,591	$ 37,000.00	$ 13,955.00	$ 50,955.00
1991	8	7	2,834	$ 42,000.00	$ 15,570.00	$ 57,570.00
1992	12	12	3,798	$ 61,000.00	$ 22,464.50	$ 83,464.50
1993	11	9	4,318	$100,000.00	$ 25,082.00	$125,082.00
1994	14	--	4,692	$162,000.00	$ 28,422.00	$190,422.00
TOTAL	**64**	**59**	**24,177**	**$571,000.00**	**$163,473.50**	**$734,473.50**

Other Agency Participation in Sheep Management in California

Mountain sheep occur on land managed by the U. S. Forest Service (USFS), Department of Defense, California Department of Parks and Recreation, Los Angeles Department of Water and Power (LADWP), National Park Service (NPS), U. S. Fish and Wildlife Service (USFWS), and the Bureau of Land Management (BLM); the majority of wild sheep in California occur on BLM lands. Memoranda of understanding exist with each of these agencies regarding the management of wildlife and habitat occurring on their respective lands.

The Inyo National Forest, Yosemite National Park, Sequoia-Kings Canyon National Park, LADWP, and the Bishop Resource Area of BLM have entered into an agreement with CDFG regarding mountain sheep in the Sierra Nevada (Sierra Nevada Bighorn Sheep Interagency Advisory Group 1984). This agreement is directed specifically at restoring populations of this subspecies on historical ranges, as well as maintaining existing populations. Mountain sheep also occur on the Los Padres, Angeles, and San Bernardino National Forests, and throughout southeastern California on lands administered by the California Desert District of BLM. Recently, BLM has embarked on a planning effort emphasizing a metapopulation approach to the conservation of habitat for desert-dwelling mountain sheep, and approximately 6 months/year are expended by a planner working on that effort.

Death Valley National Monument (DVNM) receives the majority of funding from NPS specifically directed toward mountain sheep management. Currently, research is directed at describing the demography of sheep occurring in DVNM. Aside from the planning position noted above, few funds are expended by BLM specifically for mountain sheep; operating costs for sheep activities are borne by the individual resource area biologists. Mountain sheep occur on USFWS lands adjacent to the Colorado River; few, if any, funds have been expended specifically for sheep management. Recently, USFWS personnel have become involved in several planning efforts that have arisen as a direct result of the proposed listing of *O. c. cremnobates* as a federally-threatened population.

Additional Funding and Foundation for North American Wild Sheep Participation

In 1986 the California Legislature authorized the harvest of mountain sheep for the first time in more than 100 years. With that authorization, the legislature provided for special harvest tags for fund-raising purposes. In 1987 the first such tag sold for $70,000; total income from 1987 to 1994 is $571,000. The majority of these tags (7 of 9) have been auctioned by the Foundation for North American Wild Sheep (FNAWS). Because state law mandates that all proceeds from the sale of these tags must be returned to the state of California, specifically for wild sheep management, CDFG annually donates a special Research and Management Adventure to FNAWS, which retains 100% of the proceeds from the sale of that item.

Although CDFG receives all of the monies from the sale of fund-raising tags, relatively few requests have been submitted by CDFG to FNAWS requesting support for projects. Since 1983, CDFG has received funds totalling $50,500 that have been expended for research ($32,500), translocations ($15,000), and inventories ($3,000).

DISCUSSION

Management activities for mountain sheep in California are highly visible and are at the highest level in history. Funds provided through the sale of environmental license plates and through the auction of special fund-raising permits have enabled the department to support a number of important research efforts concentrating primarily on demography and the disease status of mountain sheep.

Although funds are adequate to augment in-house personnel to work specifically on mountain sheep conservation and research, requests for such positions have been consistently denied by the Department of Finance. The lack of adequate internal staffing has been detrimental to the department's sheep management program, because individuals outside the department perceive CDFG personnel as being incapable of completing research projects without contracting with academic personnel or other consultants. Although funds are available to support a formal mountain sheep research program within CDFG, no such program exists because no positions have been allocated for such a program. Hence, most formal research conducted on mountain sheep has been contracted to individuals associated with a number of academic institutions. Some significant research has been carried out by permanent department employees, however, largely in addition to their regular duties.

The management of mountain sheep is one of the few programs within CDFG that annually is growing and becoming more strongly supported. At this time, the statewide program coordinator and the regional coordinator work closely to ensure that funds are allocated to the most meaningful projects, but burgeoning administrative tasks, such as the preparation of environmental documents for the hunting program or the preparation of contracts and budgets, supersede activities that would directly benefit mountain sheep. There is more work than can be accomplished by personnel currently involved with sheep management, and the augmentation of the sheep program with additional positions would be welcomed. In the absence of such an event, planning, coordination, and implementation will be carried out at a rate consistent with available time constraints.

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Bienn. Symp. North. Wild Sheep
and Goat Counc. 9:192-193.

1994 NWS&GC MANAGEMENT WORKSHOP QUESTIONNAIRE RESPONSE: IDAHO'S MOUNTAIN BIGHORN SHEEP MANAGEMENT PROGRAM

LLOYD OLDENBURG, Idaho Fish and Game, 600 South Walnut/Box 25, Boise, Idaho 98501-1091

QUESTION: Does your state or province have an identifiable sheep management program?

The Idaho Department of Fish and Game (department) has the statutory responsibility to conserve, protect, perpetuate, and manage all wildlife within the state (Idaho Code, Section 36-103).

QUESTION: How do/did you do management planning?

Department personnel develop 5-year species plans which are approved by the department. These plans then are given widespread public review followed by commission action to approve or disapprove each recommendation. The technical plan includes 1) biological consideration, 2) habitat management, 3) harvest strategies, 4) management information requirement, 5) economic considerations, 6) trapping and transplanting, 7) issues and strategies, and 8) statewide management direction for each subspecies.

The department maintains biological surveys to determine population status (aerial herd composition counts). A monitoring program for pathogenic and parasitic organisms is maintained. Habitat considerations are requested of land management agencies to enhance conditions for bighorns whenever and wherever possible.

Harvest is only by controlled hunts with available permits limited annually to no more than 20% of legal rams observed on the most recent survey in each hunt area. Only rams with 3/4 curl or larger, or 4 years old or older, can legally be taken under the once-in-a-lifetime regulations for each subspecies, California and Rocky Mountain bighorn rams. The harvest of a ewe does not affect the once-in-a-lifetime rule for rams. Low drawing odds for permits are maintained with a regulation prohibiting application for any other controlled hunt permit if you apply for a bighorn permit. A trap and transplant program has been very effective in reestablishing bighorn populations in vacant, suitable historic habitat.

QUESTION: What are your management goals?

The department's management goals are:

1. To increase bighorn populations to allow a corresponding increase in hunting opportunity and recreational viewing.
2. To establish new herds through transplants.
3. To promote nonconsumptive values of bighorns.
4. To continue bighorn disease research.
5. To survey all populations at least once every 5 years.

QUESTION: What methods do you use to reach them?

Population increase is achieved through harvest strategy, habitat enhancement by working with federal land management agencies, and transplanting into unoccupied, suitable historic habitat. Research for methods of disease and parasite control is ongoing. Popular articles are written to promote nonconsumptive use of the bighorn resource and to develop support for bighorn management and research programs.

QUESTION: How much effort is devoted to reaching them?

Six of the eight administrative regions in the state have bighorn populations. About 150 regional man-days (13 people) and $34,000 are earmarked for management each year. There is 1/2 man-year veterinarian research time, 1 man-year wildlife health technologist time, and 1/2 man-year wildlife technician time devoted to bighorn disease research each year.

