NORTHERN WILD SHEEP AND GOAT COUNCIL

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Edited by W.M. Samuel

Northern Wild Sheep and Goat Council

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ACKNOWLEDGEMENTS

If our biennial symposium in Banff, Alberta and the resulting Proceedings publication are deemed successful, it is only because a lot of people and agencies worked very hard. Special thanks go to Bill Wishart, organizer of the conference, and Jon Jorgenson, certainly the hardest working member of the Planning and Program Committee. The aforementioned committee met long and often. Committee members were: Bill Brown (Parks Canada), Bill Hall, Jon Jorgenson, Kirby Smith, Bob Stevenson, and Bill Wishart (Alberta Fish and Wildlife Division), Detlef Onderka (Alberta Agriculture), Brian Horejsi, John Stelfox, and Bill Samuel (University of Alberta).

The conference was assisted financially by a number of public groups and private companies with a genuine interest in the conservation of mountain sheep and goats. Contributions were used primarily in the publishing of the 1988 Symposium. It was also possible to republish all back issues of the Symposium for distribution to university libraries and sale. We are extremely grateful to the following organizations for financial assistance:

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Special thanks are extended to Charles Lacy, Rick Kunnelius, and John H. Batten for providing awards for presentation, a fund-raising raffle, and a special gift for Bill Wishart on his retirement. The continued support of Jonas Brothers Taxidermy in providing a bighorn statue award for the best paper presentation is especially appreciated. Numerous people ensured the smooth running of the conference through help with registration, audio-visual equipment, coffee, doughnuts, and attending to all the details inherent to such meetings. Thanks are extended to C. Elverum, M. Gibeau, Horejsi, D. Hunter, C. Pacas, B. Fougere-Tower, M. Westbrook, and especially to Laura-Lyn Grooms of the Alberta Fish and Wildlife Division and Terry Skjonsberg of Parks Canada.

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IN MEMORIAM
ORVAL GEORGE PALL
1951-1986

Orval Pall, regional wildlife technician with the Alberta Fish and Wildlife Division in Calgary, died instantly in a plane crash on June 6, 1986 while radio-tracking bighorn sheep from the Mt. Allan herd. A native Albertan, Orval graduated with a B.Sc. from the University of Alberta in 1979 and worked for the Fish and Wildlife Division for 14 years. His special interest was the mountain lion, but he worked with many species including squirrel, elk, bear, birds of prey, and bighorn.

Orval Pall was a dedicated wildlife biologist with a keen and boundless love for knowledge of wilderness. In reverence, love, and fellowship, we dedicate these proceedings in memory of him, his enthusiasm, his friendship, and his ethic.

BILL WISHART RETIRES

Attendees at the Biennial Symposium gratefully acknowledged one of the long time leaders of the Sheep and Goat Council, W. D. Wishart, who had retired recently from the Alberta Fish and Wildilfe Division. Colleagues, young and old, benefited from Bill's expertise; no one has worked harder for the welfare of the beloved bighorn than Bill. Since retirement, his impact upon golf has not been nearly as productive! Bill is currently an Adjunct Professor, Department of Zoology, University of Alberta.

BEST PAPER AWARDS

Jon T. Jorgenson (left), Alberta Fish and Wildlife Division, received the Jonas Bighorn Trophy for the outstanding presentation at the conference. Executive Chairman Wayne Heimer made the presentation.

presented one of his beautiful drawings to Scott.

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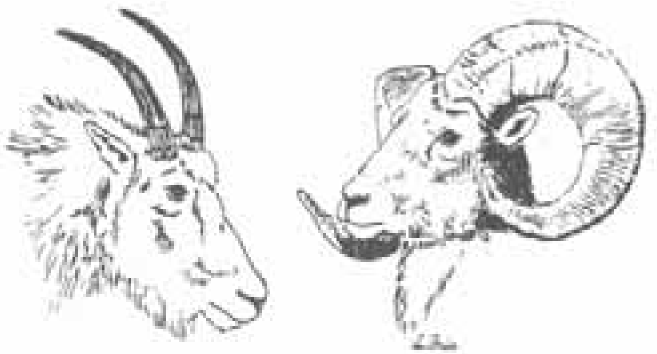

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STATUS OF BIGHORN SHEEP OF BANFF NATIONAL PARK

TERRY SKJONSBERG, Park Warden, P.O. Box 900, Banff, AB TOL OCO

Abstract: Helicopter censuses from 1984 to 1987 during October and March for Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) in Banff National Park resulted in a summer estimate of 2200 and a winter estimate of 1930 bighorns for 1986-87. Several factors (modest lamb production, low lamb mortality, stable herd composition, recent mild winters and no major sources of mortality) account for a very slow annual increase in the population. Between 20 and 30% of the summer park herds migrated eastward to use Alberta winter ranges. Three major eastern slope watersheds, Bow, Cascade - Panther - Dormer, Red Deer - Clearwater, were used by park bighorns.

This study was initiated to gather basic inventory information to assist in management of bighorn sheep by Banff National Park (BNP) and the province of Alberta. The time frame of the study was from May 1984 to May 1987. The study area was primarily the eastern slopes of BNP. In addition, there was some surveys of provincial lands along the entire length of the east park boundary and the western half of BNP. The main study objectives were to: estimate summer and winter populations, identify migration routes, determine the percentage of the population that migrated outside the park, identify important park and provincial habitats, determine the percentage of the population that is harvested through hunting and estimate other mortality sources.

METHODS

A Bell 206 jet ranger helicopter with rear bubble windows was used for aerial census during October and March of each year. Flight lines were established so that all known and potential ranges were censused as completely as possible. Aerial surveys were flown in accordance with a survey methodology outlined in the Wildlife Monitoring Plan (Jacobson and Kunelius 1983: Appendix 1). Maximum flight speed was 50 mph (80 km/hr) and herds were approached from below so that animals ran uphill. Yearlings could not be clearly identified and were counted as adult females.

Through repetitive surveys, trained observers, extensive knowledge of the area from 40 years of warden patrols, several biological studies, and the fact that bighorn sheep inhabit open alpine terrain the helicopter census work was judged to be 85% effective in counting the actual animals present. This assessment is close to the opinion of Stelfox and McGillis (1977) of a 75% observation rate. Thus the park population estimates were raised by 15%. October flights counted bighorn sheep before they left the park, while the March survey counted animals on winter ranges.

Twenty-four areas within BNP, 14 of which had a provincial land component had ground surveys. These land units, seasonal-year round range or travel corridors, varied in size due to terrain features but overall averaged 8 square miles. A full, one day ground inspection occurred once a month from June to November. The interval between surveys was 3 to 5 weeks. The park warden assigned to survey the area observed and reported on sheep numbers, movements, habitat uses, predators and related influences.

Additional population data was obtained from: incidental wildlife observations of park wardens, Alberta Fish and Wildlife survey and hunting harvest statistics, personal communication with field and academic wildlife experts.

RESULTS

By using a combination of helicopter and ground counts to census BNP in 1986-87 the minimum summer and winter bighorn populations were 1906 and 1682, respectively. These numbers were maximum counts, with no chance of duplication within the count. Based on an 85% observation rate, the estimated populations for BNP were 2200 and 1930 animals.

The 3 year trend for the bighorn sheep population was a slow increase, under 5% annually. Summer classified ground counts for the 1984-86 period resulted in an average production rate of 25 lambs per 100 females. Based on helicopter surveys, good overwinter survival of lambs was evident as there was only a 25% reduction from fall to spring. Herd composition along the eastern slopes average 44% male, 47% female and 9% lambs. A ratio of 94 rams/100 ewes was similar to the ratio of 90/100 reported by Geist (1971) in BNP.

A population reduction of 12% from October to March based on helicopter surveys in the park does not accurately reflect population changes due to migration. Bighorns periodically moved back and forth across the eastern park boundary in spring and fall. In April and May they used low elevation provincial ranges extensively (Morgantini 1988). During the fall hunting season, the park appeared to be used as a sanctuary. At the end of August when the season opened, there was a westward movement into the park. After the end of October when the season closed, there was an eastward movement across the park boundary. The majority of the late season migration was composed of rams that wandered extensively during the breeding season. They filtered through numerous mountain passes along the eastern park boundary to access ewe bands.

DISCUSSION

Overall, the trend points toward a gradual population increase. Winter range appears to be a critical limiting factor that should become manifest during a severe winter in the future. The estimate of the migratory component of the park population was doubled above seasonal helicopter count differences. Marked and radio-collared bighorns plus field knowledge and observations indicated that more than 12% of the park population used Alberta bighorn sheep ranges.

Alberta Fish and Wildlife statistics show that approximately 65 trophy rams (4/5 curl) are harvested every year near Banff's eastern park boundary. Between the migratory park rams and provincial resident rams, this is roughly 10% of the ram population for the region. An additional 1% of the ram population or 10% of the legal take is estimated to be lost through wounding/crippling by hunters (Eldon Bruns, Alberta Fish and Wildlife, pers. comm.). Non-trophy sheep (male lambs or any female) that potentially use BNP are harvested at an approximate rate of 22 animals per year. Native harvest within the same region averages at least 10 bighorn sheep per year.

Bighorn sheep populations generally experience an annual mortality rate of less than 10% from natural predators, primarily cougar, coyote and wolf (Stelfox 1974). Other natural mortality is extremely variable but may average 10% annually over the long term. Built into this long term estimate is the fact that a die-off of about 75% of the population has occurred every 25-40 years since the 1800's in the mountain parks of Alberta (Stelfox 1974).

Poaching activity in BNP has rarely been observed but it is thought that 2 to 5 large trophy rams are taken every year. An average of 11 bighorn sheep per year are lost to highway mortality.

The percentage of the ram population harvest was based on several estimates; i.e., the estimated park ram population and the number that migrate into the province, the estimated resident provincial ram population and the hunter information given during mandatory registration of legal rams. Heavy hunting pressure exists along the eastern park boundary, but the harvest is not excessive. Other mortality sources (non-trophy and native harvest, predation, winter starvation and die-offs) were based on local experience and a number of field studies (Geist 1971, Carbyn 1973, Stelfox 1974, Schmidt and Gunson 1985).

Canadian Parks Service, formally called Parks Canada, is concerned about a number of issues, that affect bighorn sheep as well as other wildlife. Some subjects which require future consideration are: assessment of impacts of development within important wildlife habitats and the enactment of appropriate mitigative measures; the problems of bighorn sheep habituation to national park visitors; protection of our large trophy animals from poaching; unobstrusive and alternative methods for capture, handling, marking and studying wild animals in their natural environment; a set of standards for monitoring and collecting data when a major bighorn sheep die-off occurs; co-operative studies that include sharing manpower, equipment, expertise and funding to efficiently produce high quality information on animal populations; development of an Eastern Slopes Management Plan so that the federal and provincial governments can jointly manage migratory wildlife.

LITERATURE CITED

Carbyn, L. N. 1973. Wolf predation and behavioural interactions with elk and other ungulates in an area of high prey diversity. Ph.D. Thesis, University of Toronto. 233 pp.

Geist, V. 1971. Mountain Sheep: A Study of Behaviour and Evaluation. University of Chicago Press. 384 pp.

Jacobson, P. and R. Kunelius. 1983. Wildlife monitoring plan. Banff National Park. 52 pp.

Morgantini, L. E. 1988. Bighorn sheep movements and distribution along the eastern boundary of Banff National Park. (Two year study used 15 radio-collared sheep to help determine effects on the local sheep population by development of an oil field). 125 pp (In press).

Schmidt, K. P. and J. R. Gunson. 1985. Evaluation of wolf-ungulate predation near Nordegg, Alberta: Second year progress report 1984-85. Alberta Fish and Wildlife, Edmonton. 53 pp.

Stelfox, J. G. 1974. Range ecology of Rocky Mountain bighorn sheep in Canadian national parks. Can. Wildl. Serv. Rpt. to Parks Can., Calgary. 235 pp.

Stelfox, J. G. and J. R. McGillis, 1977. Ungulate surveys manual for prairie and western Canadian national parks. Can. Wildl. Serv. Rpt. to Parks Can., Calgary. 87 pp.

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STATUS AND DISTRIBUTION OF ROCKY MOUNTAIN BIGHORN SHEEP IN UTAH

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Abstract: Historically, Utah supported Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) on its northern mountain chains. From the late 1800's through to the 1960's a steady decline in bighorn reduced the once numerous herds to fewer than 100 animals. Beginning in 1966 and continuing up to the present, several transplants and reintroductions have occurred to reverse the trend and restore bighorn to their former ranges. The purpose of this report is to document and review the current status and distribution of Rocky Mountain bighorns in Utah.

During the past two decades several reports have dealt with the status and historical distribution of Rocky Mountain bighorn sheep in Utah (Dalton and Spillett 1971, Stapely 1974, John 1975, Wishart 1978, Thorne et al. 1984). Population estimates have ranged from as low as 200 in 1984 (Thorne et al. 1984) to as high as 350 in 1978 (Wishart 1978). This report documents the current status and distribution of Rocky Mountain bighorn sheep in Utah, specifically reviewing transplant histories. All future references herein to bighorn will refer strictly to the Rocky Mountain subspecies, though both Rocky Mountain and desert bighorn subspecies (*Ovis canadensis nelsoni*) occur in Utah.

Prior to the late 1800's, much of Utah supported large numbers of bighorn, the Rocky Mountain subspecies on the northern mountain chains and desert subspecies in precipitous canyons to the south (Dalton and Spillet 1971). However, by the close of the 1800's bighorn populations had begun a steady decline, which slowed only by the mid-1930's when record lows (possibly as low as 100) were reached (Dalton and Spillett 1971). In 50 years, a few hundred sheep remained where once perhaps thousands had roamed. The usual causes for decline have been cited (domestic livestock diseases, competition, and changes in the habitat quality, human impacts, as well as indiscriminate hunting) though precise reasons are unkown. To date, fewer than 300 Rocky Mountain bighorn sheep are known to exist in the state. Consequently, this subspecies is not legally hunted in Utah.

TRANSPLANT AND REINTRODUCTION HISTORY

Efforts to restore the Rocky Mountain subspecies to former Utah ranges have spanned a 20 year period, including 8 releases within, and bordering, the state (Figure 1). Presently, all Rocky Mountain bighorn

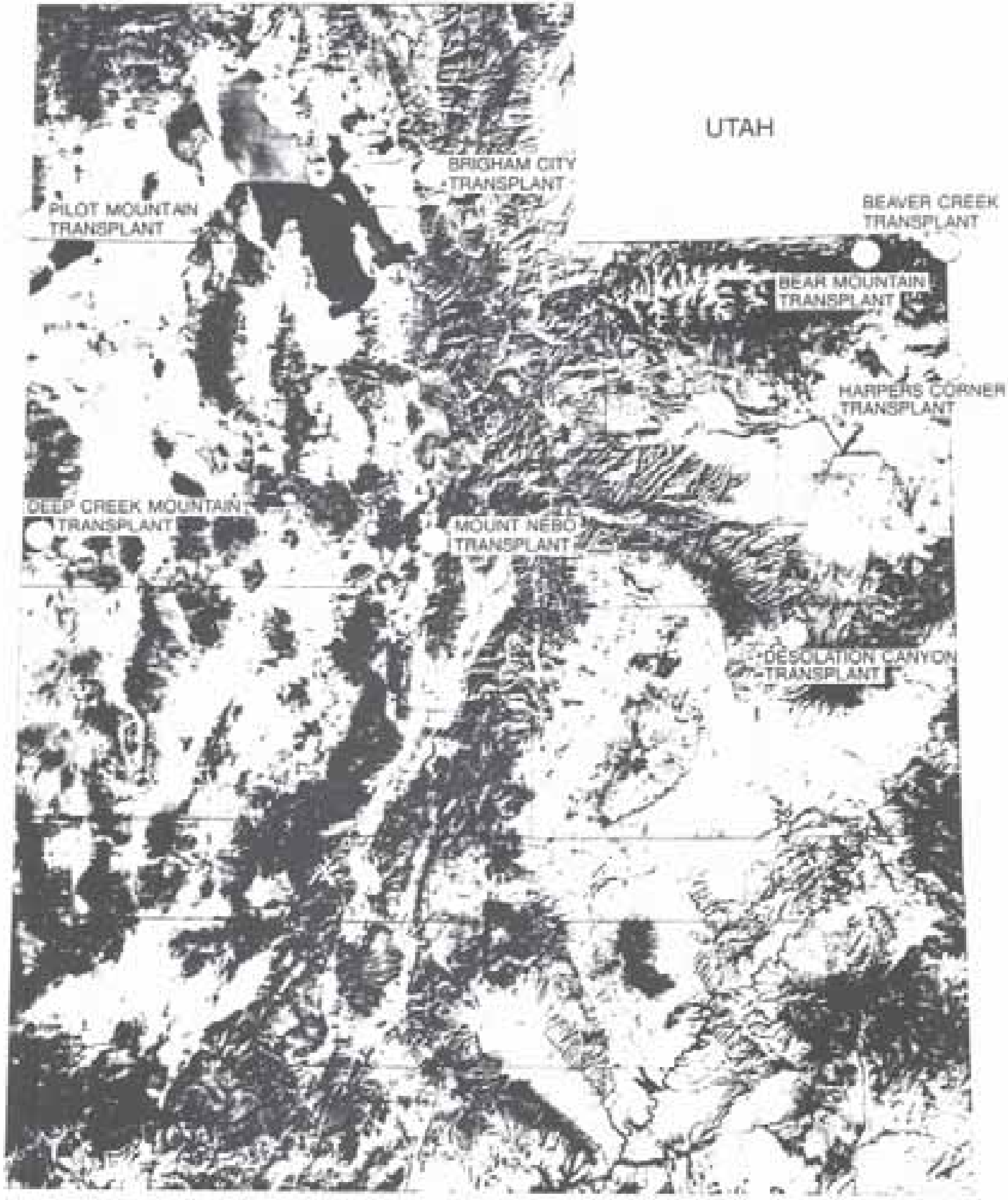

Figure 1. Rocky Mountain bighorn sheep have been reintroduced at eight release sites in Utah.

sheep in the state are the result of these transplant and reintroduction efforts. The following discussion and Table 1 summarize data for each release.

Brigahm City Transplant - 1966

In 1966 the Utah Division of Wildlife Resources (UDWR) began the initial efforts to reestablish Rocky Mountain bighorn sheep to their former Utah ranges. These efforts are recounted in detail by Stapely (1974). A 512 ha paddock was fenced near Brigham City, Utah and over a 4 year period a total of 60 sheep were brought in. Plagued by significant human disturbance, illegal killing, and diseases (pneumonia and bronchitis) the transplant faltered. During the severe winters of 1971 and 1972, hard, drifted snows enabled the sheep to escape the enclosure to the surrounding area. In 1973 and 1974, many sightings verified that the sheep had not strayed far, having spread out into the nearby Willard Peak area. However, by 1975, sheep sighting had decreased significantly. Currently none are believed to survive (J. Pederson, biologist, UDWR, pers. comm.). A summary of data is contained in Table 1.