QUESTION: What is your operating budget for sheep management?

The budgets for these projects and fund source include:

1. Veterinarian 1/2 year$50,000(F&G)
2. Wildlife Disease Research41,300(P.R.)
3. Laboratory Services79,000(P.R.)
*4. Laboratory Construction100,000(P.R.)
5. Regional Personnel34,000(P.R.)
6. Statewide Personnel30,000(P.R.)
7. Statewide Personnel10,000(F&G)
8. Trap and Transplant35,000(F&G)
9. Trap and Transplant30,000(FNAWS)
10. Census50,000(F&G)
11. Harvest Survey/Pinning5,000(P.R.)
12. Controlled Hunt Draw10,000(F&G)
13. Regulations Develop/Print10,000(F&G)
14. Research Facility Upgrade6,500(FNAWS)
15. Mount Ram for Education 1,800 (900 donation; 900 FNAWS)
16. Purchase Transplant Trailer8,000(3,000 FNAWS; 5,000 Grand Slam Club)
17. Lab Technician 1/2 year8,800(Lottery Tag)
18. Wildlife/Domestic Research100,000

* This was a one-time (1992) Commission authorization to expend $100,000 (F&G).

Other Agency Participation in Sheep Management in Idaho

The Idaho Legislature in cooperation with the Idaho Woolgrowers transfers $100,000 each year to the Idaho University Caine Veterinary Training (Agriculture Research) Center for work on disease research as it pertains to interactions between domestic animals and wildlife. Not counting the $100,000 transferred to University of Idaho Agriculture Research, the department spent $409,400 on bighorn sheep research/management in Fiscal Year (FY) 1994. The 1993 bighorn permit/tags, excluding auction and lottery tags, provided $22,755 income to the department (133 residents paid $9,443 and 26 nonresidents paid $13,312 for permit/tags). The department, license buyers, and the Foundation for North American Wild Sheep (FNAWS) fundraisers subsidized the bighorn management/research in Idaho in FY 1994 for $486,645 or 95.5% of the program.

The Bureau of Land Management was involved in California bighorn research through FY 1993, but currently is not involved beyond Environmental Analysis (EA) for transplant sites. The U. S. Forest Service is doing an EA which, if approved, would remove domestic sheep allotments from Hells Canyon National Recreation Area. I have no data on exact time and cost of this project.

Additional Funding and Foundation for North American Wild Sheep Participation

The department obtains funding from FNAWS (and associated organizations) on an annual basis as needed in the form of direct grants. In 1993 we received $54,000 in grants; $46,700 was from FNAWS, $5,000 was from the Grand Slam Club, and $2,500 was from the Iowa Chapter FNAWS.

We also offer 1 tag for purchase at the annual FNAWS auction and 1 tag for marketing by the Idaho Chapter of FNAWS through a lottery. In 1993 the auction tag sold for $31,000, and the lottery tag produced over $11,000. The income from all FNAWS sources supplements our statewide management program.

DISCUSSION

The cooperation between FNAWS and the Idaho Department of Fish and Game has been excellent. FNAWS has provided money for census, transplants, and emergency sampling when disease outbreaks occur. I personally believe FNAWS returns more dollars of those raised to field work, directly benefitting bighorns, than any other interested sportsman organization returns to any other species. The percentage of money raised by FNAWS returned to the state bighorn management/research programs will remain very high as long as this organization continues on their current course of few paid employees, intense fundraisers, and concern for the resource.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 9:194-195.

1994 NWS&GC MANAGEMENT WORKSHOP QUESTIONNAIRE RESPONSE: MONTANA'S BIGHORN SHEEP MANAGEMENT PROGRAM

JOHN J. MCCARTHY, Montana Department of Fish, Wildlife & Parks, Box 306, Augusta, Montana 59410

GLENN ERICKSON, Montana Department of Fish, Wildlife & Parks, P.O. Box 200701, Helena, Montana 59620-0701

QUESTION: Does your state or province have an identifiable sheep management program?

Montana does not currently have a detailed sheep management program planning document. We are in the process of putting together a Programmatic EIS for the Wildlife Division that will cover bighorns, trapping, transplants, and hunting. This document is due out in 1997.

QUESTION: How do/did you do management planning?

Montana has been divided into 8 wildlife management regions. Sheep management is carried out on a herd basis within each region. The regional wildlife manager takes recommendations from field biologists on seasons, habitat acquisition or manipulation projects, transplants, and trapping; prioritizes them; and submits them to the divisional office in the state headquarters. The season recommendations are compiled by wildlife division administrative staff in the state office and must be approved by the Fish, Wildlife and Parks Commission which is appointed by the governor. Trapping, transplanting, acquisitions, studies, and other projects based on regional recommendations to the division are prioritized, and spending on such projects is coordinated through the division.

This system works well and should continue to do so as long as open lines of communication exist between and among all levels of management. Occasionally, it breaks down when individual priorities are not shared at higher or lower levels within the management framework.

Other Agency Participation in Sheep Management in Montana

Other agencies that participate in bighorn management programs within the state include the National Park Service (NPS), the U. S. Forest Service (USFS), the U. S. Fish and Wildlife Service (USFWS) and the Bureau of Land Management (BLM). A brief description of the level of these agencies' activities with sheep follows.

NPS has funded population and movement studies in Glacier National Park and provided partial funding of studies adjacent to and in Yellowstone National Park.

USFS has entered into several cost-share projects dealing with habitat manipulation to improve bighorn ranges. Prescribed burns and logging have been the main methods employed to date. USFS has also contributed money, manpower and administrative assistance towards several studies done in the state. They also monitor vegetation on several grazing allotments and other bighorn ranges that have been impacted with some type of development, and have adjusted grazing systems and made other alterations in management methods for bighorns.

USFWS monitors range and population parameters for transplanted herds on the C. M. Russell Wildlife Refuge (CMR) and the Moiese National Bison Range (MNBR). They have provided funding for studies on the MNBR and for population and vegetation monitoring on the CMR. USFWS has also helped to fund studies and aided in trapping and transplants through the Cooperative Wildlife Unit at the University of Montana.

BLM has provided funding for studies in various parts of the state. They have monitored vegetation and population changes associated with bighorns in the Missouri Breaks, and have helped fund and assist trapping and transplant operations.

Operational, administrative and study costs vary annually between the different agencies. It is estimated an average of $10,000 per year is contributed by these agencies toward sheep management in Montana.

Additional Funding and Foundation for North American Wild Sheep Participation

Montana does provide a bighorn permit to be auctioned off by the Foundation for North American Wild Sheep (FNAWS). Dollars generated by the auction are earmarked for habitat improvement or acquisition, and trapping, transplanting, or studies of bighorns. In our 8 years of participation in the auction, the permit has raised $789,000; 90% of permit earnings ($710,000) has gone into the sheep program in Montana and 10% has remained with FNAWS for their grant program.

During the same period, Montana has received between $5,000 and $10,000 annually in grants for bighorn work in the state from FNAWS. It would appear that for this period, we are essentially getting full price of the tag we auction but no additional funding from the organization. We do feel that FNAWS offers the best opportunity to raise money through the auction of a tag, and we are ahead of the game in total dollars raised for the sheep program because of their ability to bring in the bucks for such an event. There are some second thoughts, however, on the merits and morality of raising money using this method.

DISCUSSION

Montana's sheep management program, while not well documented on paper, runs smoothly and is providing the license holders and other interested publics a wide variety of opportunities in regards to bighorn sheep. The central coordination for spending programs such as trapping, transplants, and habitat acquisition and manipulation at the divisional level allows for statewide prioritization and enactment of these programs. Each region in turn is allowed the leeway to manage the populations within their jurisdiction as well as recommend transplants, studies, and habitat acquisition or alteration programs. It is a system that is driven from the bottom up rather than from the top down. This has resulted in a diversity of management strategies and season types being applied across a diversity of habitats rather than 1 or 2 management strategies being applied across the state.

As with any program, documented or not, when individual management directions are not held in check at the regional or state level a wreck is going to occur. Consequently, we have reached the point where it has become necessary to document broad regional objectives and lay out a statewide program that will still allow managers to deal with real sheep in real situations.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 9:196-200.

1994 NWS&GC MANAGEMENT WORKSHOP QUESTIONNAIRE RESPONSE: NORTH DAKOTA'S CALIFORNIA BIGHORN SHEEP MANAGEMENT PROGRAM

JAMES V. MCKENZIE, North Dakota Game and Fish Department, 100 N. Bismarck Expressway, Bismarck, North Dakota 58501-5095

QUESTION: Does your state or province have an identifiable sheep management program?

North Dakota has a loosely structured, participative management program for bighorn sheep that is identifiable under special big game.

QUESTION: What is your guiding policy statement?

It is the responsibility of the North Dakota Game and Fish Department to be the principal governmental proponent for fish and wildlife populations (including bighorn sheep) and their habitats. The department must aggressively conserve and enhance these resources and protect them from irreversible harm to ensure their existence in perpetuity for the citizens of the state. It is on that premise that the following management policies (for all species, including bighorn sheep) are formulated:

(NOTE - only those policies relating to bighorn sheep or their habitat are included.)

MANAGEMENT POLICIES

Resource Use

1. The department will support, promote and actively defend biologically sound sport fishing, hunting and trapping as traditional and legitimate uses of North Dakota's fish and wildlife resources.

2. The fish and wildlife resources of North Dakota belong to the residents of the state and, while national interests will be considered (especially as they pertain to our abundant migratory bird resources), these resources will be managed for the recreational and other legitimate benefits that can be derived primarily by the residents of North Dakota.

Education

3. The department will promote and conduct training and educational programs that emphasize outdoor skills, ethical outdoor behavior, safe hunting and boating practices, the needs of fish and wildlife, and the wise use and appreciation of the state's fish and wildlife resources.

Promotion and Marketing of Outdoor Opportunities

4. In order to ensure continued familiarity with and participation in acceptable use of renewable fish and wildlife resources, the department will market its products to residents using contemporary advertising methods.

5. Working with appropriate governmental agencies, and with input from resident sportsmen and women, the department will identify acceptable limits of nonresident use of North Dakota fish and wildlife resources and coordinate with state and local promotional groups to keep marketing to nonresidents at appropriate levels and directed at appropriate programs.

6. The department recognizes the value of rural economic development through promotion of the state's natural resources that provides exposure to and understanding of resource management requirements, as long as it is consistent with sustained use and does not negatively impact resident public use opportunities.

General Fish and Wildlife Management

7. The department will advocate that fish, wildlife and their habitats receive favorable consideration relative to other resources in land and water management decisions.

Habitat Management and Protection

8. The department will actively support and participate in efforts to protect and enhance the integrity of our native woodlands, shrublands, prairies, wetlands, and natural landscapes.

Cooperation with Other Agencies and Entities

9. The department will develop cooperative working agreements and relationships with governing agencies to ensure effective cooperative management of fish and wildlife resources involving shared management responsibilities.

10. The department will actively oppose or work to modify programs and procedures of agencies or entities whose impacts to fish and wildlife resources are unacceptable or in direct conflict with stated department program goals and objectives.

Introductions and Stocking

11. The department's management will maintain self-perpetuating populations of sport fish and wildlife whenever possible.

12. Introduction of fish or wildlife species may be considered when: (a) substantial benefits are anticipated; (b) sufficient suitable habitat is available; (c) impacts to native species, habitat, and the human environment are acceptable; and (d) where necessary, approval is obtained from appropriate agencies or private landowners.

Mitigation

13. Whenever unavoidable fish and wildlife habitat or population losses occur, the department will, where practical and legally possible, actively seek compensation for the state's losses under the following guidelines (in order of priority):

    A. For long-term losses caused by habitat elimination or degradation, compensation by acquisition and improvement of alternate habitat will be sought rather than monetary restitution. Compensation must be permanent and include funding necessary for annual operations, maintenance, and monitoring if these are required to ensure that target goals for fish and wildlife benefits are achieved.

    B. Monetary restitution, based on costs to replace lost resources, will be sought for losses caused by direct mortality.

    C. Whenever possible, replacement of losses will be by the same fish and wildlife species or by habitat capable of producing the same species that suffered the loss and compensation programs will be located in the immediate area of loss, or in a more desirable location if appropriate.

    D. "Off-site" locations and different species may be substituted in compensation programs if "on-site" and "in-kind" compensation is not possible or practical.

    E. Compensation levels will be based on loss of habitat and loss of potential for fish and wildlife production and recreation rather than numbers of animals or days of use of animals occurring at the time of loss.

Captive Fish and Wildlife

14. The department will work closely with captive fish and wildlife propagators and appropriate state and federal regulatory agencies to:

14A. Ensure only genetically pure, disease-free stock is brought into the state.

14B. Ensure aquatic or terrestrial holding facilities are adequate to prevent escape of captive populations into the state's waterways or terrestrial habitat.

14C. Ensure protection for all wild, free-ranging fish and wildlife populations from disease, interbreeding, or habitat competition from escaped captive fish and wildlife.

Financial

15. The department will investigate alternative funding sources (beyond license sales and

federal aid) that will allow all North Dakotans the opportunity to financially contribute to the future well-being of our fish and wildlife resources.

QUESTION: How do/did you do management planning?

As a state agency, the North Dakota Game and Fish Department is subject to various mandates as provided in the State Constitution, North Dakota Century Code, and other governmental regulations and policies. Within these guidelines, the department can manage fish, wildlife and their habitats to benefit a variety of publics. As part of developing the PArticipative MAnagement (PAMA) process for the department, the main fish and wildlife species that the department manages were sorted and placed into categories called Programs. The programs are grouped to represent similar management strategies.

Table 1. Programs of the North Dakota Game and Fish Department.

Big game	Small game	Recreational fisheries	Other
Special Big Game	Ring-necked Pheasant	Missouri River System	Nongame
Mule Deer	Prairie Grouse	Devils Lake	Educational Services
White-tailed Deer	Wild Turkey	Mid-sized Reservoirs	
Pronghorn	Other Small Game	Small Lakes and Reservoirs	
	Ducks	Rivers and Streams	
	Geese		
	Other Migratory Game		
	Fox and Coyote		
	Other Furbearers		

SPECIAL BIG GAME PROGRAM PLANNING

History

The term "Special Big Game" refers to 3 species of big game in North Dakota – moose, California bighorn sheep, and elk. Although they are quite different animals with very different habitat requirements, they have several things in common. In North Dakota, habitat for these species is quite limited and populations are small. To keep populations within the capacity of the range to sustain them, recreational hunting is a valuable management tool. Yet the recreational opportunities provided by these hunts are very limited. To give all North Dakota hunters equal chances to hunt these animals, licenses for these species are issued by lottery on a once-in-a-lifetime basis.

Goal

The goals of the Special Big Game Program are to maximize populations in areas where feasible and compatible with habitat and people, to provide unique hunting opportunities, and to meet appreciative-use demands.