Desolation Canyon Transplant - 1970

Historically, Rocky Mountain bighorn had inhabited the rugged Desolation Canyon area of eastern Utah, as borne out by abundant Indian petroglyphs and occasional sightings up through the 1930's. Though precipitous, the region was extensively utilized by domestic sheep into the early 1950's (Woody 1973). In the 1960's, the Uintah Band of the Northern Ute Tribe (Fort Duchesne, Utah), became interested in reintroducing the bighorn to their former ranges. Extensive field investigations in search of an appropriate transplant site were conducted. As a result, the Florence Creek area of Desolation Canyon was selected. In March, 1970, 9 sheep obtained form Whiskey Mountain, Wyoming, were released. However, prospects for success appeared poor as the only male was a 10-month-old lamb. Efforts to obtain additional sheep were rewarded when Canada's Waterton National Park provided 12 head in April, 1973. Unlike the first reintroduction, this group included 3 adult rams. Subsequent census attempts failed to locate more than a handful of sheep in the Desolation Canyon area. However, in January, 1985, 45 sheep were sighted near the original release site (K. Corts, biologist, Ute Indian Tribe Fish and Wildlife Department, pers. comm.). In addition to the 45 counted in 1985, a small band of bighorns were observed south of the Reservation lands and were suspected to have dispersed from Desolation Canyon (J. Karpowitz, biologist, UDWR, pers. comm.). Presently, Tribal Fish and Wildlife personnel estimate the herd to be between 75 to 100 and slowly increasing (Table 1). Future plans include a study of habitat selection and home ranges to being in 1988.

Mount Nebo Transplant - 1981

Aware of the multiple factors contributing to the failure of the Brigham City transplant effort, the UDWR laid plans for a second reintroduction in the late 1970's. Again, an enclosure was constructed, but this time in the more remote area of Mount Nebo, 112 km south-southeast of Salt Lake City. However, it was not until 1981 that bighorns

Table 1. *Status of Rocky Mountain bighorn in Utah, 1988*

Transplant	Date Released	Source	Classification	Total	Trend Summary	Limiting Factors	1988 Status
Brigham City	03/08/66 04/07/66 04/29/66 12/09/69 01/13/70	Whiskey Mtn, WY Waterton N.P., CAN Waterton N.P., CAN Banff, N.P., CAN Banff, N.P., CAN	5 rams, 9 ewes 4 rams, 6 ewes 2 rams, 8 ewes 3 rams, 9 ewes 5 rams, 9 ewes	14 10 10 12 15	Slowly increased, declined until all extirpated	Human harassment Pneumonia - bronchitis Poaching	None existing, Transplant failure
Desolation Canyon	03/01/70 04/11/73	Whiskey Mtn, WY Waterton N.P., CAN	1 ram, 8 ewes 3 rams, 9 ewes	09 12	Slowly increasing	Predation Poaching	Highest count = 45 Estimate = 75 - 100
Mount Nebo	01/13/81 01/07/82	Whiskey Mtn, WY Whiskey Mtn, WY	13 rams, 14 ewes 1 ram, 20 ewes	27 21	Increased at first, steadily declined to few remaining in 1988	Inadequate winter range Deer & elk competition	Highest count = 5 ewes Estimate = 10 - 15
Bear Mountain	01/07/83 01/08/84	Whiskey Mtn, WY Whiskey Mtn, WY	6 rams, 13 ewes 3 rams, 14 ewes	19 17	Steadily increasing	Predation Low lamb survival	19L:7Yrlg:31E:13R Highest count = 70
Beaver Creek	02/08/83	Basalt Ranch, CO	7 rams, 14 ewes	21	Slowly increasing	Lion predation suspected	3L:18E:9R Highest count = 30
Deep Creek Mountains	01/18/84	Whiskey Mtn, WY	4 rams, 12 ewes	16	Steadily increasing	Elk competition Domestic sheep pose a threat	8L:15E:4R Estimate = 35
Harper's Corner	04/13/84	Rocky Mtn N.P., CO	3 rams, 16 ewes	19	Slowly increasing	Lion predation Accidental death	Estimate = 30 - 35
Pilot Mountains	02/05/87	Basalt Ranch, CO	4 rams, 16 ewes	20	Slowly increasing	Lion predation Water availability	6L:14E:4R Estimate = 24

Transplant Totals = 242

Total Estimated Utah Population in 1988 = 239 (low)
Total Estimated Utah Population in 1988 = 309 (high)

became available for the release. In a 2 year period, 1981-1982, a total of 48 bighorn were released into the fenced paddock. In 1981, sheep received supplemental feed weekly, anthelminthic drug treatments (fenbendazole) monthly, and appeared to do well. When the first lambs were born, around June 1, all sheep were released from the enclosure into the surrounding area. This was repeated for the second transplant of sheep in 1982. By summer 1983, it was estimated that the herd had expanded to 55 and was on the increase. However, severe winters in 1983 and 1984, coupled with inadequate winter range (limited area and excessive shrub cover) and intense competition with deer and elk, precipitated a steady decline. During these winters, sheep abandoned the mountainous winter range and fed on grass along a nearby interstate highway. Biologists speculate that this displacement was the result of stress and competition. Complicating matters, domestic sheep and cattle shared the ranges with the bighorn, although it is unknown whether the bighorn and domestic livestock intermixed. Numbers declined rapidly until fall of 1987 when 5 ewes were all that remained of the once expanding herd (P. Tervort, biologist, UDWR, pers. comm.). Relevant data are summarized in Table 1.

Bear Mountain Transplant - 1983

Numerous skeletal remains and petroglyphs of bighorn indicate that the rugged canyons of the Green River corridor of northeastern Utah once supported a thriving population of Rocky Mountain bighorn sheep. After a thorough survey of the area, UDWR personnel selected Bear Mountain, a plateau incised on 3 sides by sheer cliffs, for a future bighorn release. In January, 1983, 19 sheep were released followed by a transplant of 17 more in January 1984. By 1985 the herd was estimated to have increased to 54 animals and by 1986 a post-lambing count numbered 67. In 1987, a total of 70 sheep was confirmed, making the Bear Mountain transplant one of the most promising to date. To more effectively manage bighorn, as well as to enhance transplant success in the future, the UDWR initiated an intensive research project of the Bear Mountain herd in May 1986, which continues to present. This is discussed in more detail in Smith et al. (1988). See Table 1 for herd statistics and additional information.

Beaver Creek Transplant - 1983

In keeping with the established goal of increasing bighorn numbers and distribution within the state of Colorado, the Colorado Division of Wildlife (CDOW) selected the Beaver Creek Drainage and adjacent Cold Springs Mountain, on the Colorado-Utah stateline, for a bighorn release in 1982. Numerous records of early travellers as well as abundant bighorn petroglyphs indicated the area had historically supported sheep. In February 1983, 21 sheep captured at CDOW's Basalt Ranch were released. The sheep remained in the vicinity of Beaver Creek until June, 1983. At that time a radio-collared ram could not be found, apparently having dispersed from the area. One month later, this ram, in the company of 2 others, was found to have joined the Beaver Mountain herd, 43 km to the west. The 2 radio-collared ewes released at Beaver Creek did not disperse and facilitated location of the herd over the next few years. Numbers gradually increased when on December 23, 1986 a total of 30 sheep were observed near the release site (J. Ellenberger, biologist, CDOW, pers.

comm.). The herd spends approximately half its time in Utah. Presently, Colorado has no plans to release more sheep into the area, but will monitor lungworm levels and population dynamics.

Deep Creek Mountains Transplant - 1984

Having established that bighorn sheep once lived in the Deep Creek mountains, UDWR officials planned to reintroduce bighorn as soon as a source of sheep were made available. The Deep Creek mountains offered minimal human disturbance, excellent summer and winter ranges, and insignificant competition from deer and elk. However, domestic sheep in the area have been a concern. In January 1984, 16 sheep were obtained from Whiskey Mountain, Wyoming. Several were fitted with radio-collars then released. Nearly 2 years later numbers had risen to 27, and as of fall of 1987 UDWR personnel censused 35 sheep (P. Tervort, biologist, UDWR, pers. comm.). The UDWR presently censuses the population in the fall and immediately following lambing season. Given a source of sheep, additional transplants to the area are anticipated. UDWR biologists are optimistic for the herd's future. See Table 1 for a data summary.

Harpers Corner Transplant - 1984

Presently, 2 populations of Rocky Mountain bighorn sheep live within Dinosaur National Monument of the National Park Service, both the result of reintroductions. Historically, sheep inhabited much of this area, but in the early 1930's a die-off occurred such that by 1944 no bighorn remained. In 1952 the CDOW transplanted 32 bighorn near the mouth of Ladore Canyon in Colorado, just outside the monument. As of September of 1987, 47 sheep were censused in Ladore Canyon, though biologists suspect more in the vicinity.

To supplement the bighorn population, a second reintroduction was made in April, 1984 when 19 head captured in Rocky Mountain National Park, Colorado, were released within monument boundaries at Harpers Corner, Utah. Reproduction was good in 1984, but the no lambs could be found the following year. Biologists surmised that reproduction had failed, in part, as only 3 males had been released, the oldest being a 2 year old. In 1986 and 1987, reproduction improved and currently 30 to 35 sheep are estimated (S. Petersburg, biologist, National Park Service, pers. comm.). The Green River is all that separates the Harper's Corner herd from the Ladore Canyon herd and Park Service biologists do not feel the 2 populations have yet mixed. The herd spends approximately half of its time in Utah, the remainder in the Colorado portion of the monument. See Table 1 for a summary of herd data.

Pilot Mountain Transplant - 1987

Straddling the Utah-Nevada border, the isolated Pilot Mountains appeared to offer a bighorn reintroduction an excellent chance for success. In February 1987, the Nevada Department of Wildlife (NDOW) acquired 20 bighorns from CDOW's Basalt Ranch and released them into the Pilot Range, 1.6 km from the Utah border (Table 1). As the sheep were expected to spend some time on Utah ranges, the UDWR furnished 6 radio collars and periodically conducts aerial surveys of the herd. Subsequent observations indicate the herd spends less than 5% of their time within the state of Utah (J. Williams, biologist, NDOW, pers. comm.). On June 5, 1987, 6 lambs were observed, though higher production was expected in the coming weeks. In September 1987, UDWR estimated the herd at 24 animals (M. Welch, biologist, UDWR, pers. comm.). Wildlife personnel became concerned when the BLM reactivated a former domestic sheep grazing permit within the occupied bighorn range. Currently, interagency management plans are being developed to ensure minimum negative impacts to bighorns. Although the transplant is too recent to speculate on its success, biologists are optimistic. Habitat quality and condition appears to be good to excellent and human disturbance minimal.

FUTURE OF ROCKY MOUNTAIN BIGHORN SHEEP IN UTAH

The Utah Division of Wildlife Resources is vigorously pursuing reestablishment of Rocky Mountain bighorn sheep to all available habitats. As evident elsewhere in mountain sheep ranges, a source of sheep for reintroductions is an obstacle. Nonetheless, UDWR hopes to include bighorns from various capture sites in subsequent releases to insure greater diversity and to prevent problems relative to genetic drift or founders effect. A statewide strategic management plan has been drafted to identify and prioritize reintroduction sites, evaluate and improve habitat quality and to closely monitor and manage reestablished populations.

Close coordination with federal land management agencies is developing to identify and improve sheep habitat. An intensive management research project at the Bear Mountain site was initiated in 1986. Results of this research will be utilized for tuning bighorn management throughout the state.

SUMMARY AND CONCLUSIONS

The past 2 decades in Utah have not only seen the extirpation of all native Rocky Mountain bighorn sheep but also the importation of 242 sheep from sources outside Utah. These sheep have been utilized in 15 releases at 8 locations throughout the state. Now, 22 years after the first reintroduction, the minimum statewide Rocky Mountain bighorn population totals 239 animals, or approximately the same number as has been brought in for reintroductions. Considering the highest estimated number of Rocky Mountain bighorn in Utah, 309, at best the state has seen an increase of 28% in 22 years. Of 8 reintroduced herds in 2 decades, 2 have been complete failures while the other 6 have met with variable success. Of the 6 "Utah" Rocky Mountain bighorn herds in existence, only 3 are completely within state boundaries, totalling at least 150, and at most 205. One of these 3 herds falls within the boundaries of the Ute Indian Tribe Reservation. Currently, the Bear Mountain transplant has the highest verified count, though the Desolation Canyon population may exceed it.

LITERATURE CITED

Dalton, L. B. and J. J. Spillet. 1974. The bighorn sheep in Utah - past and present. Transactions 1st North American Wild Sheep Conf. Fort Collins, CO April 1971. 187 pp.

John, R. T. 1975. Report from Utah. Pp 46-48 in J. B. Trefethen, (Ed.), The wild sheep in North America. The Boone and Crockett Club and Winchester Press, New York. 302 pp.

Smith, T. S., J. T. Flinders and D. W. Olsen. 1988. The Bear Mountain bighorn sheep transplant research project: a progress report. Bienn. Symp. North. Wild Sheep and Goat Counc., 6:(in press).

Stapely, H. 1974. Resume of Utah's bighorn management. Pp. 30-31 in K. Constan and W. Mitchell (Eds.), Proc. Bienn. Symp. North. Wild Sheep Counc., Great Falls, Montana.

Thorne, E. T., W. O. Hickey and S. T. Stewart. 1984. Status of California and Rocky Mountain bighorn sheep in the United States. Pp 56-81 in M. Hoefs, (Ed.), Wild sheep, distribution, abundance, management, and conservation of the sheep of the world and closely related mountain ungulates. Spec. Rpt., North. Wild Sheep and Goat Counc., Yukon Wildl. Br., Whitehorse. 218 pp.

Wishart, W. D. 1978. Bighorn sheep. Pp. 161-171 in J. L. Schmidt and D. L. Gilbert (Eds.), Big game of North America. Stackpole Books. Harrisburg, PA. 494 pp.

Woody, J. B. 1973. Trip report and history of the bighorn sheep transplant project. Uintah and Ouray Fish and Wildlife Dept. internal report. 17 pp.

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and Goat Council 6: 13 - 25

FORAGING BEHAVIORS AMONG DIFFERENT AGE AND SEX CLASSES OF ROCKY MOUNTAIN GOATS

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Abstract: Social and foraging behaviors of Rocky Mountain goats (*Oreamnos americanus*) within nanny bands were studied on the alpine tundra of Mt. Evans, Colorado from 19 July to 10 September 1987. Females and young (1 to 3 years) males were compared to investigate the possibility that differential behaviors during feeding encourage these males to leave nursery bands. Averaged over all group sizes, yearling males and females were similar in feeding, alert and social time. Analyzed by group size, however, yearling males' foraging time decreased with increased group size, while adult females' foraging time increased. Alert time of yearling males was higher in larger groups, while adult females' was lower. Yearling females feeding and alert time was not correlated to group size. Two and three-year-old males were similar to nannies and barren females in feeding and alert time; however, these males spent significantly more time in aggressive behavior than all other classes. Social time was independent of group size for all classes. The increased aggressive time of young males in nanny groups and the adverse effects of larger group sizes specifically on yearling males encourages young males leave the female bands. Further examination of group positioning within these groups may explain the negative effects of increased groups size on yearling males.

The social organization of mountain goats is characterized by the formation of segregated male and female herds. This segregation seems to occur after males are 2 years old. Typically there are separate nursery bands, small bachelor male groups and solitary males. Why should this be the case? There are many examples of species that live in mixed herds (Estes 1974, Jarman 1974, Sinclair 1977).

Although segregation among mountain goats has not been studied in depth, it has been examined in a number of other Northern ungulates. There are four main theories for herd segregation:

(1) Parental-offspring competition.--Geist and Petocz (1977) suggested that bighorn males leave nanny groups to limit competition with their own offspring. However, male goats leave the nanny groups before their first rut. These young males are not very successful in their first ruts (Geist 1964); therefore, they do not begin contributing their own offspring to the nanny groups until at least 2 years after leaving the band. Competition with their own offspring is, therefore, non-existent or minor for the young males that leave the nanny groups.

(2) Differential metabolic requirements of males and females.--In

general males and females have different metabolic needs due to size dimorphism, differential reproductive activities and parental output (Kleiber 1961; Gasaway and Coady 1974). Different metabolic requirements are correlated with differential habitat use (Belovsky 1978). In order to maximize intake, males and females must feed in different habitats. Adult male and female goats have little size dimorphism; therefore, any metabolic differences between them is mainly due to different reproductive activities or parental output. Neither 2-year-old females nor 2-year-old males engage in reproductive activities. Thus, the metabolic costs for each should be similar, but young females stay in the group while males leave. Barren older females also stay with the nanny groups. If differences in metabolic needs are responsible for segregation, 2-year-old females and barren females should also leave.

(3) Nanny-male competition.--Clutton-Brock et al. (1982) theorized that red deer females expel young males to reduce competition for forage. Mountain goat nannies drive males out of female bands in some instances (Reisenhoover and Bailey 1985; Chadwick 1977). However, 2-year-old females are not expelled; although, they also compete for forage.

(4) Male aggression.--It has suggested that nannies force young males from the group because the males are more aggressive and increase the danger to both females and kids. In the Mt. Evans population, Risenhoover and Bailey (1985) found that nannies were the most aggressive. Two-year-old males were no more aggressive than 2-year-old females. Yearlings (male and female) directed 50% of their aggression toward other yearlings, 34.3% toward 2-year-olds and only 13.8% to nannies and kids. While 12.5% of nanny aggression was directed to other nannies. Therefore, young males do not pose a greater threat than other females to nannies and kids due to higher aggression.

The current theories on ungulate herd segregation do not adequately explain sexual segregation in mountain goats. This suggests that there are other factors causing segregation. To investigate interactions influencing the social structure of male and female goats, this study examined the foraging behaviors and group spacing of different classes of mountain goats in order to determine if the classes behave differently within nanny bands. Such differences, if present, will help uncover the benefits and disadvantages that different goats derive from being in a group. Conversely, they will also indicate the advantages or disadvantages to females of males being within nanny groups. The effects of group size on the different goat classes was examined because group size was shown to have a large impact on goat behavior (Risenhoover and Bailey 1985).

I am indebted to Professor James Bailey at the University of Colorado, Fort Collins who was instrumental in the initial phases of the research. He provided technical, logistic, and academic support during the field stage of my research. I would also like to thank Dr's. Carol Boggs and J. Roughgarden from Stanford University whose knowledge and scholarship contributed greatly to the analysis of the results and the quality of the exposition. Finally I would like to thank Ralph and Loraine Reiner at the University of Denver High Altitude Laboratory for

their hospitality and assistance. Without their technical support the field work would have been difficult if not impossible.

STUDY AREA AND METHODS

Mount Evans (4346 m) is in the Colorado Front Range approximately 45 km west of Denver, Colorado. The peaks of Epaulet Mountain and Rosalie Mountain were also in the study area. The vegetation in the study area is open alpine tundra.

Although the herd is hunted, the goats are habituated to people as the alpine areas are accessible via a paved road and there is heavy traffic along the road during the summer. This provided an excellent opportunity to study goat behavior as the goats could be approached quite closely (within 20 m). Foraging behavior of goats within nanny groups has been previously described on Mt. Evans although not analyzed by goat age or sex (Risenhoover and Bailey 1985).

From 25 July 1987 to 26 August 1987, 130 foraging mountain goat nanny groups were videotaped for 5 min periods. Nanny groups were defined as any group containing at least 1 nanny and kid. Filming occurred throughout the day in various weather conditions. Filming locations were mainly open alpine areas, but also in rocky (not cliffs) and wet alpine areas at a distance of 20 to 200 m. Group composition and the class of individual goats were identified in field. Goats were separated into five classes: nannies, barren adult females (no kid), yearling females, yearling males and adult males (2 years or older) using horn characteristics, external genitalia, urination posture and nanny-kid association. Individual goats were filmed in different groups on different days.

From the tapes, the time spent in feeding, alert, social behavior (Table 1) and the foraging steps per minute during the observation period (4 to 5 min) were recorded. The class of and distance to the nearest-neighbor at 1 min intervals were also recorded. Data were taken for 2 to 10 goats per group and if possible, at least 2 goats in each class were observed. For each group, the data for each class were then averaged. Data were not recorded for kids although they were counted in the total group size.

Table 1. Classification of mountain goat behavior (adapted from Risenhoover and Bailey 1985).

Type	Description
Feeding	Ingesting forage; looking at forage; moving toward forage. Head oriented toward the ground.
Alter	Surveying surroundings. Head upright. Often in alarm posture (head fully upright and rigid body).
Social	Interactions among goats; play; aggression; display; looking at other goats; moving toward other goats.

The feeding, alert and social behaviors were recorded as the percent of the observation period spent in each behavior. Overall differences between the 5 classes were determined with planned comparisons (from ANOVA analysis) and Scheffe's comparisons (unplanned) after the percentages were normalized with an arcsin transformation. A non-parametric test (Friedman-Rafsby test) was also performed on the foraging behaviors data. For each class, these behaviors were then tested for correlation with group size by calculating the correlation coefficient (Sokol and Rohlf 1981).

RESULTS

Foraging and Alertness

Foraging behaviors were recorded for 60 nanny groups ranging in size from 2 to 39 goats. Averaging all groups together, adults (nannies, barren females and adult males) were significantly more alert than yearlings (male and female). Nannies were more alert than barren females but not more than adult males. Yearling females and males were not significantly different. Adult males were significantly more aggressive than all other classes (Table 2, Figs. 1-3).

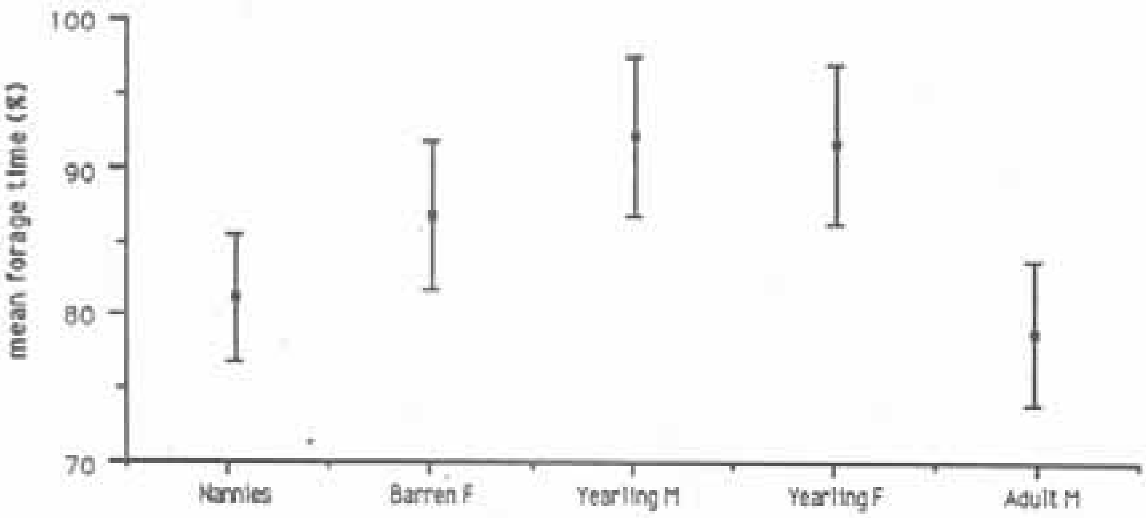

Figure 1. Mean percent of time spent in foraging during 130 five min observations on Mt. Evans, Colorado, late July to early September 1987. Data was averaged over all group sizes. Figure includes the standard error of the mean.

When foraging data were correlated to group size, nannies' foraging time increased with increasing group size up to approximately 15 goats/group after which it levelled near 95% foraging time. Nannies in 2 large groups (32 and 38 animals) foraged less (Fig. 4A). Similarly barren females increased feeding time in larger groups, however, without the

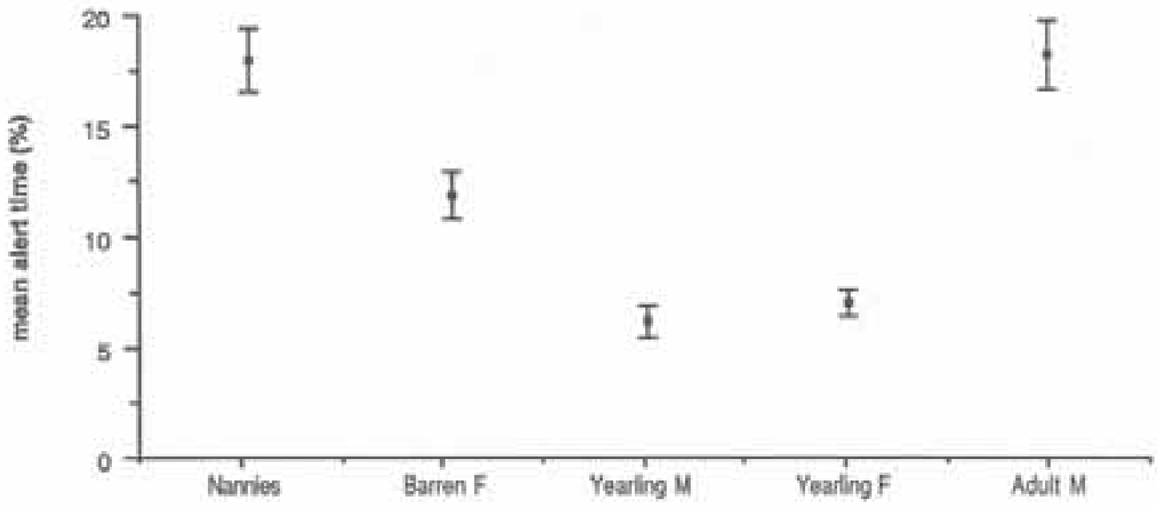

Figure 2. Mean percentage of time spent in alertness during 130 five-min observations on Mt. Evans, Colorado, late July to early September 1987. Data was averaged over all group sizes. Figure includes the standard error of the mean.

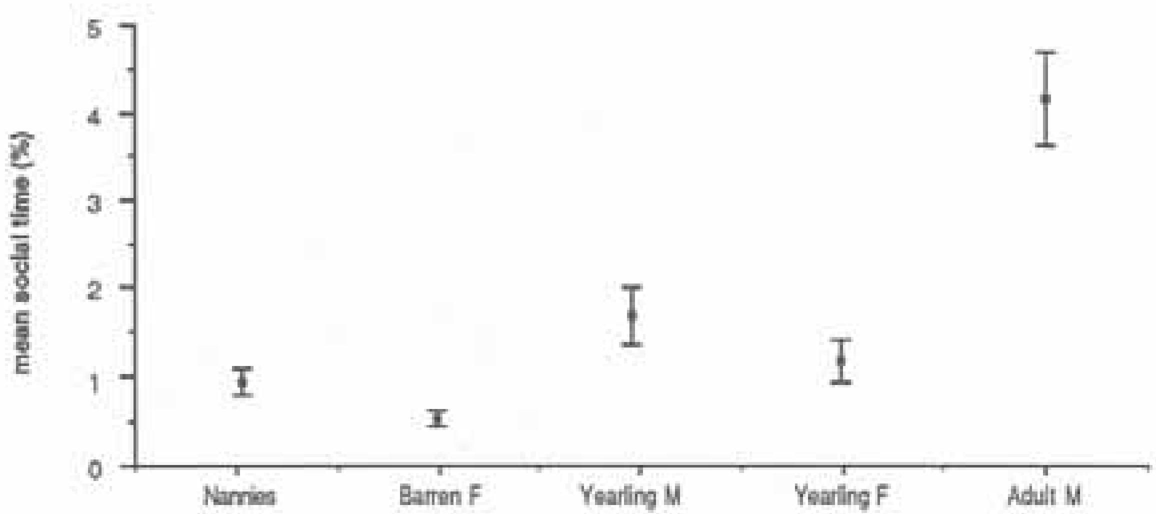

Figure 3. Mean percentage of time spent in social behavior during 130 five-min observations on Mt. Evans, Colorado, late July to early September 1987. Data averaged over all group sizes. Figure includes the standard error of the mean.

Table 2. Mean proportion of time spent in foraging, alert and social behavior for each goat class. In order to normalize the data, the proportions were arcsin transformed (x = arcsin(proportion)); thus, the proportions do not sum to 1.0. Significance is based on results from planned comparisons and Scheffe's comparisons (in parentheses) Scheffe's test is a conservative test to account for making ma:/comparisons.

		Mean proportion of observed time		
Class	n	Foraging	Alert	Social
Nannies	75	.999	.185	.007
Barren females	47	1.112	.121	.006
Yearling females	44	1.240	.062	.017
Yearling males	65	1.200	.069	.012
Adult males	13	.963	.186	.042

	Significance ($p <$)		
Comparisons:			
Adult vs yearlings	ns (ns)	.005(.01)	.75 (ns)
Nannies vs barrens	ns (ns)	.05 (ns)	.75 (ns)
Yearling males vs females	ns (ns)	.75 (ns)	.75 (ns)
Adults females vs males	ns (ns)	.75 (ns)	.001(.10)
Adults w/o kids vs nannies	ns (ns)	.10 (ns)	.50 (ns)
Nannies vs yearlings	ns (ns)	.005(.01)	.50 (ns)
Adult males vs yearlings	ns (ns)	.025(.10)	.50 (ns)
Adult males vs barrens	ns (ns)	.25 (ns)	.001(.10)

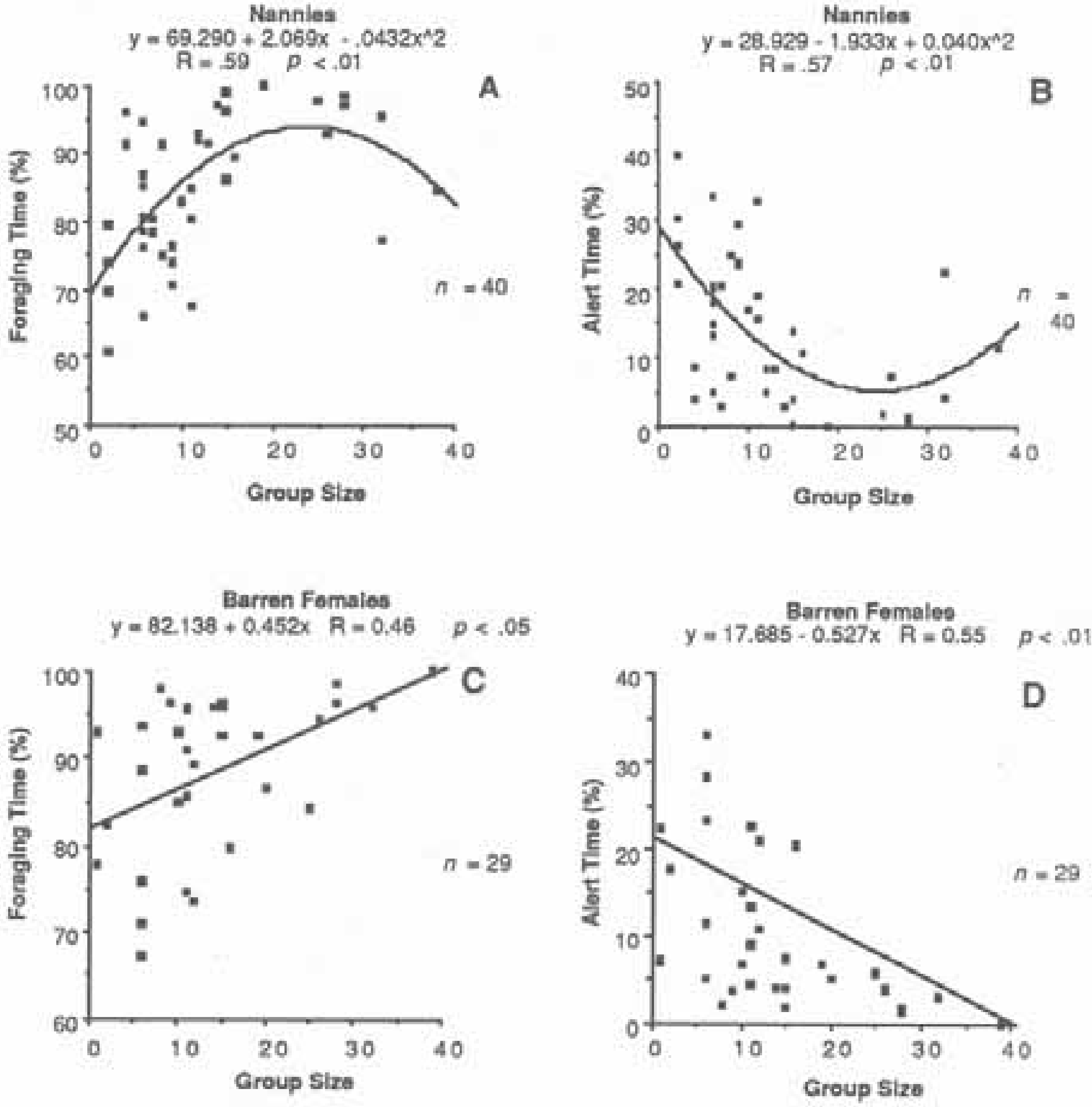

Figure 4. Foraging and alert behavior of nanny and barren female mountain goats in relation to group size on Mount Evans, Colorado, late July to early September 1987. Foraging and alert behavior expressed as the average percent of time spent in each behavior during the observation period. Each point is the average of all the goats of the specified class in that group. On graph A, a linear regression to the points has $R = .46$ ($p < .05$).

decline in foraging time in larger groups (Fig. 4B). The increase in feeding time in larger groups corresponded to the decrease in alert time with increased group size for nannies and barren females (Figs. 4C and D).

Although yearling male and female foraging behaviors were not different when averaged over all group sizes, they did show differences when correlated to group size. Foraging times of yearling males declined with increased group size (Fig. 5C). This decline corresponded to higher alertness in larger groups (Fig. 5D). On the otherhand, yearling females did not significantly increase in foraging within larger groups. Alert time of yearling females was lower in large groups compared to smaller groups, but this was not significant (Figs. 5A and B).

Social Behavior

The percent of time spent in social behavior was not correlated with group size for any class; however, because goats were only studied for 5 min periods, little social behavior was recorded for individual goats.

Nearest-Neighbors

Adult males stayed the farthest from other goats in nanny bands, averaging 3.5 m from their nearest-neighbor. Other classes' average nearest-neighbor distances were 1.9 to 2.9 m. The distance to their nearest-neighbor did not significantly differ ($p > .05$) between nannies, barren females and yearlings. Differences between goat classes, however, were seen in the class of the nearest neighbor. The nearest-neighbor of adult males was most often a nanny. Nannies and barren females were equally likely to be near each class. Yearling males and females were mostly likely found near another yearling (Fig. 6, Table 3). Nearest-neighbor distances were not correlated to group size for any class.

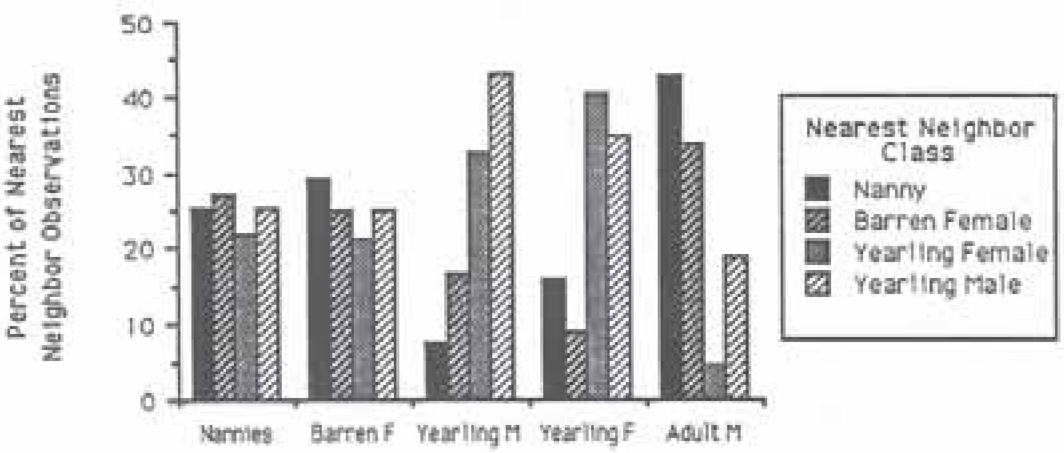

Figure 6. Standardized frequencies of the nearest-neighbor classes for nanny, barren female, yearling feamle, yearling male and adult male mountain goats, Mount Evans, CO, Summer 1987. The observed frequency of a certain class being the nearest-neighbor was standardized by the observed proportions of each class in the study groups (35.6% nannies, 21.5% barren females, 24.8% yearling females, 14.1% yearling males, 4% adult males). Not enough data was available to include adult males.

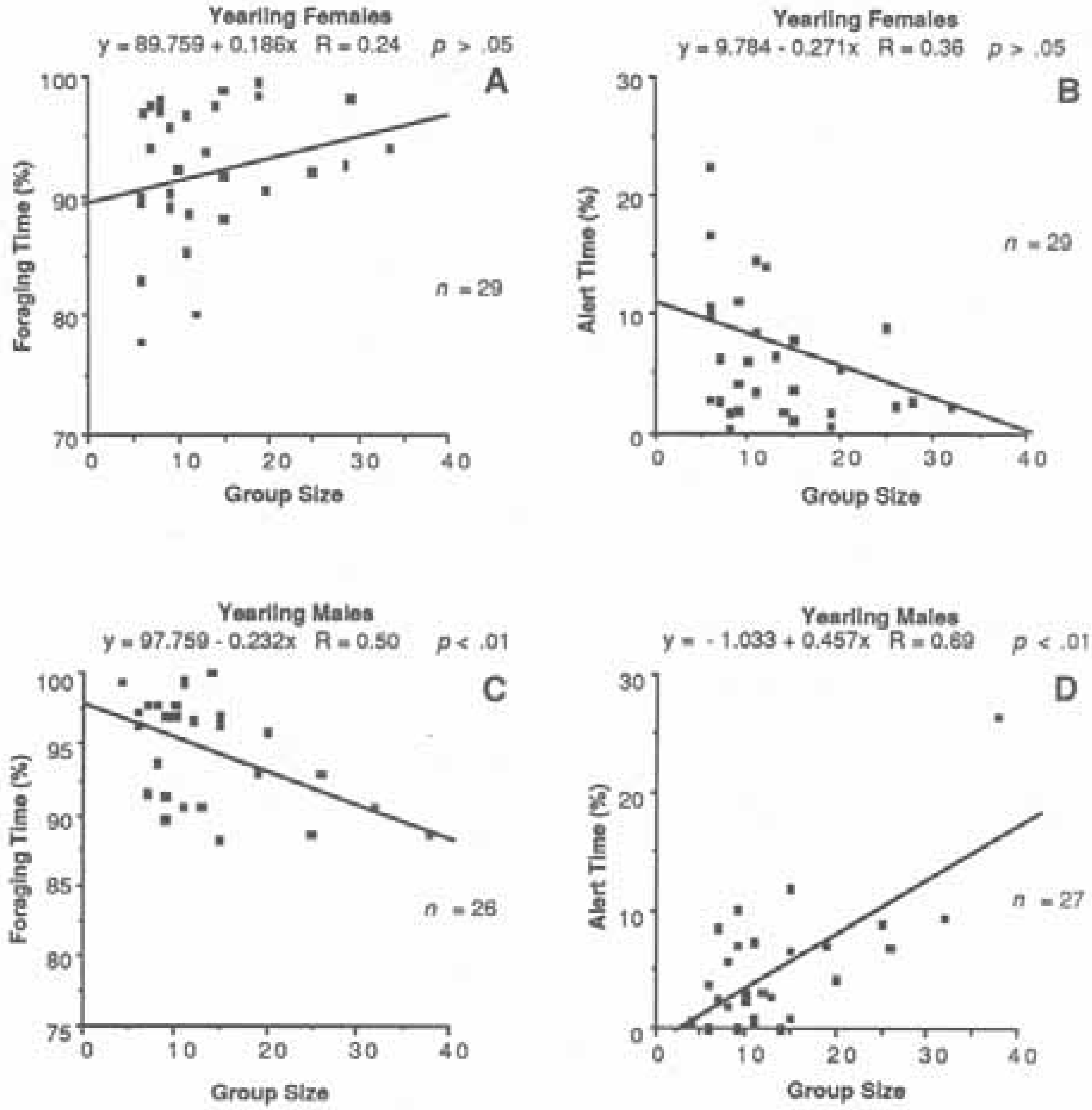

Figure 5. Foraging and alert behavior of yearling male and female mountain goats in relation to group size on Mount Evans, Colorado, late July to early September 1987. Foraging and alert behavior expressed as the average percent of time spent in each behavior during the observation period. Each point is the average of all the goats of the specified class in that group. If the high alertness data point on graph D (group size 38) is removed, R = .45. This is significant at the .05 level.