In the strategic planning process (PAMA), 4 basic components are/were considered: Inventory (Where are we?), Strategic (Where do we want to be?), Operational (How do we get there?), and Evaluation (Did we make it?).

At this point in time, the bighorn sheep management plan has progressed from inventory through strategic phases and is now involved with operational efforts. We will be evaluating the results in 1995.

History - Bighorn Sheep

Bighorn sheep are native to North Dakota. But the subspecies of bighorn native to the badlands of the southwest -- the Audubon bighorn -- has been extinct since the early 1900s, a victim of unregulated hunting and the changes brought about by settlement.

The department became interested in reestablishing bighorns in the badlands in the mid-1940s. It was not until 1955 that the department found a population that was both available and thought to be adaptable to the badlands environment. These sheep were California bighorns, native to the lower elevations of the mountains of central British Columbia. In November 1956 the North Dakota Game and Fish Department and the British Columbia Game Commission cooperated to trap and transplant 18 California bighorns to the North Dakota badlands. Since 1956, sheep management has emphasized a trap/transplant program to establish new herds from the original 18 sheep. In 1989, the Game and Fish Department returned to British Columbia to trap 9 additional sheep and release them into the badlands. In 1990 and 1991, the department cooperated with the state of Idaho to bring 23 and 38 California bighorns, respectively, to North Dakota.

Current Status - Bighorn Sheep

Typically, bighorn sheep in North Dakota inhabit topography which includes plateaus that altitudinally range from 2500 to 2900 feet and encompass areas of 0.6 square miles or more. These plateaus are surrounded by steep cliffs. Habitat such as this provides escape cover which is critical for sheep. Most daily movements of bighorns are on or near these plateaus with a small amount occurring on flat-top ridges. Bighorn sheep are now distributed in 11 separate bands over 151 square miles of the badlands (see Figure 1). Additional bighorn sheep habitat exists that would be suitable for future introduction.

The first recreational hunting season was proclaimed in 1975 and, with the exception of 4 years (1980-1983), seasons have been open each year since. These permits are issued by lottery on a once-in-a-lifetime basis for male sheep. In 1986 the regulations for issuing bighorn permits were changed to allow 1 permit each year to be auctioned to the highest bidder at the annual convention of the Foundation for North American Wild Sheep (FNAWS). This annual auction has raised nearly $250,000 for sheep in management in North Dakota.

Table 2. Management objectives for North Dakota's California bighorn sheep in 1995.

Year	Population Index[1] (Spring)	Hunters	Hunter Days	Days/ Hunter	Harvest	Hunter Success
1986	91	7	13	1.9	6	86%
1987	78	8	33	4.1	8	100%
1988	97	8	20	2.5	8	100%
1989	81	8	33	4.1	8	100%
1990	76	8	24	3.0	7	88%
1995	**120**	**13**	**40**	**3.1**	**12**	**95%**

[1] Relative indicator of population level based on an annual aerial survey of a designated study areas.

QUESTION: What are your management goals?

OBJECTIVES

Objectives for 1995 are highlighted in the Table 2. Data from previous years are shown for comparison purposes. Complementary Sheep Objectives

1. By 1995, determine carrying capacity of existing habitat and increase effort to improve the reliability of the population index.

QUESTION: What methods do you use to reach them?

Our own methods and research from other jurisdictions have and will provide the basis for filling voids of knowledge as our bighorn program moves toward established goals.

Field biologists conduct spring and fall aerial population surveys. Seasonal assistants determine lamb production and lungworm larvae loads in the various bighorn bands, and bait for lungworm control prior to parturition.

Department crews trap and translocate bighorns, from both in-state and other jurisdictions, to control population numbers, improve genetic diversity, and establish new breeding populations on acceptable new habitats. Biologists man field-checking stations during annual hunting seasons to gather data deemed necessary to attain management goals.

QUESTION: How much effort is devoted to reaching them?

During an average year, 3 big game biologists, 2 other biologists and 2 wildlife technicians spend 4 man-months and 3 seasonal part-time assistants spend 8.6 man-months on bighorn sheep management. The total man-months of effort for bighorn management averages 12.6 with salaries and benefits totalling $19,581.13.

QUESTION: What is your operating budget for sheep management?

The average budget for the same timeframe as referred to in answering the preceding question is $39,742.42. All line items (including salaries and benefits) are included in this figure.

Other Agency Participation in Sheep Management in North Dakota

The Bureau of Land Management, the National Park Service and the University of North Dakota are involved in sheep research and/or management in North Dakota. The amount of their funding is unknown.

Additional Funding and Foundation for North American Wild Sheep Participation

North Dakota has requested grants from FNAWS each year since the mid-1980s. During that 8-year period, grants have averaged about $5,000 per year.

This same time-frame (1986-1993) saw the North Dakota governor's permit to FNAWS average about $26,000 per year.

In recent years (since 1990) the Minnesota-Wisconsin Chapter of FNAWS has additionally funded the bighorn sheep program in North Dakota with 2 large grants, 1 for $13,000 in 1991 and a 2nd for $5,000 in 1992.

DISCUSSION

The PArticipative MAnagement Process in North Dakota is a fact of life. It is a well-structured strategic plan that involves the department and the various publics it serves. However, it may prove to be top-heavy in planning and lacking in that operational component that is to answer the question "How do we get there?" I see a real danger in managing to satisfy publics over scientifically-based management that benefits bighorn sheep.

LITERATURE CITED

PAMA, North Dakota Game and Fish Department's PArticipative MAnagement Process; 1992; North Dakota Game and Fish Department.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 9:201-203.

1994 NWS&GC MANAGEMENT WORKSHOP QUESTIONNAIRE RESPONSE: OREGON'S ROCKY MOUNTAIN AND CALIFORNIA BIGHORN SHEEP MANAGEMENT PROGRAM

RON ANGLIN, Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, Oregon 97207

QUESTION: Does your state or province have an identifiable sheep management program?

Sheep management for both species is guided by the state Bighorn Sheep Management Plan adopted by the Fish and Wildlife Commission in 1992. Flexibility does exist within the plan to take advantage of changing conditions and philosophies of other agencies and public interest groups.

QUESTION: What is your guiding policy statement?

Oregon Department of Fish and Wildlife management policy (revised 1993):

1. It is the policy of the State of Oregon that wildlife shall be managed to prevent serious depletion of any indigenous species and to provide the optimum recreational and aesthetic benefits for present and future generations of the citizens of this state.

2. The department will continue to serve as an advocate for habitat protection and restoration measures on both public and private lands.

3. The department will aggressively seek to reestablish sheep throughout historical ranges. However, those areas with domestic or exotic sheep will not be restocked.

4. The department will continue to manage sheep to provide hunting opportunities for the public.

5. Maintain the biological integrity of both species of bighorn sheep through spatial separation.

6. Testing of all transplanted stock to establish herd health profile.

QUESTION: How do/did you do management planning?

Up until 1992, management efforts were guided by the staff big game biologist working in cooperation with district personnel to move forward with transplants and hunting seasons. The management plan was a combined effort of staff and district biologists and contains plans for restoration efforts, habitat protection, and for maintaining species integrity.

QUESTION: What are your management goals?

1. Reestablish sheep throughout as much of their historical range as possible.

1A. The department recognizes potential conflicts with domestic and exotic sheep and has excluded those areas from the list of transplant sites until such a time as land use changes occur.

1B. Habitat may be in poor condition and in need of restoration. The department will work with private and public land managers to provide technical assistance to improve habitat to levels which will support and sustain viable populations of sheep.