Table 3. Class composition of the nearest neighbor data for nannies, barren females, yearling females, yearling males and adult males, Mt Evans, CO, Summer 1987. For example, nannies' nearest neighbors were other nannies in 25.4% of the observations, were barren females in 30.0%, etc. Data were standardized by the frequency of each class in the observations. For a given class, I compared the frequency that one class was the nearest neighbor as opposed to another class. For instance, for yearling males, the frequency of their nearest neighbor being a yearling and it being another class are significantly different ($p < .01$).

	Nearest neighbor observations by class (% of total)				Comparisions of nearest neighbor classes (significance level α)					
Class	nanny	barren female	yearling female	yearling male	nannies vs others	barren females vs others	yearling females vs others	yearling males vs others	yearlings vs adults	yearling males vs females
Nannies	25.4	30.0	22.1	25.5	.75	.75	.75	.75	.75	---
Barren F	28.8	24.9	21.4	24.8	.75	.75	.75	.75	.75	---
Yearling F	7.7	16.4	32.8	43.0	.001	.05	.05	.001	.001	---
Yearling M	15.9	8.8	40.4	34.7	.2	.001	.001	.1	.001	.75
Adult M	42.8	33.7	4.6	18.9	.5	.75	.1	.75	.05	.75

DISCUSSION

Foraging Behaviors

This study found that larger group size had a positive or at least neutral effect on the foraging time of females but had a negative effect on the foraging time of yearling males. This was due to increased alert time for yearling males and decreased alertness for females in large groups.

This adverse effect of large group size on yearling males may lead to segregation by encouraging young males to leave large nanny bands. Young males cannot avoid large nanny bands if they stay with the same individual females. Fidelity to one set of goats was seen in females in this population and in the Gladstone Ridge population of the Sawatch range. Throughout the course of a day or number of days, a group of females on Mt. Evans will combine with other groups to form larger foraging bands and that new group may later combine with another to form an even larger band. Unless male goats leave goat groups whenever they become too large, they must forage in different size groups at different times. The disadvantage of foraging within large groups encourages yearling males to either shift from small group to small group or to leave the nanny groups altogether. In this situation the young males must spend a large segment of their time outside of female bands after they have left a band that became too large and before they have found another smaller group.

Why is there a differential effect of group size on male and female behavior? The advantages of large groups for predator defense and detection are well known for many animals (Bertram 1978) including ungulates (Berger 1978 and 1983, Halls 1984, Underwood 1976). Increased security allows decreased individual alert time and increased foraging time. Female goats with kids are more vulnerable and at the same time have higher forage intake and quality needs while lactating. Foraging in large groups increases their security, allowing them to feed in open areas with more abundant forage. Competition increases and social interactions also increase, however, resulting in a higher likelihood of injury. Goats are dangerously equipped with sharp horns and violent contact causes significant damage (Geist 1964).

For nannies, the risk of injury is evidently outweighed by the need for increased foraging opportunities. Barren females do not have higher metabolic needs due to lactating; therefore, increased foraging opportunities are not as important while the risk of injury is still increased. This risk, however, is diminished for both nannies and barren females due to established dominance hierarchies that serve to reduce the chances for violent contact.

While increase foraging and decreased alert time was observed for nannies and barren females, yearling females showed only a slight (not significant) increase in foraging time due to lowered alert time. Yearling females have lower metabolic needs than adult females due to their smaller size (Kleiber 1961). This may account for the lack of a greater increase in foraging in the larger group sizes.

A strong foraging time to group size relationship is not expected for yearling males because like yearling females they have lower metabolic requirements but this could not cause a negative relationship. There are three factors that could have caused the increase in alertness:

1) Yearling males feed on the periphery of nanny bands. In the open areas where large groups feed, the periphery is the most vulnerable and higher alertness is expected for these periphery goats. The relative position of yearling males in foraging bands can easily be examined. In this study, the few adult males observed foraged on the periphery groups, generally far from their nearest-neighbor. Such positioning was not clear for yearling males and could not be quantitatively studied because the position of goats relative to the group was not directly examined.

2) The distance to escape terrain not the group size causes the increase in alert time. The relationship, if any, between distance to escape terrain and alertness can be easily tested by measuring escape distance for different foraging bands.

3) The alert behavior of yearling males in large groups is not actually "alert" behavior, but relations to other goats that are indistinguishable from scanning the area for danger. While observing goat bands at close range, I found goats very vocal and continually making small body and head motions to which other goats respond. These vocal responses and small motions cannot be detected except a few feet from a group. The increased alertness of yearling males may actually be such responses. In this case, the alert behavior is not scanning the area for danger from without but scanning the group for danger from other goats.

This is only one look at sexual segregation in mountain goats. Obviously other factors such as male aggression and forage preferences most likely play a role in segregation. It does indicate, however, that differences in the foraging behaviors of yearling males and females encourage segregation.

LITERATURE CITED

Berger, J. 1978. Group size, foraging, and antipredator ploys: an analysis of bighorn sheep decisions. Behav. Ecol. Sociobiol. 4:91-99.

________. 1983. Pronghorn foraging economy and predator avoidance in a desert ecosystem: implications for the conservation of large mammalian herbivores. Biol. Cons. 25:193-208.

Bertram, B. C. R. 1978. Living in groups: predators and prey. Pp. 64-96 in J. R. Kerbs and N. B. Davies (Eds.), Behavioral ecology: an ecological approach, Blackwell Scientific Publications Ltd., Oxford.

Chadwick, D. H. 1977. The influence of mountain goat social relationships on population size and distribution. Pp. 74-91 in W. M. Samuel and W. G. Macgregor (Eds.), Proc. First Internat. Mountain Goat Symp., Kalispell, MT. 243 pp.

Clutton-Brock, T. H., F. E. Guinness, and S. D. Albon. 1982. Red deer: behavior and ecology of two sexes. University of Chicago Press, Chicago.

Estes, R. D. 1974. Social organization of the African Bovidae. Pp. 166-205 in V. Geist and F. Walther (Eds.), The behavior of ungulates and its relation to management. Morges IUCN New Ser. Publ. No. 24.

Gasaway, W. C. and J. W. Coady. 1974. Review of energy requirements and rumen fermentation in moose and other ruminants. Naturaliste can. 101:227-262.

Geist, V. 1964. On the rutting behavior of the mountain goat. J. Mammal. 45:551-568.

Geist, V., and R. G. Petocz. 1977. Bighorn sheep in winter: do rams maximize their reproductive fitness by spatial and habitat segregation from ewes? Can. J. Zool. 55:1802-1810.

Halls, L. K. 1984. White-tailed deer. Stackpole Books, Harrisubrg, Pa.

Jarman, P. J. 1974. The social organization of antelope in relation to their ecology. Behavior. 48:215-267.

Kleiber, M. 1961. The fire of life. Wiley, New York.

Risenhoover, K. L., and J. A. Bailey. 1985. Relationships between group size, feeding time, and antagonistic behavior of mountain goats. Can. J. Zool. 63:2501-2506.

Sinclair, A. R. C. 1977. The African Buffalo. Univ. Chicago Press, Chicago. Pp 53-65, 122-125.

Sokol, R. R., and F. J. Rohlf. 1981. Biometry. W. H. Freeman and Co., San Francisco.

Underwood, R. 1976. Vigilance behavior in grazing African antelopes. Behavior, 79:81-107.

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and Goat Counc. 6: 26 - 38

DO PERSISTING MATRILINEAL GROUPS PARTITION RESOURCES ON MOUNTAIN GOAT WINTER RANGES?

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Abstract: Agonistic behavior within foraging groups of mountain goats (*Oreamnos americanus*) was studied both at and away from an artificial food bait for 2 winters in south-central Colorado. During this study, 3 frequently observed marked nannies belonged to separate, relatively stable groups of mostly female goats. Of these 3 nannies, the oldest and most dominant was most often seen at the bait, had the smallest home range, and was most likely to be near the bait site. Results suggested that social groups persisted within this population. We speculate that: the groups observed were matrilineal; there may have been resource partitioning among groups, and; groups led by older more dominant nannies achieved priority access to preferred resources.

Relations between social behavior and density-dependent population regulation in mountain goats are not understood. It is likely that social behavior influences population regulation in a K-selected species, such as mountain goats, by distributing goats in relation to the physical habitat and available food resources (Kuck 1977). On cliff winter ranges areas with optimum snow-shedding characteristics (Adams and Bailey 1980) are distributed patchily, as are food resources, which occur on benches or as scattered trees and shrubs. These patchy resources are used by small, stable groups of goats (Brandborg 1955, Smith 1976, Chadwick 1977), in which the rate of agonistic behavior among goats is high (Chadwick 1977, Dane 1977). Results of several studies cited below, indicate there are matrilineal relationships within these groups.

The social system of mountain goats has been described as a dominance hierarchy based upon defense of a mobile personal space (Chadwick 1977), and adult females appear dominant in winter (Chadwick 1977, Kuck 1977, Smith 1977). Female-subadult groups are common during summer and winter, and adult males use ranges separate from female-subadult groups (Geist 1964, 1974; Chadwick 1977; Kuck 1977; Stevens 1983; Risenhoover and Bailey 1985).

Mountain goat kids usually remain with their mothers for 10-11 months (Brandborg 1955, DeBock 1970, Foster and Rahs 1982, Chadwick 1983),

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and longer associations have been reported when the female does not produce a new kid (Hutchins and Hansen 1980). A prolonged nanny-juvenile bond could confer survival advantages to the offspring, and possibly increased reproductive fitness to the female (Trivers 1974, Hutchins and Hansen 1980, Clutton-Brock et al. 1982).

Density dependence has been observed in our study herd. Six mountain goats were introduced onto Sheep Mountain, in the Sawatch Range of Colorado, in 1950 (Rutherford 1972). Reproductive success (measured as kid:older animal ratios) of these goats declined by 47%, beginning in 1976, after the herd had doubled in size during 1970-1975 (Adams and Bailey 1982). We hypothesized that social mechanisms influenced this density-correlated decline in reproductive success.

We studied agonistic behavior of foraging mountain goats during 2 winters to explore social mechanisms of population regulation (Masteller 1987, Masteller and Bailey In Press). During this study, it appeared that goats wintering on the study area were members of distinct social groups. While the data were not conclusive, we are reporting our findings and proposing further research.

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STUDY AREA AND METHODS

Sheep Mountain is approximately 14 km west of Buena Vista, in south-central Colordao. Vegetation includes conifer forests, old burns with quaking aspen (Populus tremuloides), and mountain shrubs. Cliffs and outcrops dominate most south and southeast exposures. The geology, flora and vertebrate fauna have been described by Adams (1981).

Goat behavior at Sheep Mountain was observed during November-April, 1984-85 and 1985-86, with 10X50 binoculars and a 15-60X telescope. Observations were recorded on tape. Goats were classified by horn characteristics, rostrum length (relative to head size), urinating posture, size, and association with a kid (Brandborg 1955, Smith 1976, Chadwick 1977). Two and 3 collared females of known age were consistently present during the first and second winters respectively. For these goats, ages in 1986 and years when first collared and aged were: 9.5+years, 1979 (Goat no. B57); 9.5 years, 1979 (R96); 3.5 years, 1985 (YBS).

A localized, potentially-defendable food resource (diameter = 1 m) was established near steep cliffs on Sheep Mountain in late November 1985. Data were collected at the site during January-April, 1986. When goats were seen at or away from the bait site, group size and composition, location, and presence of marked animals were noted. Goats were grouped into 10 classes; adult-female-with-kid (FK), or with no kid (F); adult male (AM); unidentified adult (U); 2-year-old male (2M), female (2F) or unidentified (2U); yearling (Y); kid-with-female (KF), or without female (K). Interactions between marked females were used to determine dominance.

Group sizes were compared between marked nannies with a _t_ test (Statistical Graphics Corporation 1985). Home ranges were calculated as minimum-area polygons (Mohr 1947). If goats were located more than once a day, only the first sighting was used in home range analysis.

RESULTS

Mountain goat groups were observed 1,111 times on Sheep Mountain during the 2 winters. Goats sometimes congregated at the bait site. No goat or group of goats continuously defended the bait from other goats (Masteller 1987, Masteller and Bailey In Press).

Grouping Behavior

In 1986, the 3 most frequently observed marked nannies appeared to belong to different social groups. Each of these females was most often seen in groups without either of the other marked nannies (Table 1), and the attraction of the bait appeared responsible for most instances when marked females were seen in the same group. Of 13 sightings including any 2 of these marked nannies, 62% were within 200 m of the bait site, and all 3 sightings including all 3 nannies were within 200 m of the site.

Average group size (excluding kids and groups with other marked nannies) was less for 1 nanny (Table 1), but variation in mean group size was similar among the 3 nannies. The most frequent group sizes were 7, 5 and 3 for B57, R96 and YBS, respectively (Fig. 1). Group composition of the most frequent group size of each female was relatively stable (Table 2). The 2 oldest nannies were most likely to have subadults (other than kids) in their groups, and were not seen with adult males. Comparing the 2 oldest nannies, the dominant (B57) had the highest average numbers of kids and adult females in her group.

Agonistic Behavior Among Marked Individuals

During January-April 1986, dominance relationships were established for the 3 marked nannies by observing interactions both at and away from the bait. B57 dominated both R96 (4 times) and YBS (3 times), and R96 dominated YBS (1 time). The oldest and most dominant goat, B57, was most often seen at bait, had the smallest home range, and was most likely to be nearest the bait site (Table 3). However, the home range of each female included the bait site (Fig. 2). It was not possible to establish dominance relations among other members of the 3 groups because the goats were not marked.

DISCUSSION

Matrilineal Groups

The social groups we found were mostly female, perhaps related, individuals. For mountain goat kids, metabolic weaning is usually

Table 1. Grouping behavior of the 3 most frequently observed marked nannies, January-April, 1986, Sheep Mountain, Colorado.

Nanny (S)	Age[a]	Rank	No. of sightings	Sightings without other marked female present (%)	Ave. group size without kids
B57	9.5+	1	34	72	4.1 (1.7)
R96	9.5	2	20	57	4.6 (2.3)
YBS	3.5	3	34	83	3.2[b] (1.6)

[a] Ages were determined when goats were collared in earlier years.

[b] Significantly lower than both B57 and R96 ($P < 0.05$ and $P < 0.01$, respectively).

completed by 3-4 months of age; but complete behavioral weaning may not occur until 1 year (Brandborg 1955, DeBock 1970, Foster and Rahs 1982, Chadwick 1983). Hutchins and Hansen (1980) reported several cases of yearling and 2-year-old offspring being "retained" by female goats which had either lost their young-of-the-year or failed to conceive. These retained offspring maintained a close relationship, including close physical contact and some nursing, to their mother.

Females and their daughters (and sometimes sisters) have been shown to maintain matrilineal bonds in *Cervus* sp., *Capreolus* sp., and *Odocoileus* sp. (Clutton-Brock et al. 1982; Franklin and Lieb 1979; Bubenik 1965, reported in Lent 1974; Hawkins and Klimstra 1970; Dasmann and Taber 1956). There are similar indications in the little-studied *Nemorhaedus* sp., *Capricornus* sp. and *Rupricapra* sp. (Myslenkov 1978, Kishimoto 1981, Pachlatko and Nievergelt 1985), the closest relatives of *Oreamnos americanus*. In Africa, matrilineal groups occur in *Alcelaphus* sp. and *Loxodonta* sp. (Gosling 1969, review in Leuthold 1977). In most of these ungulates, associations are maintained between a mother and her young-of-the-year and female yearling, but in extensively-studied populations the association sometimes extends to older daughters and sisters (Clutton-Brock et al. 1982, Hawkins and Klimstra 1970).

The sizes of matrilineal groups in ungulates may depend on: 1) age of the female, 2) sex of previous young, 3) dominance of the female, and 4) habitat characteristics such as visibility and forage continuity (Estes 1974, Jarman 1974, Owen-Smith 1977, Cluttton-Brock et al. 1982). There are apparent limits on matrilineal group size, however. In red deer (*Cervus elaphus*), "clusters" were usually less than 4 related animals, but clusters up to 7 occurred (Clutton-Brock et al. 1982). Hawkins and Klimstra (1970) reported that 8 white-tailed deer (*Odocoileus virginianus*) was the maximum number found together. Our oldest, most dominant nanny,

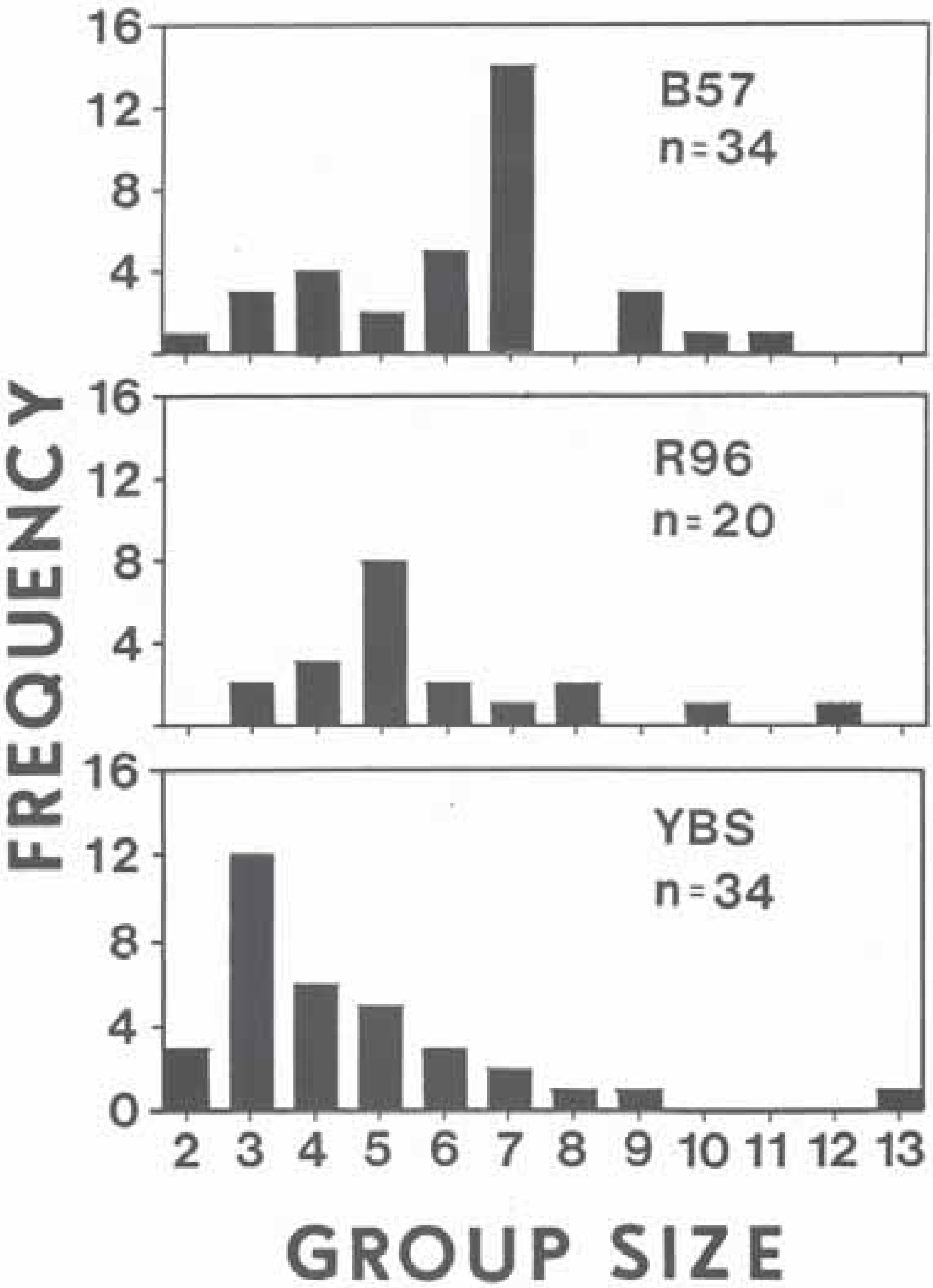

Figure 1. Frequency distributions of group sizes for the 3 mountain goat nannies of known rank, January-April, 1986, Sheep Mountain, Colorado. The rank order was B57 > R96 > YBS.

Table 2. Group composition of the most frequent group size for marked females, January-April, 1986, Sheep Mountain, Colorado. Most frequent group size was 7 for B57, 5 for R96, and 3 for YBS.

Nanny (no. groups)	Average number present with marked nanny (range)[a]							
	AF	2M	2F	Y	K	2U	U	AM
B57 (14)	1.92 (1-2)	1.00 (1)	0.92 (0-1)	0.17 (0-1)	2.00 (2)	0 (0)	0 (0)	0 (0)
R96 (8)	0.37 (0-1)	0 (0)	0.25 (0-1)	0.62 (0-2)	1.12 (1-2)	0.25 (0-1)	1.37 (0-3)	0 (0)
YBS (12)	0.58 (0-1)	0 (0)	0.08 (0-1)	0 (0)	1.00 (1)	0 (0)	0.17 (0-1)	0.17 (0-1)

[a] AF=Adult female, 2M=2-year-old male, 2F=2-year-old female, Y=yearling, K=kid, 2U=2-year-old unidentified, U=unidentified adult, AM=adult male.

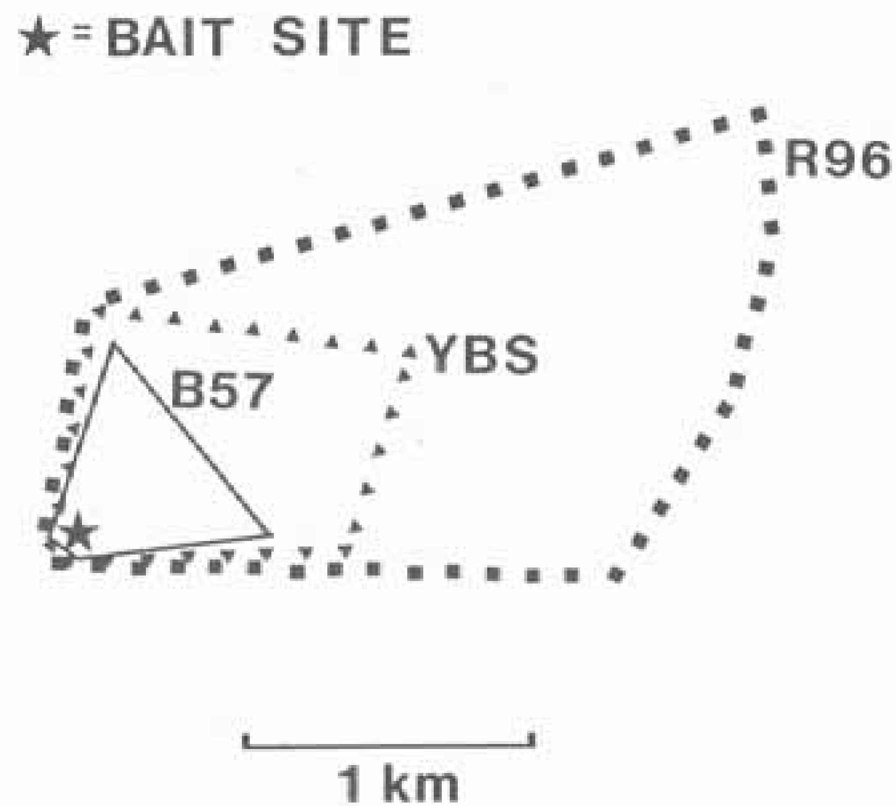

Figure 2. Winter home ranges of 3 marked mountain goat nannies of known rank, January-April, 1986, Sheep Mountain, Colorado. The rank order was B57 > R96 > YBS.

Table 3. Dominance, home range, and access-to-bait for the 3 most frequently observed marked females, January-April, 1986, Sheep Mountain, Colorado.

Goat	Age[a]	Dominance Order	No. Times seen at bait	Home Range (ha)[b]	Average Distance (m) of all sightings to bait site	(N)
B57	9.5+	1	15	34	208[c]	(41)
R96	9.5	2	10	219	768[d]	(31)
YBS	3.5	3	5	85	374	(37)

[a] Ages were determined as 3.5 or 3.5+ when goats were collared in earlier years.

[b] Calculated with minimum-area polygon method.

[c] Lower than both R96 and YBS ($\underline{P} < 0.001$ and $\underline{P} < 0.01$, respectively).

[d] Greater than YBS, $\underline{P} < 0.05$.

B57, was most frequently found in a group of 7 (Fig. 1), which was the largest modal group size for the 3 marked nannies.

Resource Partitioning

There were indications of resource partitioning between the mountain goats we observed. The dominant nanny was most often seen at bait, had the smallest home range, and was most likely to be near the bait site (Table 3). However, this may be an artifact of the bait location. If the bait was placed within the home range of only 1 nanny, other nannies would have to extend their home ranges to visit the bait and may therefore be seen at bait less often.

Resource partitioning may vary with environmental conditions such as snow depth (Petocz 1973). During an unusually harsh week-long snowstorm in February 1986, the 3 nannies (and the unmarked goats associated with them) remained separate and were especially sedentary, with the 2 oldest nannies in the steepest cliffs. B57 and her group used the cliffs directly below the bait site during this storm. Kuck (1977) felt that dominant nannies occupied the best habitat (steep, snow-shedding slopes), and that when these nannies were removed subordinate nannies moved from marginal habitats to replace them.

The ancestors to mountain goats were probably territorial (Chadwick

1983). Indeed, mountain goats wintering on native ranges exhibit territorial-like behavior (Walther et al. 1983): fidelity to small home ranges (Smith 1976, Rideout 1977, Kuck 1977), high rates of aggression (Chadwick 1977, Dane 1977), small group sizes (Smith 1976, Brandborg 1955), and dispersal of young (Rideout 1977, Smith and Raedeke 1982). Additionally, serow (Capricornis crispus) and goral (Nemorhaedus caudatus) exhibit territoriality (Kishimoto 1981, Myslenkov 1978). Resource partitioning among social groups of goats on winter ranges could be a manifestation of territorial ancestry.

Our results suggest there may be distinct social groups of goats on this wintering area, and the literature suggests these groups may be matrilineal groups. While not conclusive, there is some supporting evidence from a non-native goat population in Washington (Hutchins and Hanson 1980).

Our results further suggest resource partitioning among these social groups, similar to that described for black-tailed deer (O. h. columbianus) by Miller (1974). Although no group of goats continuously defended the food resource, there were indications that one group had priority access to it (Table 3). If social groups exist in mountain goats, understanding population regulation in this species will require studying both inter- and intra-group variation in reproduction, survival and dispersal (Clutton-Brock and Albon 1985). Knowledge of these group relations may be necessary for evaluating impacts of harvests, especially of females, upon goat populations.

Differential resource partitioning among groups has implications for possible supplemental feeding of goats during winter. Goats readily accepted the food bait (once they found it), but in a concentrated supplemental feeding situation the subordinate goats most in need of food would have least access to it. Espmark (1974) described similar problems among roe deer at winter feeding stations in Sweden.

The work of Hutchins and Hansen (1980), Stevens (1983), Clutton-Brock et al. (1982), and Lent (1974) represent important first steps in the study of social groupings among goats and other ungulates. While Chadwick (1977) and Singer and Doherty (1985) found no strong evidence of extended associations between individual mountain goats, determining existence of associations such as matrilineal groups requires a large number of marked animals (see Clutton-Brock et al. 1982:189) and long-term research.

LITERATURE CITED

Adams, L. G. 1981. Population dynamics and ecology of mountain goats, Sheep Mountain-Gladstone Ridge, Colorado. M. S. Thesis, Colorado State Univ., Fort Collins. 189 pp.

Adams, L. G., and J. A. Bailey. 1980. Winter habitat selection and group size of mountain goats, Sheep Mountain-Gladstone Ridge, Colorado. Pages 465-479 in Bienn. Symposium Northern Wild Sheep and Goat Counc. 2:465-479.

________, and ________. 1982. Population dynamics of mountain goats in the Sawatch Range, Colorado. J. Wildl. Manage. 47:1237-1243.

Brandborg, S. M. 1955. Life history and management of the mountain goat in Idaho. Project Completion Report P-R Proj. 98-R. Idaho Fish and Game Dep. Bull. No. 2, Boise, Id. 142 pp.

Chadwick, D. H. 1977. The influence of mountain goat social relationships on population size and distribution. Pages 74-91 in W. M. Samuel and W. G. Macgregor, eds. Proc. First Int. Mountain Goat Symposium, Kalispell, Mont. 243 pp.

________. 1983. A beast the color of winter: the mountain goat observed. Sierra Club Books, San Francisco. 208 pp.

Clutton-Brock, T. H., F. E. Guinness, and S. D. Albon. 1982. Red deer: behavior and ecology of two sexes. University of Chicago Press, Chicago. 378 pp.

________, and S. D. Albon. 1985. Competition and population regulation in social mammals. Pages 557-575 in R. M. Sibley and R. H. Smith, eds. Behavioural Ecology. Symposium Br. Ecol. Soc. 25. Blackwell Sci. Publ., Oxford.

Dane, B. 1977. Mountain goat social behavior: social structure and "play" behavior as affected by dominance. Pages 92-106 in W. M. Samuel and W. G. Macgregor, eds. Proc. First Int. Mountain Goat Symposium, Kalispell, Mont. 243 pp.

Dasmann, R. F., and R. Taber. 1956. Behavior of Columbian black-tailed deer with reference to population ecology. J. Mammal. 37:143-164.

DeBock, E. A. 1970. On the behavior of the mountain goat (*Oreamnos americanus*) in Kootenay National Park. M. S. Thesis, Univ. Of Alberta, Edmonton. 173 pp.

Espmark, Y. 1974. Dominance relationships as a possible regulating factor in roe deer and reindeer populations. Pages 787-796 in V. Geist and F. Walther, eds. The behavior of ungulates and its relation to management. IUCN New Series Publ. No. 24.

Estes, R. D. 1974. Social organization of the African bovidae. Pages 166-205 in V. Geist and F. Walther, eds. The behavior of ungulates and its relation to management. IUCN New Series Publ. No. 24.

Foster, B. R., and E. Y. Rahs. 1982. Implications of maternal separation on overwinter survival of mountain goat kids. Bienn. Symposium North. Wild Sheep and Goat Counc. 3:351-363.

Franklin, W. L., and J. W. Lieb. 1979. The social organization of a sedentary population of North American elk: a model for understanding other populations. Pages 185-198 in S. Boyce and L. D. Hayden-Wing, eds. North American elk: ecology, behavior and management. Univ. of Wyoming Press, Laramie.

Geist, V. 1964. On the rutting behavior of the mountain goat. J. Mammal. 45:551-568.

_______. 1974. On the relationship of social evolution and ecology in ungulates. Am. Zool. 14:205-220.

Gosling, L. M. 1969. Parturition and related behavior of Coke's hartebeest, Alcelaphus buselaphus cokei. J. Repro. Fert. Sup. 6:265-286.

Hawkins, R. E., and W. D. Klimstra. 1970. A preliminary study of the social organization of white-tailed deer. J. Wildl. Manage. 34:407-419.

Hutchins, M., and C. Hansen. 1980. Mother-infant interactions among free-ranging, non-native, Rocky Mountain goats (Oreamnos americanus) in Olympic National Park, Washington. pp. 319-340 in Proc. Second Conf. on Sci. Res. Natl. Parks, U. S. Dep. of Interior, Natl. Park Serv. Washington, D. C.

Jarman, P. J. 1974. The social organization of antelope in relation to their ecology. Behavior 48:215-267.

Kishimoto, R. 1981. Behavior and spatial organization of the Japanese serow (Capricornis crispus). M. S. Thesis, Osaka City University, Osaka, Japan. 59 pp.

Kuck, L. 1977. The impacts of hunting on Idaho's Pahsimeroi mountain goat herd. Pages 114-125 in W. M. Samuel and W. G. Macgregor, eds. Proc. First Int. Mountain Goat Symposium, Kalispell, Mont. 243 pp.

Lent, P. C. 1974. Mother-infant relationships in ungulates. Pages 14-25 in V. Geist and F. Walther, eds. The behavior of ungulates and its relation to management. IUCN New Series Publ. No. 24.

Leuthold, W. 1977. African ungulates: a comparative review of their ethology and behavioral ecology. Springer-Verlag, New York. 307 pp.

Masteller, M. A. 1987. Winter social behavior, resource partitioning, and movement patterns of mountain goats in Colorado. M. S. Thesis, Colorado State Univ., Fort Collins, 68 pp.

_______, and J. A. Bailey. In Press. Agonistic behavior among mountain goats foraging in winter. Can. J. Zool.

Miller, F. L. 1974. Four types of territoriality observed in a herd of black-tailed deer. Pages 644-660 in V. Geist and F. Walther, eds. The behavior of ungulates and its relation to management. IUCN New Series Publ. No. 24.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. Am. Midl. Nat. 37:223-249.

Myslenkov, A. I. 1978. The social organization of goral (Nemorhaedus caudatus). Page 347 in R. Orbtel, C. Folk, and J. Pellantova, eds. Second Int. Theriol. Congr. (Abstracts).

Owen-Smith, N. 1977. On territoriality in ungulates and an evolutionary model. Q. Rev. Biol. 52:1-38.

Pachlatko, T., and B. Nievergelt. 1985. Time budgeting, range use pattern and relationships within groups of individually marked chamois. Pages 93-101 in S. Lovari, ed. The biology of mountain ungulates. Croon Helm Publ., Dover, New Hampshire.

Petocz, R. G. 1973. The effect of snow cover on the social behavior of bighorn rams and mountain goats. Can. J. Zool. 51:987-993.

Rideout, C. B. 1977. Mountain goat home ranges in the Sapphire Mountains of Montana. Pages 201-211 in W. M. Samuel and W. G. Macgregor, eds. Proc. First Int. Mountain Goat Symposium, Kalispell, Mont. 243 pp.

Risenhoover, K. L., and J. A. Bailey. 1985. Relationships between group size, feeding time, and agonistic behavior of mountain goats. Can. J. Zool. 63:2501-2506.

Rutherford, W. H. 1972. Status of mountain goats in Colorado. Colorado Game, Fish and Parks Div. Game Inform. Leaflet No. 90. Fort Collins, CO. 4 pp.

Singer, F. J., and J. L. Doherty. 1985. Movements and habitat use in an unhunted population of mountain goats (Oreamnos americanus). Can. Field-Nat. 99:205-217.

Smith, B. L. 1976. Ecology of Rocky Mountain goats in the Bitterroot Mountains, Montana. M. S. Thesis, University of Montana, Missoula. 203 pp.

________. 1977. Influence of snow conditions on winter distribution, habitat use, and group size of mountain goats. Pages 174-189 in W. M. Samuel and W. G. Macgregor eds. Proc. First Int. Mountain Goat Symposium., Kalispell, Mont. 243 pp.

Smith, C. A., and K. J. Raedeke. 1982. Group size and movements of a dispersed, low-density goat population, with comments on inbreeding and human impact. Bienn. Symposium North. Wild Sheep and Goat Counc. 3:54-67.

Statistical Graphics Corporation. 1985. Statistical Graphics Corporation. 2115 East Jefferson Street, Rockville, Maryland, 20852.

Stevens, V. 1983. The dynamics of dispersal in an introduced mountain goat population. Ph.D. Thesis, University of Washington, Seattle. 203 pp.

Trivers, R. L. 1974. Parent-offspring conflict. Am. Zool. 14:249-264.

Walther, F. R., E. C. Mungall, and G. A. Grau. 1983. Gazelles and their relatives: a study in territorial behavior. Noyes Publ., New Jersey.

Bienn. Symp. North. Wild Sheep
and Goat Council 6: 39 - 46

TOWARD A WORKING HYPOTHESIS FOR MOUNTAIN SHEEP MANAGEMENT

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Abstract: Working models of species biology (working hypotheses) are the basis of management decisions, and should form the basis for management planning. Unfortunately, working hypotheses have seldom been articulated The purpose of this paper is to demonstrate one method for developing a working hypothesis by giving an example for Dall sheep (*Ovis dalli dalli*). Components of the ecology of Dall sheep were identified. These included population biology, range resource limitation, habitat component importance, predation, weather, and disease influences, and management of hunting and disturbance. The data base about each component was reviewed, and simple predictive statements with qualification were prepared. Some discussion of the benefits of working hypotheses to researchers, planners, and managers is included.

It is unusual for sheep managers to have large, situation-specific data bases upon which to make management decisions. Consequently, most sheep management responses are based on limited data tempered by the manager's impression of what is appropriate at each opportunity. Working management hypotheses (data-based predictions of how sheep are likely to react to the spectrum of possible uses or abuses) have seldom been articulated, and are not generally available to managers and planners unless they also happen to be specialists in sheep ecology. Published working hypotheses predicting probable sheep responses to specific ecological situations should provide a basis for setting sheep management policy, improve management planning efforts, and aid sheep managers in identifying first-response management options. Working hypotheses should also improve research planning by defining management-relevant questions.

DEFINITION

For purposes of this discussion, a working hypothesis is a data-based working model of species biology which is relevant to possible species uses or abuses. It should be predictive statement which integrates the available biological knowledge with management experience and summarizes the known aspects of species biology, management experience, and probable reaction to specific potential management actions or concerns. It should not be thought of as a definitive statement of the natural history of the managed species, and all involved persons should be continually reminded that the hypothesis requires constant testing, re-examination, and modification as management and research proceed. That is, it is just our best guess about how any species will respond to management options.

METHODS

Components of mountain sheep ecology which have been found to be, or are anticipated to be, important in wild sheep management were identified. These included population biology, nutritional range limitation, habitat components, predation effects, weather influences, disease influences, and disturbance effects.

Once these aspects of sheep ecology were identified, documented knowledge produced by research over the years, management experience, anecdotal information, evolutionary relevance, behavioral theory, and personal insights were factored into summary statements about species adaptations, and anticipated population responses.