1C. The department will work with public and private land managers to maintain existing habitat and prevent degradation.

2. Provide quality hunting opportunity.

   All tags are issued through a controlled drawing. This is a once-in-a-lifetime opportunity for successful applicants. During 1994 a total of 86 resident and 4 nonresident tags will be issued. Resident hunter tags cost $94 while nonresident hunter tags cost $979.

Season lengths vary from 9 to 14 days with no more than 7 hunters during any hunt. Oregon currently operates under an "any ram" rule where no minimum horn size is required.

3. The department recognizes that the recreational opportunities associated with bighorn sheep are highly valued by the public. Places and times for viewing sheep are identified and provided to the public.

QUESTION: What methods do you use to reach them?

1. The department maintains an active role in public and private land management plan reviews. Positive and negative impacts of different management practices are defined and recommendations are presented to the appropriate managers. Herd health is monitored through an aggressive blood screening and disease testing program and animals are treated when possible.

2. Census is conducted twice a year to determine lamb survival and recruitment. Ram to ewe ratios are noted and trend-developed. Some districts are beginning to use modeling (Pop-II) to predict herd growth and what component of the population can be removed through hunting and trap and transplant programs.

3. As populations have grown, hunt areas and tag numbers have been increased to take advantage of surplus rams. Efforts have been made to protect the quality of the hunt through manipulation of seasons, hunt areas, and hunter numbers.

QUESTION: How much effort is devoted to reaching them?

There are currently 8 biologists who have sheep within their respective districts. Each of these biologists oversees a variety of programs for all wildlife species within their jurisdiction. Time and effort spent on sheep varies to a certain extent with the workload and the interests of the local biologist; however, most districts probably average around 1 man-month per year for a total cost of $50,400/year.

Staff time spent coordinating sheep transplants, securing grant moneys, and analyzing data accounts for another 3-4 man-months for an additional $19,600.

Total manpower costs associated with implementing the state's sheep management program come to $625,000/year. All of these positions are paid for out of the general game management fund. No grant dollars are used for personnel costs.

QUESTION: What is your operating budget for sheep management?

The department currently has $200,000 per biennium dedicated to the sheep program. These dollars are used for habitat restoration, special research, sheep transplants, and disease work. All personnel-related expenses come out of the general game management budget of $14,000,000 per year.

Other Agency Participation in Sheep Management in Oregon

Cooperative programs are currently conducted with the U. S. Forest Service (USFS), Bureau of Land Management (BLM), and the U.S. Fish and Wildlife Service (USFWS). All USFWS activities are conducted on the Hart Mountain National Wildlife Refuge in southeastern Oregon. USFS and BLM have concentrated on habitat protection issues, and only recently have these agencies looked to commit dollars to on-the-ground projects; consequently, a spending history is unavailable.

Additional Funding and Foundation for North American Wild Sheep Participation

The department has been successful in procuring commitments of funding from private sources/groups to assist with bighorn sheep transplants, disease work, radio telemetry projects, and habitat work. Several loose-knit groups have "adopted" herds of new releases and are provided with periodic updates on herd status. Additional funds have been received from the Foundation for North American Wildlife Sheep (FNAWS) for various transplant, habitat, and disease projects. During the last year, approximately $30,000 in grant/donation funds were received. The department has an excellent working relationship with FNAWS. FNAWS personnel have been instrumental in providing political pressure within various land management agencies to speed up environmental documents, and to discuss conflicts between sheep restoration/livestock interactions. The department has been committed to providing timely responses to all informational requests from FNAWS and has been rewarded with prompt responses to requests for help.

The department was also granted permission by the 1991 legislature to raffle off a bighorn sheep permit.

Oregon does participate in a bighorn sheep auction tag. Legislation was passed during 1985 that permitted the department to auction a governor's tag. Since 1992, this auction has been overseen by FNAWS.

DISCUSSION

The department has been operating under a sheep management plan since 1987. This plan was updated with new information during 1992. The department has historically been very conservative in hunting seasons and tag allocations. Many of the present herds have a large surplus of legal rams. All California bighorn sheep transplants have originated from British Columbia to Hart Mountain. This stock has served as the basis for most new herds in Oregon. Continual removal of lambs and ewes from Hart Mountain may be skewing the population towards rams. All surveys are conducted twice with efforts made in June/July to determine lamb production and again in March to determine overwinter survival. Additional surveys are conducted by local biologists depending on their individual interests and time allotments. The current management plan outlines trap and transplant opportunities for 1992-1997. Systematic relocation efforts are conducted on an annual basis depending on funding and sheep availability. The department operates under an "any ram" rule and mandatory check-in is required of all successful hunters. Age structure of the harvest is very complete and indicates an abundance of older age rams are available. More liberal season and hunting opportunities are being proposed and implemented while still protecting the quality of the hunt. Restoration of sheep into historical ranges has been accelerated with the addition of FNAWS-GIA dollars, auction and raffle tag proceeds, and private donations. Loss of revenue would mean a curtailment of the current aggressive restoration program.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 9:204-205.

1994 NWS&GC MANAGEMENT WORKSHOP QUESTIONNAIRE RESPONSE: WASHINGTON'S BIGHORN MANAGEMENT PROGRAM

ROLF JOHNSON, Washington Department of Wildlife, Big Game Program, 600 Capitol Way N., Olympia, Washington 98501-1091

QUESTION: Does your state or province have an identifiable sheep management program?

Washington has a very general bighorn plan that is revised every few years. The plan is of little value because it is not used by field personnel. We are in the process of revising our species management plans at the present time and hopefully will have a more functional sheep plan in the future.

QUESTION: What is your guiding policy statement?

1. Maintain Population Status: Develop an improved system for measuring population parameters, trends and/or estimating populations.

2. Inventory, Protect and Improve Habitat:

2A. Encourage controlled burning and other range improvement techniques to enhance bighorn sheep.

2B. Identify and seek mitigation/compensation for impacts on bighorn range from logging, mining, road construction, etc., through review of environmental documents.

2C. Encourage the U.S. Forest Service (USFS) and the Department of Natural Resources to pattern timber sales to protect habitat at 5-year action plan meetings.

3. Manage Harvest and Use: Evaluate population dynamics, harvest, and other pertinent data; make hunting season recommendations in accordance with data.

4. Obtain Game Law Compliance: Ensure that 90% of bighorn sheep harvested are lawfully taken.

5. Establish New Populations: Supplement introduced populations of bighorn 5 years after original release.

6. Control Wildlife Disease:

6A. Prevent contamination of bighorn ranges by restricting use by domestic sheep and cattle.

6B. Treat sheep to be transplanted with antihelmintics.

QUESTION: How do/did you do management planning?

Planning efforts change every few years depending on department priority. We have used the team approach and the single plan writer approach. We have had planning as a high priority function with a single person responsible in the agency for planning. At the present time, our emphasis is on Integrated Landscape Planning. Planning is done on specific geographic area (i.e., watershed) for all species.

QUESTION: What are your management goals?

We have outdated population and harvest objectives. Our population objectives are to increase populations from the 1970-79 mean of 450 sheep to 700 sheep by 1989. (We currently have about 900 sheep.)

Harvest objectives are to increase annual harvest from the 1970-79 mean of 8 rams to 10 rams by 1989 while maintaining the hunter success of 33%. (Last year 11 permits were issued and all were successful. Therefore, we exceeded our outdated objectives.)

QUESTION: What methods do you use to reach them?

We monitor hunting seasons by questionnaire sent to all hunters and a follow-up phone call if hunter does not return the questionnaire. All harvested sheep must be inspected and branded by a department agent or biologist.