RESULTS

A review of the material relating to the biology and management of thinhorn sheep in general and Alaskan Dall sheep in particular was conducted. I judged the following points to be reasonably enough established that they could safely be used as the beginning of a working hypothesis for Dall sheep management in Alaska.

1. The number of Dall sheep in Alaska has been minimally established with acceptable accuracy (Heimer 1984).

2. Most Dall sheep populations exist on continental ranges and exhibit normal population size variations up to 20% of their long-term means over time. Densities vary from range to range (Hoefs and Cowan 1979, Heimer 1979, Heimer and Watson 1986).

3. The tendency of sheep populations to be predictably loyal to seasonal ranges has been established (Nichols 1976; Heimer 1973; Watson and Heimer 1984; Ayers 1986; Durtsche, pers. commun.).

4. Examples of effect of heavy winter snowfall on adult Dall sheep survival on continental ranges have been reported to affect older sheep more than prime age sheep (Burles and Hoefs 1984, Watson and Heimer 1984).

5. Examples of disturbances which Dall sheep tolerate have been reported (Heimer 1979, Heimer et al. 1980). These include road, bridge, and pipeline construction work as well as observations at Usibelli coal mine, Cooper Landing and Sheep Mountain Closed Areas, Seward Highway near Girdwood, and Denali Park.

6. The horn growth patterns and capabilities (potential for trophy management) of Dall sheep in Alaska have been described by area (Heimer and Smith 1975).

7. It has been shown that moderate harvest of mature (full curl) rams has little effect on viability of Dall sheep populations (Heimer and Watson 1986).

8. Removal of virtually all Class III and Class IV rams (all rams

above 3/4 curl) in various areas of Alaska was associated with low harvest rates (Heimer 1980a) and increased mortality among remaining young rams (Heimer et al. 1984).

9. Removal of most Class III and Class IV rams was associated with compromised lamb production (Nichols 1978; Heimer and Watson 1982, 1986).

10. Differences in population quality and performance are not likely to be functions of nutrition (Heimer 1980b, 1983; Heimer and Watson 1986).

11. Dall sheep in the eastern Alaska Range are generally free from diseases associated with domestic livestock (Heimer et al. 1982; Foreyt et al. 1983; R. Zarnke, pers. commun.). Disease is not a major component of Dall sheep ecology.

12. Parasite loads are minor factors in Dall sheep ecology (Nielsen and Neiland 1974).

13. Wolf predation can control and depress sheep populations (Murie 1944, Heimer and Stephenson 1982).

The basic tenets of the Dall sheep working hypothesis for Alaska are detailed below:

1. POPULATION BIOLOGY: Dall sheep are a climax habitat species adapted to relatively stable environments throughout most of their range. As such, we do not expect them to show explosive population growth, and we anticipate (in presence of normal predation) population stability OVER THE LONG HAUL.

Population size may vary considerably from year to year depending on a variety of factors; our experience indicates abrupt, weather-related changes of plus or minus 20% in ewe population size may occur from 1 year to the next. Favorable weather occasionally causes transiently high numbers of ewes when given cohorts of ewes experience higher survival for a year or so longer than expected due to mild winters. When weather "catches up" with these populations, the old ewes usually die, but few prime age ewes succumb. Temporary accumulation of (or removal of) entire cohorts of old ewes does not materially affect long-term, numerical lamb production in the population except in a positive way--the ewes may produce 1 or 2 "extra" lambs in their lifetime given an extra season or 2 of mild winter weather. These changes do not affect production by prime age ewes.

Slow population growth is expected. Population growth may occur under favorable conditions (mild winters and depressed predator populations), but these conditions are usually transient, and increasing populations will be stabilized by difficult weather or increased predation before habitat quality declines enough to cause reductions in the population.

2. RANGE LIMITATION: It seems reasonable that the quality of forage on winter ranges limits Dall sheep population performance. However, the

limitation is typically one resulting from poor food quality rather than insufficient quantity of forage.

We do not expect sheep populations to reach sufficiently high densities that concern about density-related nutritional stress is warranted. Nutritional stress my occur in unusual circumstances, but normal circumstances do not lead to this problem. Comparisons of nutrient quality of winter range plants selected by sheep, the summer nutrient quality of these food plants, and the body condition of ewes during rut and in late winter revealed no caloric advantage for a low-density population when compared with a high-density population. Still, population performance was strikingly different between the two; the low-density population had better performance. Nutritional stress or run-away population growth should not be primary management concerns.

3. HABITAT COMPONENTS: All components of Dall sheep habitat are considered critical to population welfare.

Dall sheep habitat consists, most simply, of winter and summer ranges. Specific life functions such as rutting, lambing, geophagy (mineral licking), and migration may involve specific habitats. However, our present understanding is inadequate to define whether any given habitat-centered activity is not essential to population survival. Certainly, mineral licks are the most clearly identifiable of the habitat components. We cannot say whether this makes them the most important or critical. A major concern of management should be habitat preservation; at this point, we should not relinquish any Dall sheep habitat components in the belief that little or no harm will result.

4. PREDATORS: Predators can limit and depress Dall sheep populations.

Predators, particularly wolves, and possibly coyotes and eagles, can depress sheep populations. Our data suggest wolves have little if any effect on lamb survival in Alaska. If prey selection occurs, mature rams are most probably preferred. Also, our data indicate wolves generally use sheep as alternate prey, perhaps relying on them most during summer months when larger animals like moose and caribou are difficult to capture. We found little evidence of sheep in the late-winter diets of wolves killed adjacent to sheep habitat in the GMU 20A wolf reduction program. Still, sheep population trajectory changed from decline to stability with wolf removal. Coyote predation may be important in some areas. In recent years, the observed incidence of eagle predation on lambs has increased dramatically. Eagles may be a significant predator on Dall sheep, particularly in areas where eagles are abundant and sheep population sizes are small.

5. WEATHER INFLUENCES: Dall sheep distribution is determined by climate. Wind action, snow depth, and hardness appear to be limiting factors in determination of suitable habitat. Prevailing winds are required to reliably remove snow from winter food.

The effects of severe winter weather act primarily on older animals from sheep populations. Weather severity influences survival of lambs to yearling age and the production of lambs. Severe weather may reduce lamb production if it is operative during gestation or parturition. It may also lower lamb survival to yearling age while not depressing lamb production. We have never documented an all-age winter die-off. Such die-offs are alleged to have occurred historically, but data have always been gathered long enough after the fact that such die-off explanations are suspect. In modern times, the only well-documented all-age die-offs have been caused by disease.

6. DISEASE: Dall sheep are not expected to tolerate introduction of exotic diseases. Bulk losses will probably result from introduction of virulent, new diseases to Alaska's sheep ranges. While Dall sheep, at least in the Alaska Range, apparently live with contagious ecthyma, lumpy jaw, and a fairly spectacular array of parasites, they are free from other diseases known to have lethal effects on other species of wild mountain sheep. Most investigators think the major cause of bighorn sheep decimation in the western United States was introduction of diseases common to domestic grazers, most notably domestic sheep. We have done little experimental work, but suspect Dall sheep will be unable to adjust to new diseases without extensive selection through mortality of susceptible individuals.

7. HUNTING: Hunting of Dall sheep can produce marked depressive effects on populations. Ewe hunting at less than 2% per year can limit growth in a vigorous population with nominal wolf and eagle predation. Ram hunting has less impact on population performance, but the effects are significant. Maximum harvest of rams at 3/4 curl is associated with breeding by younger rams and immature ewes, extended lactation, and lowered rates of ovulation and lambing. It is also associated with reduced survival of young rams. Hunting 7/8-curl rams seems to fix the problems associated with lamb production, but the effect on survival of young rams is unknown. It is probable that the sustainable harvest of rams is higher when the social structure is not disrupted by removal of most or all of the socially mature rams.

8. DISTURBANCE: Dall sheep may be considered disturbance-tolerant species.

Dall sheep are so bound to their home ranges it is difficult to make them leave. This is reflected in a behavioral syndrome that may be construed as tolerant of disturbance. Whether they are stubbornly committed to home ranges or tolerant of disturbance doesn't really matter. The result is that they will put up with an amazing amount of disturbance in their environment (coal mining, pipeline construction, intense human contact by viewers, heavy hunting, heavy automobile and air traffic, scientific study, etc.) without leaving. They apparently require some time to habituate to "new" environmental components, but they do adapt with SEEMINGLY few problems as long as they are not killed and their range remains habitable.

DISCUSSION

I have identified 3 specific management consequences which may occur because of the lack of a working hypothesis of species biology. The first, and most serious, problem is improper response to management opportunity or challenge. Our first response to any management opportunity or challenge is dependent on the depth of our understanding of species biology. An incomplete, inaccurate, or poorly informed perception may lead to unproductive, expensive, and possibly disastrous management reactions to challenges and opportunities.

The second consequence of an inadequate model of species biology is inefficient and unproductive use of limited research resources. In designing species-specific research, we rely heavily on our mental model (a working hypothesis which has not usually been articulated) of species biology. As a consequence, assumptions often get more attention in the discussion sections of reports than in research planning.

Articulating assumptions in a working hypothesis for research proposal reviewers should raise the level of project review as well as define areas of inadequate information (Heimer 1987). This should increase the chances of making major contributions toward better management. Of course, it should be recognized that some aspects of species biology are time and area specific. This emphasizes the importance of stressing the hypothetical nature of the working model as well as the hazards of overgeneralizing.

The third undesirable consequence of poorly expressed or supported hypotheses of species biology is controversy. When a working model of species biology is not widely understood and accepted, management actions consistent with the working hypothesis may not be understood or accepted by peripherally involved biologists or managers. This can lead to confusion and disagreement over appropriate management activities. It also leads to unhealthy emphasis on legitimate differences of opinion and may compromise the productivity of management programs.

For optimum progress to occur, information used to produce a working hypotheses need not be absolute truth. It is probably little more likely we will ever "prove" a working hypothesis of species biology than that we will "prove' organic evolution. Working hypotheses will, of necessity, be syntheses of gathered data, empirical observation, behavioral and evolutionary theory, and ecological principles. They will require adjustment for specific circumstances, new knowledge, and the failure of broad principles to predict accurately in all cases. I think it is the responsibility of research and management biologists to prepare working hypotheses as well as participate more actively in the planning process.

LITERATURE CITED

Ayers, L. 1986. The movement patterns and foraging ecology of Dall sheep in the Noatak National Preserve, Alaska. M.S. Thesis. Univ. California, Berkeley. 94 pp.

Burles, D., and M. Hoefs. 1984. Winter mortality of Dall sheep, Ovis dalli dalli, in Kluane National Park, Yukon. Can. Field Nat. 98:479-484.

Foreyt, W. J., T. C. Smith, F. F. Evermann, and W. E. Heimer. 1983. Hematologic, serum chemistry, and serologic values of Dall's sheep (Ovis dalli dalli) in Alaska. J. Wildl. Dis. 19:136-139.

Heimer, W. E. 1973. Dall sheep movements and mineral lick use. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Final Rep. Proj. W-17-2, W-17-3, W-17-4, and W-17-5. Job 6.1R. Juneau. 35 pp.

________. 1974. The importance of mineral licks to Dall sheep in Interior Alaska and its significance to sheep management. Pp. 49-63 in K. Constan and W. Mitchell (Eds.), Proc. Bienn. Symp. North. Wild Sheep Counc., Great Falls, MT.

________. 1979. Dall sheep responses to human activity. Alaska Dep. Fish and Game. Fed. Aid In Wildl. Rest. Final Rep. Proj. W-17-10. Job 6.13R. Juneau. 5 pp.

________. 1980a. A summary of Dall sheep management in Alaska during 1979 (or how to cope with a monumental disaster). Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:355-380.

________. 1980b. Can population quality be related to population density through nutrition? Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:288-310.

________. 1983. Dall sheep body condition and nutritional profile. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Final Rep. Proj. W-17-8 through W-21-1. Job 6.12R. Juneau. 52 pp.

________. 1984. Population status and management of Dall sheep in Alaska, 1984. Pp. 1-15 in M. Hoefs (Ed.), Wild sheep, distribution, abundance, management and conservation of the sheep of the world and closely related mountain ungulates. Spec. Rpt., North. Wild Sheep and Goat Counc., Yukon Wildl. Branch, Whitehorse. 218 pp.

________. 1987. Publication of Dall sheep findings and development of future research direction. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Final Rep. Proj. W-22-5. Job 6.10R. Juneau. 33 pp.

________, and A. C. Smith, III. 1975. Dall ram horn growth and population quality and their significance to Dall sheep management in Alaska. Alaska Dep. Fish and Game. Tech. Bull. 5. 41 pp.

________, and R. O. Stephenson. 1982. Responses of Dall sheep populations to wolf control in interior Alaska. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:320-330.

________, and S. M. Watson. 1982a. Interior sheep studies. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Prog. Rep. Proj. W-22-1. Job 6.9R. Juneau. 31 pp.

________, and ________. 1982b. Differing reproductive patterns in Dall sheep: Population strategy or management artifact? Bienn. Symp. North. Wild Sheep and Goat Counc. 3:330-338.

________, and ________. 1982b. Comparative dynamics of dissimilar Dall sheep populations. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Final Rep. Proj. W-22-1 through W-22-4. Job 6.9R. Juneau. 101 pp.

________, S. D. DuBois, and D. G. Kelleyhouse. 1980. The usefulness of rocket nets for Dall sheep capture compared with other capture methods. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:601-614.

________, S. M. Watson, and T. C. Smith, III. 1984. Excess ram mortality in a heavily hunted Dall sheep population. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:425-433.

________, R. L. Zarnke, and D. J. Preston. 1982. Disease surveys in Dall sheep in Alaska (preparing for domestic grazing). Bienn. Symp. North. Wild Sheep and Goat Counc. 3:188-198.

Hoefs, M., and I. McT. Cowan. 1979. Ecological investigation of a population of Dall sheep. Syesis 12:81 pp.

Nielsen, C. A., and K. A. Neiland. 1974. Sheep disease report. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Final Rep. Proj. W-17-5. and W-17-6. Job 6.6R. Juneau. 111 pp.

Murie, A. 1944. The wolves of Mt. McKinley. U.S. Dep. Int., Nat. Park Serv., Fauna Ser. 5. 282 pp.

Nichols, L. 1976. An experiment in Dall sheep management, progress report. Trans. North Am. Sheep Conf., Colorado State Univ., Ft. Collins. 2:16-34.

________. 1978. Dall sheep reproduction. J. Wildl. Manage. 42:570-580.

Watson, S. M., and W. E. Heimer. 1984. An age-specific winter die-off in Dall sheep in Alaska. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:61-67.

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and Goat Council 6: 47 - 53

PERMIT AUCTION: THE GOOD, THE BAD AND THE UGLY

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Abstract: Nine states now annually provide at least one sheep permit for auction to the highest bidder. The rules and procedures utilized by each state are summarized. The revenue received from these auctions has provided significant benefits to the sheep populations in the respective states. Bids have ranged from $15,000 to as high as $109,000 for a permit. Habitat improvement and transplants into new areas are but two of the many programs supported by the auction revenue. All states indicated the benefits to their sheep management program have or will be substantial as a result of the revenue received from the auctions. Many of the states currently allow the auction permit holder more flexibility in obtaining a sheep. Arizona, Nevada, Oregon, Utah and California have provided extended or special seasons after or before the regular season for the auction permit holder. Wyoming, Idaho, North Dakota and Montana restrict the auction permit holder to the same season as other permit holders, but allow the permit holder to hunt any open district. Considering the bids received for the auction permit, one could conclude these special considerations appropriate. Another conclusion would be that big money is beginning to influence sheep management decisions and the general sportsmen is being treated unfairly. This year, the high bidder for the Montana sheep auction license requested authorization to transfer his permit to another individual. He also requested extension of the season into November and December. Montana developed special rules to answer these questions. Other states have also developed special rules in response to other problems. Some coordination between states has taken place to date, but regulations are not consistent. How far should a wildlife management agency go to respond to the auction permit holder? Sportsmen in at least Montana are beginning to question those decisions. Management agencies should not let this issue build until sportsmen are at each others throats. We need to make decisions now which will lessen this conflict? Now is the time to act before the good and the bad changes to the ugly! Recommendations are made to protect the bidder and to continue public support for the auction process.

Bighorn sheep have long been a highly prized trophy by sportsmen. This is as much related to the bighorn's massive horns and rareness as it is to the difficulty for a hunter to obtain a license.

Beginning with the state of Utah in 1980 many western states began to auction or raffle at least one bighorn permit each year to obtain revenue to support bighorn sheep management programs. The auctions to date have been very successful at raising revenue.

The highly prized nature of the bighorn sheep as a trophy together with the extreme difficulty for a sportsmen to obtain a permit to hunt the species creates a strong, emotional feeling amongst some to strongly object to the auctioning process. Are not the wildlife of the state a public resource? Why should those with the willingness to spend large sums of money be granted a license? Isn't a raffle more fair for all? Why should the auction license holder be granted more privileges than the sportsmen receiving a license by drawing?

All of these questions and more are beginning to surface in sportsmen group meetings, newspaper articles (Lindler, 1987) and magazine articles (Park 1988). This paper is intended to summarize the current situation, review the pros and cons of permit auctions and recommend a course of action to prevent further conflicts amongst sportsmen on this issue.

I wish to thank those wildlife department personnel from the states of Utah, Arizona, Nevada, Wyoming, Idaho, Oregon, California and North Dakota for providing the information which formed the basis for this paper.

METHODS

A questionnaire was sent to the wildlife department's in the state of Arizona, Utah, Nevada, Oregon, Wyoming and California to obtain information concerning the auction or raffle process utilized and the projects funded through the use of the funds generated. Followup contacts by phone yielded additional information and clarified answers to the questions which were unclear. The information from the states of North Dakota and Idaho were obtained by phone. Information from the state of Montana was obtained from Montana Department of Fish, Wildlife and Parks records by the author.

RESULTS AND DISCUSSION

In 1987, the Montana Department of Fish, Wildlife and Parks received 10,137 applications for bighorn sheep licenses issued through drawings. Only 2% (207) hunters were successful in receiving a license (Table 1). The odds for drawing a license in some areas exceeded one chance in 260. Hunter demand for bighorn sheep licenses has steadily increased (7,147 applicants in 1984 to 10,538 applicants in 1987). The demand for bighorn sheep license in other states and provinces is similar and makes a bighorn sheep license a very highly coveted prize to sportsmen.

The practice of auctioning or raffling bighorn sheep permits began in 1980 when the state of Utah auctioned one bighorn sheep permit for $20,000 through a sealed bit process. Other states have progressively followed suit through the years until presently nine states have or will offer for auction or raffle at least one bighorn sheep license. The only remaining states not utilizing the auction process are Alaska, Washington, Colorado and New Mexico. Even these states are now seriously considering the auction process as a way to increase revenue for management programs.

Since 1980 a total of nearly $1.8 million has been raised for state management programs through the auction of bighorn sheep licenses or

Table 1. Number of applications for bighorn sheep licenses in Montana, 1983-87.

Year	Number applications	Successful applicants	Percent successful
1983	8,170	1,106	14
1984	7,147	744	10
1985	8,341	562	6
1986	8,628	610	7
1987	10,538	513	4

permits (Table 2). In 1987, the highest bid ever received for a bighorn sheep license was $109,000 for a Montana license. Although the amounts received each year through the auctions have varied, the revenue generated has remained quite stable in each state.

Arizona has also utilized a raffle to raise money for sheep management projects. In 1984, the Arizona permit auction raised $64,000 and the raffle generated $82,000. Arizona's experience indicates a raffle may actually generate more revenue than an auction. However, the money generated through a raffle depends largely on the number of participants. Thus, states with lower populations might actually raise more money through an auction.

It is apparent from the bids received since 1980 that one could on the average expect a bighorn license to go for between $40,000 - $50,000. What then makes the states of Montana, Arizona, California and Idaho receive higher bids than the average. A review of the latest Boone and Crockett Records book lends some insight into this phenomenon.

A review of the 8th edition of Boone and Crockett Records shows that the Canadian provinces of Alberta and British Columbia and the state of Montana provides the majority of records for bighorn sheep. The state of Arizona and Mexico have provided a majority of the records for Desert Bighorn. In both the 18th and 19th Awards Competition for Boone and Crockett, these states and provinces maintained their place in the record book. Since 1980, 37 of the 92 rams entered in the two Boone and Crockett Awards Competition were from Montana. In 1986, at least 19 rams, and in 1987, at least 15 rams that exceed Boone and Crockett minumums were taken in Montana. The 19th Awards Competition included sixteen desert rams from Arizona, seventeen from Nevada and eighteen from Mexico.

California just recently began hunting bighorn and thus hunter expectations are that new records will be set with rams taken there in the next few years.

Bidders also cite their strong support for the sheep management programs as a reason for the high sums of money generated by the auctions. The stability of the high bids over the years support this. Additionally,

Table 2. Revenue dollars received from bighorn sheep permit auctions. (1980-1988).

State	1980	1981	1982	1983	1984	1985	1986	1987	1988
Utah	20,000	22,000	22,500	32,000	33,000	27,000	20,000	20,000	?
Nevada	21,050	21,000	25,002	22,050	67,500	42,500	57,000	57,000	80,000[a]
Arizona[b]					64,000	42,000	27,000	49,000	47,500
Montana							79,000	109,000	93,000
California								70,000	59,000
Oregon								56,000	?
Wyoming				43,000	52,000	80,400*	25,000	35,000	28,000
North Dakota							17,000	21,000	15,000
Idaho									68,000

[a] Two permits were offered (bid shown was for both permits).

[b] Arizona also offers a permit for raffle through the Arizona Desert.

Bighorn Sheep Society. The revenue generated from these raffles is not shown.

the Foundation for North American Wild Sheep emphasizes "putting sheep on the mountain" as their goal.

The main benefit of the auctions is the revenue generated provides a good funding source with which to support needed sheep management projects. All of the states indicated they used the revenue from the auctions primarily for transplants of bighorn into new areas and for the purchase of equipment utilized in that process. Most states also utilized some of the revenue to fund annual census surveys by helicopter and/or fixed wing aircraft. Habitat improvement projects such as controlled burning of winter ranges and construction of water developments was also cited as important projects. All states indicated these programs could not have been conducted without a source of revenue like the auctions.

Although most states have had few problems with the auction process, nearly all have received some negative comment from sportsmen. Most of the negative comments are related to complaints about selling a public resource. The states with the longest history of auctions indicated fewer and fewer of these complaints surface as the program results begin to surface. Montana encountered opposition from sportsmen to the auction license holder's request for a longer season.

Public perception of the auction process is pivotal to its future. At present, public perception appears to be on the positive side as evidenced by the limited number of negative complaints received by the states auctioning permits to date. All states contacted indicated a sensitivity to this and emphasized their desire to uphold the image of hunting and hunters by preventing abuses of the auctioning process by implementing reasonable rules and regulations.

A review of each state's regulation reveals that most states grant the auction license holder privileges beyond that which other license holders receive (Table 3). Although these privileges may be appropriate, the states are not consistent in their approach. This inconsistency may result in increased public and sportsmen opposition to the auction process in the future.

Other problems which have surfaced are:

1) Payment made in nonlegal tender (rubies)

2) High bidder not able to physically hunt

3) High bidder defaulted on payment

4) High bidder wanted to transfer license to another individual

5) Revenue generated utilized to fund other programs

6) Regulations prevent obtaining license more than once in a lifetime

7) Successful bidder requests special season different than that granted other license holders.

Table 3. Summary of privileges states grant auction permit holders.

States	Number Permits	Methods of Issues	Privileges
Montana	1	Auction	Larger hunt area
Utah	1	Sealed Bid	Longer season, guide, transportation, meals, lodging
Nevada	2	Auction	Larger hunt area, late separate season
California	1	Auction	Larger hunt area, longer season, earlier season
Arizona	2	Auction/Raffle	Separate season, longer season
Oregon	1	Auction	Longer season, larger hunt area
Wyoming	1	Governor Designated	Larger hunt area
North Dakota	1	Auction	Larger hunt area
Idaho	1	Auction	Larger hunt area

Each state has enacted rules and regulations to resolve the problems encountered and although some contact between states has occurred, regulations are not consistent.

RECOMMENDATIONS

States currently auctioning a sheep license or contemplating to do so have an obligation to ensure that the resource benefits from this process and the public and sportsmen maintain their support for the program. Failure in either area will eventually result in the end to the auction process and a reduction in the revenue needed to adequately fund necessary projects. Ultimately, the wild sheep resource will suffer.

What can be done to protect the bidder, ensure high bids will continue and still provide for continued public and general sportsmen support? The following suggestions are recommended for consideration.

1) Regulations should be enacted by each state which specify:

   a) How and when transfer of the license from the high bidder to another individual can occur.

b) Payment procedures to include payment in legal tender, payment deadline, percentage retained by auctioning organization, procedure if default occurs.

c) Time frame for license issue (i.e. 30 days prior to season).

d) If once in a lifetime restrictions apply.

e) Legal hunting areas, time of season, ram size restrictions, etc.

f) Statement preventing subsequent sale of the license for commercial gain.

2) States should carefully consider granting extra privileges to auction license holders beyond allowing for hunting within open hunting areas and seasons.

3) Funding received from wild sheep license auctions should be designated for use in only sheep management programs.

4) Regulations and rules governing the use of auction permits should be disseminated to all prospective bidders prior to auction.

LITERATURE CITED

Park, E. 1988. Trophies for Auction. Western Outdoors. January Issue 61-63.

Lindler, B. 1987. Dubs blames state for spoiling hunt. Great Falls Tribune. June 25.

Bienn. Symp. North. Wild Sheep
and Goat Council 6: 54 - 56

RECOMMENDATIONS OF THE NORTHERN WILD SHEEP AND GOAT COUNCIL REGARDING THE USE OF SPECIAL BIG-GAME (GOVERNOR'S) PERMITS FOR FUNDING WILDLIFE PROGRAMS

The Northern Wild Sheep and Goat Council is one of two associations of professional biologists involved in wild sheep management in North America. It consists of approximately 100 professional sheep and goat biologists as well as university faculty members and students of wild sheep and goats from Alaska, Alberta, British Columbia, Colorado, Idaho, Montana, North Dakota, the Northwest Territories, Oregon, South Dakota, Utah, Wyoming, the Yukon Territory, and Washington. As such, it represents the pooled expertise regarding management of northern wild sheep and goats throughout North America. The council has assumed, as one of its functions, an advisory role on issues involving wild sheep and goat conservation and management.

Background

Special hunting permits (commonly called Governor's permits) are available to the Governor in most western states and Department Ministers in some Canadian provinces. These permits are typically awarded as the Governor or Minister chooses to allocate them. In recent years, increasing numbers of these permits have been allocated to non-profit organizations for auction or lottery to generate money. The common applications of this revenue-generating mechanism have been limited to fundraising for programs in wildlife conservation, especially for management and research on wild sheep. The Northern Wild Sheep and Goat Council (NWS&GC) supports continuation and expansion of this innovative funding technique for enhancing wild sheep and goat management effectiveness. However, the NWS&GS is aware of some potential problems and ethical considerations attending use of Governor's permits for fundraising.

First of all, indigenous wildlife in the United States of America has been traditionally considered the "property" and is certainly the management responsibility of the states. This system is slightly different in Canada. To varying degrees, the states and provinces have been successful in meeting their management responsibilities with respect to wild sheep. In the United States, where wild sheep populations were decimated early this century, their recovery has come largely through programs funded by the hunting public.

Even given the successes at restoring wild sheep abundance, there is still a demand for sheep hunting opportunity which far exceeds the present capability of sheep and sheep habitats to provide. As a result, resident hunters must hope for selection in the permit lotteries in most states. This means that use of Governor's permits for any purpose, decreases hunting opportunity of residents by a small amount. This opportunity is virtually lost to residents because auction of the permits brings large sums (above $100,000 in some cases). When the revenue generated by auction of Governor's permits is reinvested in the resource which produced it, everyone benefits, particularly the hunting public which contributed the funds to make harvest of mountain sheep possible in the first place. The NWS&GC thinks this is the best use of the Governor's permit auction system. Maintenance of this system, however, requires some further attention, and possibly some constraints.

The NWS&GC recognizes the following problems: The large revenues generated by sale of Governor's permits may inspire attempts to divert these funds to other species or non-wildlife programs. It is also possible that a glut of Governor's permits for auction could lower the revenue generated by the system, and cut resident opportunity to participate in sheep hunting without commensurate benefit to the resource or the resident hunter. Finally, there is a temptation to provide special assistance to or exemptions from common hunting regulations and practices for the benefactor who buys the permit at auction.

In an attempt to deal with these problems, the NWS&GC offers the following recommendations regarding use of Governor's permits for fund raising. We realize these recommendations are largely in the province of our various governors and ministers. Our intent, as an association of professional sheep and goat managers, is to offer the best assistance we can, and mark our positions on these issues a matter of record.

1. Governor's permits to hunt mountain sheep or mountain goats should be allocated for sale only to provide revenues for conservation (which includes research and management) of these species.

2. State and provincial wildlife management agencies should be involved in decisions regarding the appropriate number of permits, and any necessary restrictions on permit use which may be required to protect sensitive populations of big game.

3. Allocation of permits for sale should be managed with a view toward maximizing financial return to the species programs and minimizing losses in resident hunting opportunity.

4. Granting of special privileges to Governor's permit buyers should be discouraged.

5. Several conditions of permit issuance should be clearly defined when the permit is donated. They include:

    a. If, how, and when the purchaser may transfer the permit to another person.

    b. Acceptable payment procedures, legal tender, deadline, procedure in case of default, and amount retained by any other party (such as the auctioneer).

    c. Timing for issuance of permit.

    d. Required license and guide fees.

e. Legal hunting areas, dates, and regulations.

6. Regulations and conditions of the permit should be made clear to all prospective buyers prior to auction.

Parasites and Diseases

Bienn. Symp. North. Wild Sheep
and Goat Council 6: 57 - 64

THE LOSTINE ROCKY MOUNTAIN BIGHORN SHEEP DIE-OFF AND DOMESTIC SHEEP

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Abstract: Approximately two-thirds of 100 bighorn sheep (*Ovis canadensis canadensis*) in the Lostine herd (Wallowa Mountains) of northeast Oregon died in 1986-1987. No mature rams and very few lamb survived. Pasteurella haemolytica and Pasteurella multocida were the suspected causes of disease. Circumstantial evidence linked the die-off to contact with domestic sheep. The history of the herd, its present status, and the die-off are summarized.

During the late autumn and early winter of 1986-1987, the Lostine herd of bighorns (located in the Wallowa Mountains of northeastern Oregon) suffered a major all-age die-off. The objective of this paper is to review that die-off, along with the history of the herd prior to the die-off, and its present status.

The assistance of many Oregon Department of Fish and Wildlife personnel, especially Marty St. Louis and Steve Allen, and Oregon Hunter's Association volunteers who helped with trapping, removing snow, locating carcasses, and funding for many of the drugs, equipment and follow-up studies is greatly appreciated. Special thanks are due Dr. Bill Foreyt, Washington State University (WSU), for his assistance and advice on treating bighorn sheep diseases and parasites and to Jim DeForge of the Bighorn Research Institute, Palm Desert, California, for their assistance. Thanks also to Duane and Shirley Burch for the many hot cups of coffee, warm fires on cold days, and use of their private road. Charle DeLashmutt typed and retyped the manuscript.

HISTORY OF THE LOSTINE HERD TO 1986

The Lostine Rocky Mountain bighorn herd in northeastern Oregon started in November 1971 with the introduction of 15 ewes and 5 rams from Jasper National Park, Alberta, Canada. Sheep were released at the base of a southwest facing slope in the Lostine River drainage on the north end of the Wallowa Mountains. They wintered on the open grassland slopes above the release site and the following spring moved south along the summit of the Hurricane Divide where they spent the summer. This pattern has continued, with ewes and lambs moving 8 to 16 km (5 to 10 mi) south to spend the summer in the high alpine basins above timberline. The rams used this same summer range until 1980 when many began crossing Hurricane Creek to the Hurwal Divide and moving further south along the Hurricane Divide. Limited ram hunting, which started in 1978, may have been responsible for this expansion of ram range, which continues to this day. Typical of many western big game ranges, the Lostine herd's winter range is very restricted, but the summer range is vast.

Trapping and Transplanting

The Lostine bighorns did well and 63 animals were counted in 1977 (Table 1). Trapping and transplanting was started that winter and continued annually through January 1986. A total of 152 bighorns were trapped and transplanted to 9 different sites (1 in Washington, 3 in Idaho and 5 in Wallowa County, Oregon). Of the Oregon transplants, 31 returned to the Lostine range from distances varying from 11 to 64 km (7 to 40 mi) by air. Four of 5 transplant attempts in Oregon failed and only 15 bighorns remain at the one site. Two of the 3 Idaho transplants appear to be doing well and the Washington transplant (supplemented with bighorns from several other sources) is established and doing well. Twelve bighorns from 2 nearby transplant sites (11 and 14 km, or 7 and 12 mi, by air) also moved to the Lostine range.

Table 1. Composition and numbers of the Lostine bighorn sheep herd, 1972-1988.

Year	Ewes	Lambs	Rams	Total Classified[b]	Lambs/ 100 ewes	Rams/ 100 ewes	Highest winter count
1972[a]	14	3	3	20	21	21	19
1973	13	3	3	19	23	23	19
1974	17	8	5	30	47	29	30
1975[a]	25	12	10	47	48	47	40
1976[a]	26	19	8	53	73	31	53
1977[a]	24	19	17	70	79	71	63
1978		no data					78
1979	33	23	22	78	70	67	85
1980	37	19	30	86	51	81	86
1981	55	11	26	92	20	47	92
1982	42	16	25	83	38	59	83
1983	38	27	28	93	71	74	96
1984	46	25	24	95	54	52	95
1985	58	19	20	97	33	34	97
1986	46	15	26	87	33	57	87
1987	19	2	11	33	11	58	33
1988	21	2	13	36	10	62	36

[a] June-August counts on summer range.
[b] January-April counts unless otherwise noted. Highest count by ground or supercub aircraft. Includes bighorns transplanted for herd reduction.

Ram Hunting

Hunting of rams was started in 1978 and continued through 1986. A total of 56 tags were issued and 47 rams were harvested. Five of these rams scored over the minimum for Boone and Crockett Club entry into the record book.

Winter Range Purchased

In 1975, efforts began to purchase the Lostine winter range from private landowners (90% of the range was owned by 2 individuals). Horses were grazed on the range prior to this time (the range was leased by Oregon Department of Fish and Wildlife in 1975). In 1981, 720 acres of the primary bighorn range were purchased and two additional tracts were bought by the ODFW in 1982 and 1984. A total of 388 ha (970 ac) were acquired at a cost of $397,000 U.S.

Lungworm Treatment

Periodic examinations of bighorn feces indicated low counts of lungworm larvae (Protostronglus spp.) through 1979. Samples examined by Dr. W.J. Foreyt, Washington State University, in 1981 (personal communication, February 13, 1986) indicated high levels with 5 of 10 bighorns tested having greater than 1,000 larvae/gram of feces. Lamb survival also began to decline in 1980 when 35 lambs per 100 ewes were observed compared to 74 lambs per 100 ewes from 1977-79. Field treatment of the Lostine herd with the drug albendazole (Smith Kline) incorporated in alfalfa-barley pellets began in 1982. Lungworm levels were reduced (Foreyt, et al. 1983) and lamb survival improved dramatically (71 lambs per 100 ewes in 1983). Since then, treatment with albendazole fortified pellets or fenbendazole Safe-Guard protein blocks (Hoechst-Roussel Agri-vet) has been continued annually or at 2-year intervals. In addition, all animals captured and handled were given injectable Ivomec 10 mg/50 Kg [110 lbs] (Ivermectin, MSD-Agvet, Merck & Co., Inc., New Jersey).

Population Levels

The herd has been kept at a relatively stable population level by trapping, transplanting, and limited hunting. Winter counts ranged from 63 in 1977 to a high of 97 in 1985 prior to the 1986-87 die-off (Table 1). These counts reflect a total population of 80 to 100 bighorns on the winter range before trapping and transplanting and after the annual ram harvest. A winter population objective of 80 animals was established and kept at or below that level by trapping and transplanting all except in 1982 when 83 sheep were counted.

The total winter range encompasses 530 ha (1,300 ac), supporting 1 bighorn per 5 ha (12 ac) at peak population density of 100 animals. There is presently no domestic livestock use on the range, but 100 to 150 mule deer (Odocoileus hemionus hemionus) and 25 to 50 Rocky Mountain elk (Cervus elaphus nelsoni) use the range periodically. Wintering bighorn population densities of 1 per 5 ha (12 ac) were reported by Blood (1963) for a herd of California bighorn in British Columbia. Woodgerd (1964) reported that on Wildhorse Island in Montana, a sheep density of 1 per 5 ha (12 ac) of grassland existed. This was on a range used all year on a 10.4 km^2 (4 mi^2) island with an estimated 200 mule deer present. Considering these studies and range condition that appears to be improving, the Lostine winter range does not appear to have been overstocked prior to the die-off.

THE DIE-OFF

Methods

The disease problem began in November 1986 when sick and dead bighorns were reported. Nine sick animals were captured in early December. Blood, nasal swabs, and fecal samples were collected and all animals captured were given Ivermectin at previously mentioned dosage rate (for parasite control) and a long acting antibiotic Liquamycin LA-200 [Pfizer, Agricultural Division, New York, NY) at a dosage rate of 4.5 ml/45 kg (100 lbs)]. The range was closed to all public entry. Daily trips to the winter range were initiated (as the weather permitted) to observe sick bighorns and prebait them with alfalfa pellets. In mid-December, the treatment of bighorns was started with antibiotics and ivomec. The animals were trapped in a corral trap to administer the drugs or given antibiotics via Palmer Cap-chur dart. All animals trapped were eartagged with Alflex numbered tags and individual records of symptoms and treatments received were started. This procedure was continued through March 1987 when weekly visits were initiated and treatment discontinued. Several searches were made during the winter and spring with the assistance of volunteers from sportsmen's groups. Weekly monitoring trips to the winter range were discontinued in early June as most animals had dispersed over the summer range.

Several trips to the summer range were conducted to determine ewe:lamb ratios and to visually monitor general bighorn body condition. Regular trips to the winter range were initiated in December 1987 to determine survival of the Lostine bighorns, post disease lamb survival, and to document additional survivors. Twenty of 36 (56%) of the surviving bighorns were caught and blood, nasal swabs, and fecal samples collected for analysis. Captured animals were dewormed and the few without eartags tagged.

Time of the Outbreak

The disease outbreak may have started in October 1986 on the east side of the Lostine herd's summer range. In early October, a local outfitter (E. Deardorff, personal communication, October 22, 1986) reported seeing 2 bighorn rams and a ewe with a domestic sheep (a ewe) 13 km (8 mi) southeast of this location. The domestic ewe was shot, dressed out, and found to have foot rot and lung adhesions. One of the bighorn rams was identified by its eartag to be from the Lostine herd. In mid-October, a large old ram was found dead by hikers near Ice Lake 16 km (10 mi) northwest of where the domestic-bighorn encounter occurred.