Population surveys are done via helicopter or hiking routes. Bighorn populations in Washington are small and fairly isolated. Survey data vary from area to area, and surveys are frequently conducted in coordination with surveys of other species. Accuracy of survey data varies, but in many areas sheep are a priority species and biologists devote extra time to get better data than for other species.

QUESTION: How much effort is devoted to reaching them?

We recently initiated a Pittman-Robertson contract for special species (sheep, goat, moose, and cougar). Most of the effort is for surveys for sheep and goats. The contract identifies $10,000 for sheep surveys. Unfortunately, the governor just directed all state agencies to cut budgets by 2%, and our state decided to cut all special survey dollars.

We have about 6 area biologists with sheep in their district. Time spent on sheep management activities totals 88 days or less than 40% of 1 FTE. Department expenditure for salaries, overhead, and benefits for department employees working on sheep is $23,530.

QUESTION: What is your operating budget for sheep management?

Washington does not budget by species. As mentioned above, expenditures for salary, benefits, etc. total about $23,000, and survey expenditures total about $10,000. The overall budget for sheep excluding enforcement, land management administration, etc., is about $33,000 per year.

Other Agency Participation in Sheep Management in Washington

Nearly all of the bighorn sheep in Washington State are on lands owned or managed by the Department of Wildlife. For that reason, very little participation has been received from federal agencies in sheep management.

A couple of years ago, the Bureau of Land Management (BLM) was a cooperator in a sheep transplant to Lincoln County. This year BLM and USFS have volunteered to help with a sheep project on Mt. Hull. The cooperative agreement identifies a $5,000 contribution from BLM and $5,000 from USFS.

Additional Funding and Foundation for North American Wild Sheep Participation

The Department of Wildlife does not consistently ask the Foundation of North American Wild Sheep (FNAWS) for funding. At our request, FNAWS bought a domestic sheep grazing lease in central Washington a couple of years ago to prevent domestic sheep from coming into contact with bighorns. This lease cost about $5,000 and was a 1-shot project.

This is the first year a local chapter of FNAWS has been formed. I believe their first banquet was in February 1994. We have not yet received any funding from the local FNAWS chapter.

The Washington Wildlife Commission decided this year to auction 1 sheep permit in 1994. Policies and procedures are being drafted to facilitate this permit. We expect 1 sheep permit will be auctioned in 1994 and auction revenues will be dedicated to bighorn sheep management.

DISCUSSION

Washington's sheep management program is less effective than it could be primarily because of lack of funding. To be perfectly honest, if we had funding we could develop a structured management plan, but without resources a structured plan is of little value. The proposed auction for 1994 could change that situation. We have drafted a plan on how to spend auction permit revenue, and that spending plan will direct the management plan. Our Wildlife Commission will have to review the spending plan and the department administration will have to make a decision on implementation. These political decisions will determine our future sheep management direction.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 9:206-210.

1994 NWS&GC MANAGEMENT WORKSHOP QUESTIONNAIRE RESPONSE: WYOMING'S ROCKY MOUNTAIN BIGHORN SHEEP MANAGEMENT PROGRAM

KEVIN P. HURLEY, Wyoming Game and Fish Department, 932 Arapahoe, Thermopolis, Wyoming 82443-2115

QUESTION: Does your state or province have an identifiable sheep management program?

Wyoming does have an identifiable sheep management program.

QUESTION: What is your guiding policy statement?

Our mission statement, organic act and statutory authority do not specifically mention bighorn sheep. The mission statement of the Wyoming Game and Fish Department (WGFD) is:

"It is the mission of the Wyoming Game and Fish Department to provide all publics with diverse, quality wildlife-associated recreation, contributing scientific, educational, aesthetic and economic benefits to society and ensuring that all people have equal opportunity to enjoy the wildlife resource."

Furthermore, Wyoming Statute 23-1-103 stipulates:

"For the purposes of this act, all wildlife in Wyoming is the property of the state. It is the purpose of this act and the policy of the state to provide an adequate and flexible system for control, propagation, management, protection, and regulation of all Wyoming wildlife. There shall be no private ownership of live animals classified in this act as big or trophy game."

Wyoming Statute 23-1-302 provides expressed, specific legal charges to the WGFD, under the direction of the Wyoming Game and Fish Commission.

QUESTION: How do/did you do management planning?

Wyoming employs a management-by-objective system for each of 185 individual big game herd units in the state. For bighorn sheep, there are 16 discrete (or suspected to be) populations (Table 1). Population objectives are established for each herd unit, based on biological data, various public demands, and input/review from federal and private land managers.

Once established, population objectives are reviewed at least every 5 years, more often if necessary. This flexible and dynamic system attempts to integrate biological capability with biopolitical reality.

QUESTION: What are your management goals?

Based on population objectives set for individual herd units, an aggregate objective is established. For post-season 1993 the statewide objective is 8,635 sheep. Of the 16 herds, 7 are estimated to be at or above objective, while 8 are below objective. One population was established within the past 3 years; no objective has yet been determined. The post-season 1993 statewide population estimate is 6,960 sheep, approximately 19% below objective.

Other objectives or management goals are set for each herd unit, then combined into an aggregate statewide figure. These objectives are of a lower priority, and deal with desired harvest, number of hunters, hunter success rate, total recreation days, and days per animal harvested.

Sport hunting is one of the primary management goals for Wyoming, although some sheep herds around the state are currently managed with an emphasis on non-consumptive use, viewing, and photography. Sheep licenses are issued on a 3:1 ratio, residents to nonresidents (Table 2), and successful applicants must wait 5 years before reapplying.

Table 1. Bighorn sheep population objectives and estimates for 16 herd units in Wyoming, post-season 1993.

Herdcode	Herd unit	Objective	Estimate
106	Targhee	125	120
107	Jackson	500	550
121	Darby Mountain	150	150
201	Clarks Fork	500	475
202	Trout Peak	750	615
203	Wapiti Ridge	1000	1050
204	Younts Peak	900	950
205	Francs Peak	1360	1470
NA[a]	Shell Canyon	NA[a]	80
516	Douglas Creek	350	125
517	Laramie Peak	500	200
519	Encampment River	200	50
609	Whiskey Mountain	1350	1000
610	Temple Peak	250	75
614[b]	Sweetwater	400	0[b]
615	Ferris	300	50
	Statewide Total	**8635**	**6960**

[a] Recent transplant; no objective established yet.
[b] Scheduled transplant; no population established yet.

Table 2. Wyoming Game and Fish Department bighorn sheep harvest and revenue summary, 1982-1993.

Year	Total licenses[a]	Total harvest	Percent success	Rec. days	Days per animal harvested	License revenue
1982	356	193	54.2	3382	17.5	48950[b]
1983	361	186	51.5	3915	21.1	49550[b]
1984	374	204	54.5	3963	19.4	51156[b]
1985	364	226	62.1	3889	17.2	50050[b]
1986	382	249	65.2	4150	16.7	52350[b]
1987	374	244	65.2	3353	13.7	51250[b]
1988	364	218	59.9	3732	17.1	50050[b]
1989	373	226	60.6	3828	16.9	50850[b]
1990	374	241	64.4	3804	15.8	51250[b]
1991	356	223	62.6	3444	15.4	48950[b]
1992	338	232	68.6	2962	12.8	98915[c]
1993	322	209	64.9	2936	14.0	94245[c]

[a] Licenses issued 3:1 ratio, residents to non-residents.
[b] Resident license = $50; Nonresident license = $ 400.
[c] Resident license = $55; Nonresident license = $1000.

A 3/4-curl restriction on harvesting rams has been in place statewide for years. In 1993 this restriction was changed in one hunt area near Jackson; license numbers were lowered and licenses were made valid for any sheep. Additional hunt areas are expected to make a similar change beginning in 1994.

QUESTION: What methods do you use to reach them?

For many herds, district wildlife biologists and game wardens annually attempt to gather data on sheep distribution, age/sex classification ratios, and hunter harvest. Available information is used in POP-II simulation modeling to estimate population size for each herd unit. Harvest data is collected via a mandatory registration and horn plugging program, in place since 1977.

No formal research program exists, although special projects (known as enhancements) are periodically funded to address particular management concerns. When funded, these projects are typically done using WGFD temporary/contract personnel or graduate students/technicians from the Wyoming Cooperative Wildlife Research Unit and/or the University of Wyoming.

To repopulate historic and/or abandoned habitat, trapping and transplanting of bighorn sheep has occurred in Wyoming since 1944. In the past 30 years, over 1800 sheep have been trapped at the Whiskey Basin winter range complex, southeast of Dubois. Over 1500 of those sheep have been moved to release sites in Wyoming, while over 300 have been provided to other states to assist their sheep management programs.

WGFD bighorn sheep managers routinely cooperate with federal land management agency biologists to maintain and enhance sheep habitat. One prominent example of coordinated, interagency management is the Whiskey Basin Technical Committee comprised of agency personnel from WGFD, the Shoshone National Forest, and the Lander Resource Area of the Bureau of Land Management (BLM). Since 1974, this group has developed and implemented management planning for the Whiskey Mountain sheep herd.

QUESTION: How much effort is devoted to reaching management goals, and what is your operating budget for sheep management?

There are 11 WGFD wildlife biologists with at least some sheep in their respective management districts. Other WGFD personnel (e.g., game wardens, habitat biologists) actively participate in sheep management in Wyoming. Annual trapping operations at Whiskey Basin involve personnel from WGFD, the U. S. Forest Service, BLM, conservation organizations such as FNAWS and the Wyoming Chapter FNAWS, and private citizens.

In an average year, WGFD personnel report approximately 48 work-months devoted to bighorn sheep management (Table 3). Annual expenditures on the bighorn sheep program average approximately $290,000, with approximately 65% of that total being spent on salaries, and approximately 35% as direct project expenditures.

Table 3. Wyoming Game and Fish Department bighorn sheep program costs, FY91 to FY93.

Fiscal year	Direct program costs	Estimated workhours	Estimated workmonths	~Percent spent on salaries	~Percent spent on projects
FY91	251,350	8,416	48.6	71.1	29.9
FY92	218,183	5,531	31.9	56.8	43.2
FY93	398,637	10,955	63.2	64.9	35.1
Ave.	**289,390**	**8,301**	**47.9**	**64.3**	**35.7**

Revenue from license sales (Table 2) is currently not sufficient to meet program expenses (Table 3). Funding for WGFD's bighorn sheep management is drawn from other revenue-positive big game programs (e.g., pronghorn, mule deer).

QUESTION: What other agency effort is directed at sheep management in Wyoming?

The U. S. Forest Service (USFS), BLM, U. S. Fish and Wildlife Service (USFWS), and National Park Service (NPS) are also involved with bighorn sheep management and research in Wyoming. Federal agency expenditures are allocated in a fashion similar to those of WGFD, approximately 2/3 for salaries and 1/3 for project expenditures.

USFS in Wyoming reports approximately 15 work-months and spends ~$27,000 annually on sheep management. BLM in Wyoming reports approximately 7 work-months and spends ~$15,000 annually on bighorn sheep efforts. USFWS, in an advisory capacity to the Wind River Indian Reservation, annually contributes about 1 work-month and ~$1,000 to bighorn sheep management in Wyoming. NPS reports about 1.5 work-months and $2,500 on project expenditures annually on sheep management in Yellowstone and Grand Teton National Parks.

Additional Funding and Foundation for North American Wild Sheep Participation

Since 1981, the governor of Wyoming has annually donated a sheep license to the FNAWS. This license is fully donated, with all proceeds going to FNAWS for their sheep management efforts. The Wyoming license is the only governor's permit which is fully donated to FNAWS.

Since 1989, 6 donated Wyoming governor's licenses auctioned by FNAWS have raised a total of $221,750. Grant-in-aid funding on Wyoming projects from FNAWS has totalled ~$123,671 since 1989. Funding support is also often requested from the Wyoming Chapter of FNAWS. These funds are used to supplement ongoing state and federal sheep management programs throughout Wyoming, and are typically direct project expenditures (e.g., prescribed burning, sheep transplants, flight time for surveys, etc.), rather than being used to underwrite salaries for agency personnel.

DISCUSSION

Bighorn sheep management in Wyoming has been highly visible, and has enjoyed a great degree of support from state and federal agencies, private conservation organizations, and a variety of publics. The best-known case history is that of the Whiskey Basin herd, which for years has been the source population for transplants in and outside Wyoming.

There are a number of changes which could be made to improve management of Wyoming's mountain sheep. Habitat improvement efforts should be increased. As in many western states and provinces, bighorn habitat is slowly being eroded, due to fire suppression and vegetative succession. The problem is particularly acute on the lower-elevation fringes of designated wilderness areas, where prescriptive fire may not be allowed. Acquisition of crucial seasonal habitats could guarantee future security for many of Wyoming's herds.

Overlap with domestic livestock continues to be a management concern, from both a forage competition and disease transmission standpoint. Specific guidelines to ensure spatial and temporal separation of domestic sheep and desert bighorns have been developed and adopted in the southwestern U. S.; similar guidelines should be implemented in Rocky Mountain sheep range. In many cases, livestock management may be pivotal in reestablishing bighorn populations.

Often, agency budgets are insufficient to collect basic data (e.g., age/sex classifications, seasonal distribution, productivity/survival estimates, habitat use) on many bighorn herds. License revenue, at least in Wyoming, fails to match program expenditures. Nonresident license fees were increased in 1992; resident licenses are still underpriced. Developing supplemental funding sources to maintain or expand sheep management efforts will take on greater importance in future years.

Similar to other states, Wyoming might consider a once-in-a-lifetime harvest limitation, to reduce competition in the license draw and allow more people to participate in sheep hunting. The move toward "any sheep" licenses is biologically based, but a stronger information effort must be made to explain agency rationale to the public.

Financial bonds exist between state/federal agencies and private conservation organizations, but progress could be made in strengthening philosophical bonds. Controversial issues such as prescribed burning in wilderness, wolf reintroduction, predator control, livestock management, and continuation of sport hunting need full and open discussion.

Wyoming is proud of its mountain sheep resource, and proud of the management efforts that have been made in recent years. Continued cooperation between agencies and private citizens/organizations should ensure viable bighorn sheep populations well into the future.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 9:211-212.

1994 NWS&GC MANAGEMENT WORKSHOP QUESTIONNAIRE RESPONSE: YUKON'S DALL SHEEP MANAGEMENT PROGRAM

JEAN CAREY, Yukon Department of Renewable Resources, P.O. Box 2703, Whitehorse, Yukon Y1A 2C6

QUESTION: Does your state or province have an identifiable sheep management program?

The Yukon Territory has a small, but identifiable sheep management program.

QUESTION: What is your guiding policy statement?

The greatest influence on the management direction of the Yukon's wildlife resources comes from the implementation of native land claims. General principles and obligations concerning the conservation of wildlife and habitat were adopted by the Government of Canada and the Council for Yukon Indians with the signing of the Umbrella Final Agreement (UFA) in 1990. Provisions within the UFA provide the mechanisms to implement wildlife resource management strategies in the Yukon.

The objectives of the UFA with respect to fish and wildlife conservation and use are as follows:

1. To ensure conservation in the management of all fish and wildlife resources and their habitats;
2. To preserve and enhance the renewable resources economy;
3. To preserve and enhance the culture, identity and values of Yukon Indian People;
4. To ensure the equal participation of Yukon Indian People with other Yukon residents in fish and wildlife management processes and decisions;
5. To guarantee the rights of Yukon Indian People to harvest, and the rights of Yukon First Nations to manage, renewable resources on settlement land;
6. To integrate the management of all renewable resources;
7. To integrate the relevant knowledge and experience both of Yukon Indian People and of the scientific communities in order to achieve conservation;
8. To develop responsibilities for renewable resource management at the community level;
9. To honour the harvesting and fish and wildlife management customs of Yukon Indian People and to provide for the Yukon Indian People's ongoing needs for fish and wildlife;
10. To deal fairly with all Yukon residents who use fish and wildlife resources in the settlement area; and
11. To enhance and promote the full participation of Yukon Indian People in renewable resources management.

QUESTION: How do/did you do management planning?

The first comprehensive species management guidelines are being drafted by a contract biologist (for consistency) in conjunction with the species biologists. The guidelines will be presented to the Yukon Fish and Wildlife Management Board, an advisory body formed under the provisions of the UFA, for review and subsequent public comment.

QUESTION: What are your management goals?

The goals of the Yukon's sheep management program are:

1. To maintain healthy and reasonably abundant thinhorn sheep populations and habitats within the Yukon.

2. To achieve the conservation and sustainable use of thinhorn sheep and their habitat, providing long-term cultural, subsistence, recreational, and economic opportunities associated with hunting and viewing.

3. To educate people and instill public awareness of the value, ecology, and management of thinhorn sheep and their habitat.

QUESTION: What methods do you use to reach them?

The basis of our sheep management program is a conservative harvest regime supported by periodic population assessment. The licensed harvest is restricted to rams having obtained full curl or 8 years of age, and in some easily accessible areas, permits restrict the number of hunters. The characteristics of the harvested rams are closely monitored. In areas showing a declining age average or increased hunting effort, an aerial population census may be prescribed.

Careful review of land-use issues is the other method used to ensure the conservation of sheep populations. A lack of accessibility was the saving grace of most sheep populations through the Yukon's "frontier mentality" days. Development proposals which improve access receive particularly critical review, as do any agricultural applications which may potentially put domestic livestock in proximity with wild sheep populations.

QUESTION: How much effort is devoted to reaching them?

There is 1 full-time biologist with responsibility for sheep and goat management throughout the Yukon, with the bulk of her time currently devoted to sheep issues. Approximately 67,000$Can is budgeted for personnel costs. As well, about 2 months per year of technical assistance is required during the hunting season to process the compulsory biological submissions. This adds another 10,000$Can for a total personnel allocation of 77,000$Can.

QUESTION: What is your operating budget for sheep management?

The operating budget is currently pegged at 32,500$Can. Well over 90% of this is spent on aircraft rental and fuel. The average total wildlife operating budget is 400,000$Can annually.

Other Agency Participation in Sheep Management in the Yukon

The Canadian Parks Service spends 15,000$Can annually on sheep-related issues. This includes salary and aircraft rental for population monitoring surveys, as well as the cost of an extended season at a visitor information centre. The Yukon's most easily accessed and well-known sheep viewing area lies within Kluane National Park Reserve. Sheep Mountain is an important lambing area, and an increased presence of park personnel is important both to educate the public and to protect the sheep from harassment.

Additional Funding and Foundation for North American Wild Sheep Participation

Outside funding is not routinely sought. The Foundation for North American Wild Sheep has supported projects in the past and has contributed approximately 10,000$Can towards 3 projects in the last 10 years.

DISCUSSION

With the full-curl rule, sheep are often said to "manage themselves" and so the Yukon government has not devoted a lot of resources to their management. Yukon wildlife management is largely issue-driven and issue-specific. Sheep often take a back seat to caribou and moose, the principal subsistence species, and will probably continue to do so following the implementation of the UFA. The idea of "trophy management" or treating sheep as a "trophy species" may no longer be tenable in the current context.

While having 1 person responsible for the territory's sheep management program ensures consistency and standardized data acquisition, it often does not allow for more than a superficial understanding of local concerns and conditions. The problems are compounded by the fact that much of the "most current" information dates back to the 1970s.

The major challenge ahead will be to respond to increased information demands created by the 14 new local renewable resource councils without a proportional increase in funding. New strategies and techniques will have to be explored.

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GUIDELINES OF THE NORTHERN WILD SHEEP AND GOAT COUNCIL

The purpose of the Northern Wild Sheep and Goat Council is to foster wise management and conservation of northern wild sheep and goat populations and their habitats.

This purpose will be achieved by:

1) providing for timely exchange of research and management information;

2) promoting high standards in research and management; and

3) providing professional advice on issues involving wild sheep and goat conservation and management.

I The membership shall include professional research and management biologists and others active in the conservation of wild sheep and goats. Membership in the Council will be achieved either by registering at, or purchasing proceedings of, the biennial conference. Only members may vote at the biennial meeting.

II The affairs of the Council will be conducted by an Executive Committee consisting of: three elected members from Canada; three elected members from the United States; one ad hoc member from the state, province, or territory hosting the biennial meeting; and the past chairperson of the Executive Committee. The Executive Committee elects it's chairperson.

III Members of the Council will be nominated and elected to the executive committee at the biennial meeting. Executive Committee members, excluding the ad hoc member, will serve for four years, with alternating election of two persons and one person of each country, respectively. The ad hoc member will only serve for two years.

The biennial meeting of members of the Council shall include a symposium and business meeting. The location of the biennial meeting shall rotate among the members' provinces, territories and states. Members in the host state, province or territory will plan, publicize and conduct the symposium and meeting; will handle its financial matters; and will prepare and distribute the proceedings of the symposium.

The symposium may include presentations, panel discussions, poster sessions, and field trips related to research and management of wild sheep, mountain goats, and related species. Should any member's proposal for presenting a paper at the symposium be rejected by members of the host province, territory or state, the rejected member may appeal to the Council's executive committee. Subsequently, the committee will make its recommendations to the members of the host state, territory or province for a final decision.

The symposium proceedings shall be numbered with 1978 being No. 1, 1980 being No. 2, etc. The members in the province, territory or state hosting the biennial meeting shall select the editor(s) of the proceedings. Responsibility for quality of the proceedings shall rest with the editor(s). The editors shall strive for uniformity of manuscript style and printing, both within and among proceedings.

The proceedings shall include edited papers from presentations, panel discussions or posters given at the symposium. Full papers will be emphasized in the proceedings. The editor will set a deadline for submission of manuscripts.

Members of the host province, territory or state shall distribute copies of the proceedings to members and other purchasers. In addition, funds will be solicited for distributing a copy to each major wildlife library within the Council's states, provinces and territories.

IV Resolutions on issues involving conservation and management of wild sheep and goats will be received by the chairperson of the Executive Committee before the biennial meeting. The Executive Committee will review all resolutions, and present them with recommendations at the business meeting. Resolutions will be adopted by a plurality vote. The Executive Committee may also adopt resolutions on behalf of the Council between biennial meetings.

V Changes in these guidelines may be accomplished by plurality vote at the biennial meeting.