In late November, sick and dead bighorns were reported on the Lostine winter range. A search of the area several days later revealed 5 dead and 1 sick lamb and 13 other live sick bighorns. Four of the 5 lambs were necropsied and lung samples taken to the Washington State University diagnostic laboratory. Three of the 4 were good quality lambs in excellent physical condition. The lungs of all 4 animals were very red and inflamed but other organs looked normal.

The disease appeared to be just starting in late November when the range was surveyed. Bighorns were returning to the winter range, and the rut was in progress. Both of these factors were likely responsible for the rapid spread of the disease. Deaths of sheep of all ages occurred through December and into early January. No deaths were known to occur after mid-January.

Signs of Disease

Signs of sick bighorn took 2 forms. The most common was an extremely deep cough with a heavy clear nasal discharge. In the worst cases, bighorns quit eating, laid around away from the herd and some died. Most animals with these signs continued to stay near the herd and the coughs gradually improved (little coughing was apparent after January 1987). The nasal discharge continued through the winter with some animals still showing mucous when they left the winter range in May. Many of these animals were treated with antibiotics that appeared to help recovery.

A few bighorns showed only lethargy and moved away from the group. Most of these did not appear to be feeding and also had droopy ears. In nearly all cases, they died fairly quick. Treatment was not administered to most of these animals as we did not realize they had the disease. The few that were treated with antibiotics given with a Cap-chur dart died. All surviving bighorns appeared fully recovered by July 1987.

Domestic Sheep/Bighorn Relationship

Circumstantial evidence indicates the Lostine bighorns contracted *Pasteurella* pneumonia from domestic sheep. The contact mentioned earlier could have been the source of the disease. The location of carcasses indicate the die-off started in the east and went west to the winter range. Other possible sources of the disease include strays from domestic sheep bands found on ranges in the Eagle Cap Wilderness 3.2 and 9.6 km (2 and 6 mi) west of the Lostine range.

Bailey (1936) reported concern that the few remaining Oregon bighorns might contract diseases from domestic sheep in the Wallowa Mountains. Bighorns were gone from this area by the early 1940's. Max Walker (personal communication, 1987), longtime county resident, reported bighorns once numerous in the Imnaha area (Wallowa County). Early settlers reported that bighorns died out from a "distemper" caught from domestic sheep. In recent times, Foreyt and Jessup (1982), reported on fatal pneumonia in bighorns following association with domestic sheep. Other bighorn deaths in northeast Oregon circumstantially linked with domestic sheep contact have also been reported (Oregon Department of Fish and Wildlife files, V. Coggins typewritten report, July 1984).

Mortality

The Lostine bighorn herd was estimated at 100 animals prior to the die-off. Thirty-four surviving animals including 20 ewes, 2 lambs, and 12 rams, were located after the disease had run its course. Twenty-six dead bighorn including 6 ewes, 9 lambs, 10 rams and one of unknown sex and age, were found. This accounts for 60 bighorns with about 40 missing and presumed dead. Nearly all the dead animals (24 of the 26) were located on the winter range or in a low elevation drainage below their migration route. All rams over 4 years of age died during the outbreak as did all but 2 lambs. Most surviving ewes were younger (3-6 years old) animals (Table 2).

Table 2. Sex and age of Lostine bighorns surviving the die-off of 1986-87.

Age	Ewes 1 Yr	Ewes 2 Yr	Ewes 3+ Yr	Lambs	Rams 1 Yr	Rams 2 Yr	Rams 3 Yr	Rams 4 yr	Total
Number	1	3	17	2	1	5	6	1	36

Disease Agents

Bacterial pneumonias, principally Pasteurella haemolytica or P. multocida appeared to be the cause of most bighorn deaths. Both were found in lungs examined at the diagnostic laboratory of Washington State University and were cultured from nasal swabs taken during the outbreak and during the post-disease studies (most of these were P. multocida). Antibodies to parainfluenza-3 (PI_3) and bovine respiratory syncitial virus (BRSV) were also detected in some of the sera. The significance of these two viruses is unknown at this time.

Predisposing Factors

Predisposing factors such as adverse weather, overcrowding, malnutrition and excessive harassment by humans (Feuerstein et al. 1980, Spraker et al. 1984, Thorne 1987) do not appear linked to this die-off. Bighorns were in excellent physical condition, having just returned from the summer range. A fall green-up produced good winter range forage conditions. Overcrowding did not appear to be a factor since population levels had been held relatively stable by hunting and trapping and transplanting since 1978. Also, Lostine bighorns have a very large summer range and are widely scattered at low densities. No change in human use patterns was observed, and fecal lungworm larvae levels were low.

Lamb Survival after the Die-off

Post-disease production of lambs appeared to be good, with 8 lambs located in July 1987 with 13 ewes (1 yearling and 4 two-year olds) or 62 lambs per 100 ewes. In October, some of the same ewes were seen with only 1 lamb and by December when all survivors were located, only 2 lambs (10 per 100 ewes) were with the herd. Both surviving lambs were much smaller than normal, but no coughing or nasal discharge were noted. Pasteurella spp. was not detected in nasal swabs and there were no titers to PI_3 and BRSV. Nasal swabs taken from adults indicate 72% of the bighorns sampled (13 of 18) were Pasteurella multocida carriers. This Pasteurella organism may have been responsible for the high lamb mortality in summer. Pasteurella haemolytica was detected in only one sample.

MANAGEMENT IMPLICATIONS

The most important lesson learned from this study is to keep bighorns away from domestic sheep. Although hard cause-effect data relating disease in bighorns to presence of domestic sheep are lacking, it is believed Pasteurella spp. transmitted from domestic sheep was responsible for this die-off. Where separation of the two is not possible, serious disease problems can be expected as has been reported by other observers. Bighorns should not be reintroduced to ranges where contact with domestic sheep is likely.

Field treatment results were not included in this paper, but antibiotics administered to sick animals appeared to have saved many Lostine bighorns. While antibiotics were given by injection, specially formulated antibiotics in alfalfa pellets, protein blocks, or in other food sources would probably have worked better. This would have resulted in earlier treatment with less stress to the sheep and capture of most of the herd would not have been necessary. Sick animals not able to come to the trap would have had access to antibiotics.

It is also recommended that an emergency treatment procedure be established to deal with bighorn disease outbreaks in accessible herds. It is believed that had treatment with antibiotics started when the disease was first detected, many additional animals could have been saved.

Lamb survival studies and disease surveillance are planned to continue for the next two years or until lamb survival returns to normal.

LITERATURE CITED

Blood, D. A. 1963. Some aspects of behavior of a bighorn herd. Can. Field-Nat. 77:77-94.

Bailey, V. 1936. The mammals and lifezones of Oregon. North Amer. Fauna, No. 55. U.S. Dept. Agric., Bur. Biol. Surv., Washington, D.C. 416 pp.

Feuerstein, V., R. L. Schmidt, C. P. Hibler and W. H. Rutherford. 1980. Bighorn sheep mortality in the Taylor River-Altmont Triangle area, 1978-1979: A case study. Col. Div. of Wildl. Spec. Rpt. No. 48.

Foreyt, W. J. and D. A. Jessup. 1982. Fatal pneumonia of bighorn sheep following association with domestic sheep. J. Wildl. Dis. 18:164-168.

Foreyt, W. J., R. B. Westcott, R. Johnson and V. L. Coggins. 1983. Treatment for lungworms (Protostronglus spp.) in Rocky Mountain bighorn sheep. Sci. Pap. No. 6518. Col. of Agric., Res. Ctr., Pullman, Washington. pp. 1435-1439.

Spraker, T. R., C. P. Hibler, G. G. Schoonveld and W. S. Adney. 1984. Pathologic changes and microorganisms found in bighorn sheep during a stress-related die-off. J. Wildl. Dis. 20:319-327.

Thorne, E. T. 1987. Born looking for a place to die. Wyo. Wildl. March 1987. Vol. LI, No. 3:10-19.

Woodgerd, W. 1964. Population Dynamics of Bighorn Sheep on Wildhorse Island. J. Wildl. Manage. 28:381-399.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 6: 65

FATAL *PASTEURELLA HEMOLYTICA* PNEUMONIA IN BIGHORN SHEEP FOLLOWING DIRECT CONTACT WITH NORMAL DOMESTIC SHEEP - AN EXPERIMENTAL STUDY.

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Abstract: Six Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) were raised in captivity from birth (*n* = 5) or taken from the wild as a lamb (*n* = 1). After the bighorns were in captivity for over a year, 6 clinically normal domestic sheep were placed in the same 2 ha pen with the bighorns. Nasal swabs from all animals were collected at the time the domestic sheep were introduced. *Pasteurella haemolytica* was isolated from swabs from 4 to 6 domestics and 0 to 6 bighorns. All six bighorns died of acute hemorrhagic pneumonia following exposure to domestic sheep. Deaths in bighorns occurred on days 4, 27, 27, 29, 36 or 71 after initial exposure to domestic sheep. *Pasteurella haemolytica* was isolated from all bighorns at the time of death. None of the domestic sheep were clinically ill during the experiment. At the end of the experiment, 3 of 6 domestic sheep were euthanized, and at necropsy, *P. haemolytica* was isolated from 2 of the 3 domestics. The most common serotypes in bighorns and domestics were *P. haemolytica* T-3 and A-2. Other serotypes isolated included A-1, A-9, and A-11 in bighorns and domestics.

Based on this experiment and other reports, domestic sheep and bighorn sheep should not be held in proximity because of the fatal consequence in bighorns.

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A PNEUMONIA EPIZOOTIC IN BIGHORN SHEEP, WITH COMMENTS ON PREVENTIVE MANAGEMENT

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Abstract: The case history of the Sheep River bighorn sheep (*Ovis canadensis*) herd is reviewed, and management practices that may help to avoid pneumonia epizootics are discussed. The number of females in this herd increased from 48 in 1981 to 71 in 1985, with no decline in lactation rate. Fecal counts of lungworm larvae in March and April did not vary from 1981 to 1986. The winter range was heavily grazed by livestock, and affected by road construction and recreational use. The human population of the winter range increased, as did the number of dogs. A pneumonia die-off was predicted and occurred in the winter 1985-1986. An estimated 60-65 sheep (35-40% of the herd) died. Mortality was highest among lambs and young males. Recruitment was low for 2 years following the die-off. It may be possible to reduce the occurrence of pneumonia in bighorn populations through preventative management, including habitat protection and controls on harassment, interspecific competition and sheep density.

Pneumonia epizootics and habitat loss are the major threats facing bighorn sheep (Wishart 1978). While much remains to be discovered about its proximate causes, predisposing agents, and etiology, circumstantial evidence suggests that bighorn pneumonia is induced by multiple stress factors (Potts 1938, Feuerstein et al. 1980, Spraker and Hibler 1982, Spraker et al. 1984, Onderka and Wishart 1984, Bailey 1986). In addition, pneumonia can be transmitted to bighorns by domestic sheep (Foreyt and Jessup 1982). While their role is not discussed in this paper, domestic sheep could probably cause pneumonia epizootics in bighorn populations not subject to other stressors. An underlying assumption of this paper is that a major concern of bighorn sheep management is prevention of contact with domestic sheep.

Sources of stress include overcrowding, parasites, harassment, dust, competition with livestock and habitat loss. By decreasing the resource available per capita, and increasing energy expenditures, these stressors may adversely affect resistance to disease.

The bacteria believed responsible for pneumonia (*Pasteurella hemolytica* types A and T) are found in a non-pathogenic state in healthy bighorns (Dr. D. K. Onderka, Alberta Agriculture, pers. commun.). In the past, lungworms (*Prostostrongylus* spp.) were suspected to cause pneumonia (Forrester 1971). Recent evidence casts some doubt upon the importance of

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these parasites in all-age die-offs. Lungworms may be a source of stress, but not the direct cause of the disease (Festa-Bianchet 1987, Samson et al. 1987).

The aims of this paper are: 1) to present data on population dynamics and lungworm infection before and after a pneumonia epizootic; 2) to examine the pattern of mortality during the epizootic; and 3) to discuss external sources of stress that may have contributed to this die-off, and ways in which knowledge of the effects of stress, bighorn population dynamics, and pneumonia, may be used to avoid die-offs.

I thank Bill Wishart for support and friendship during the past 8 years. Assistance or advice were received from Jon Jorgenson, Wendy King, Detlaf Onderka, Doug Richardson, Val Geist, Bill Samuel, David Boag and Judith Samson. Alberta Fish & Wildlife provided field quarters, laboratory analyses and financial support. Financial assistance was also received from Alberta Recreation, Parks and Wildlife Foundation, and Natural Sciences and Engineering Research Council of Canada (scholarships to me and operating grant to V. Geist). An anonymous reviewer vastly improved the manuscript.

STUDY AREA AND METHODS

The study was conducted in the Sheep River Wildlife Sanctuary, southwestern Alberta (50°N, 114°W). The study area, sheep populations, and methods of capturing, marking and monitoring sheep have been described (Festa-Bianchet 1986a, b, 1987, 1988a, Festa-Bianchet and Jorgenson 1985). The study, initiated in March 1981, is based upon monitoring of survival, reproductive success and fecal lungworm larval counts of marked individuals. Over 250 bighorns have been marked during this study, including 97 resident females over 1 year of age. Resident females are those that winter in the wildlife sanctuary (Festa-Bianchet 1986a); since June 1982, over 85% have been marked. Unless otherwise indicated, all data reported here were collected from tagged resident sheep, or from lambs whose mothers were tagged.

The winter range in the wildlife sanctuary is easily accessible; on average over 97% of the marked females were found during searches, conducted 2-6 times/month throughout the year. Because of the high efficiency in locating tagged females during searches, and the high proportion of tagged females, I am confident that all population estimates are correct within 1 or 2 units. Females were classed as lactating if they suckled a lamb or had an obviously distended udder. Lamb survival was estimated by comparing the number of lambs born to the number alive in October or March.

Fecal samples were collected in March and April from marked females ($\bar{x}$ = 4 samples/female/year) and analyzed for lungworm larvae following Samuel and Gray (1982). A square-root transformation was performed on larval counts to achieve a normal distribution before analysis with parametric statistics (Festa-Bianchet 1987). Frequency distributions were compared with G-tests with one degree of freedom, while t-tests were used to compare means (Sokal and Rohlf 1981).

During the die-off, the sanctuary was searched for carcasses, usually revealed by ravens (Corvus corax) and magpies (Pica pica). Some carcasses were found by staff of the Forest Service and the Recreation and Parks Department. Carcasses found before the internal organs were scavenged were recovered and later necropsied by Dr. D. K. Onderka of Alberta Agriculture. Tagged sheep that disappeared were assumed to have died.

RESULTS

Demography

The number of resident females increased from 48 in 1981 to 71 in 1985, declined during the die-off (November 1985 to April 1986) and did not increase until 1988 (Fig. 1). Four females were collected and two poached in 1986, and one female each year was shot by hunters in 1986 and 1987. Natural yearly female survival in 1986-1988 averaged 94%. The lack of recovery in female numbers was likely due to poor recruitment and artificial removals. The average number of bighorns seen during searches of the winter range followed a pattern similar to that of resident females (Fig. 1). In addition to population size, the number seen during searches is affected by the amount of use of the sanctuary by males (Festa-Bianchet 1986b) and non-resident females (Festa-Bianchet 1986a).

Lactation rates did not change in 1981-1985. Among females 3 years of age and older, the frequency of lactation was 100% in 1981 and 1982 ($N = 71$ female-years), and 92% in 1983-1985 ($N = 130$ female-years). Among 2-year-olds, the proportion that lactated remained constant at 63% from 1982 to 1985 ($N = 38$) (no tagged 2-year-olds were available in 1981). In the 2 years following the die-off, lactation rate was 10% for 2-year-olds ($N = 10$), and 87% for older females ($N = 88$ female-years). The change in lactation rate before and after the die-off was significant (2-year-olds: $G = 9.94$, $P<0.005$; older females: $G = 4.83$, $P<0.05$): as female numbers declined, so did the frequency of lactation. Lamb survival to 1 year of age was 41% in 1986-1987 ($N = 37$), 36% in 1987-1988 ($N = 39$), compared to an average of about 67% in the 4 years before the die-off. The proportion of lambs that were born after 10 June increased with the number of resident ewes (Festa-Bianchet 1988c).

Counts of Lungworm Larvae

There was no change in average counts of lungworm larvae from fecal samples collected from females in March and April from 1981 to 1986 (Fig. 2). There was a large increase in 1987.

The Die-off

In August 1985, an untagged 2-year-old female was found dead. Necropsy revealed acute pneumonia. Pasteurella hemolytica type A was recovered. No other evidence of pneumonia was found during the summer and early autumn, but lamb survival to October was poor (53%, $N = 51$), compared to the average of 71% for the previous 3 years ($N = 128$) ($G = 5.71$, $P<0.03$). Causes of lamb deaths could not be determined because no carcasses were recovered. Some coughing was observed among all sheep in

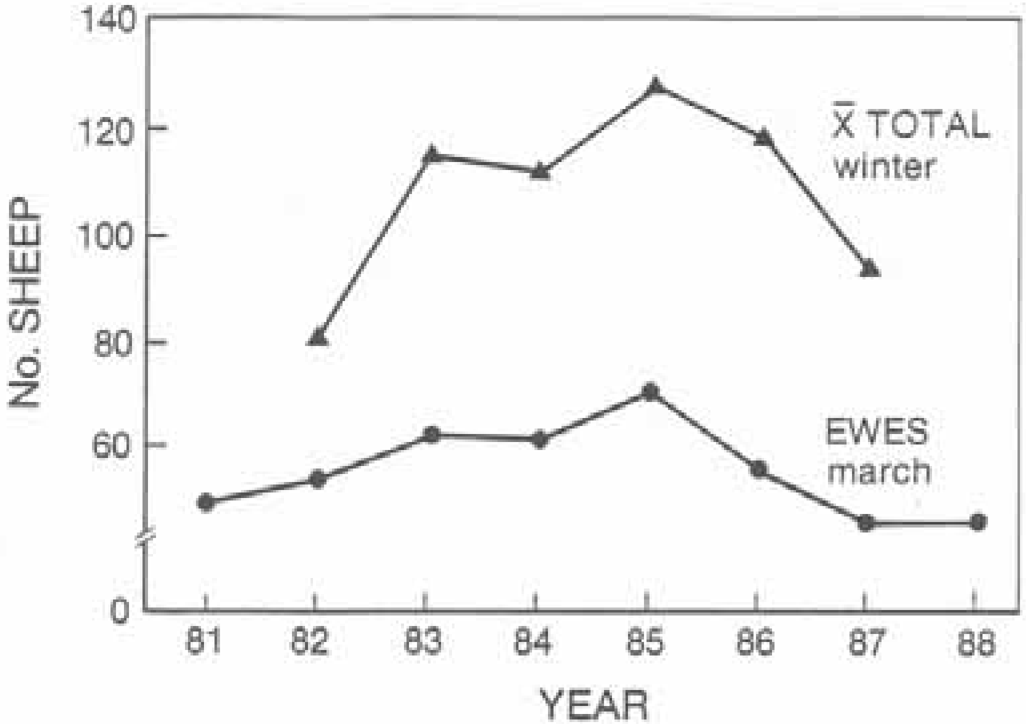

Figure 1. Average number of bighorn sheep seen during censuses of the winter range in the Sheep River Wildlife Sanctuary, Alberta, from October to March, and total number of ewes (adults and yearlings) in the Sheep River population in March of each year.

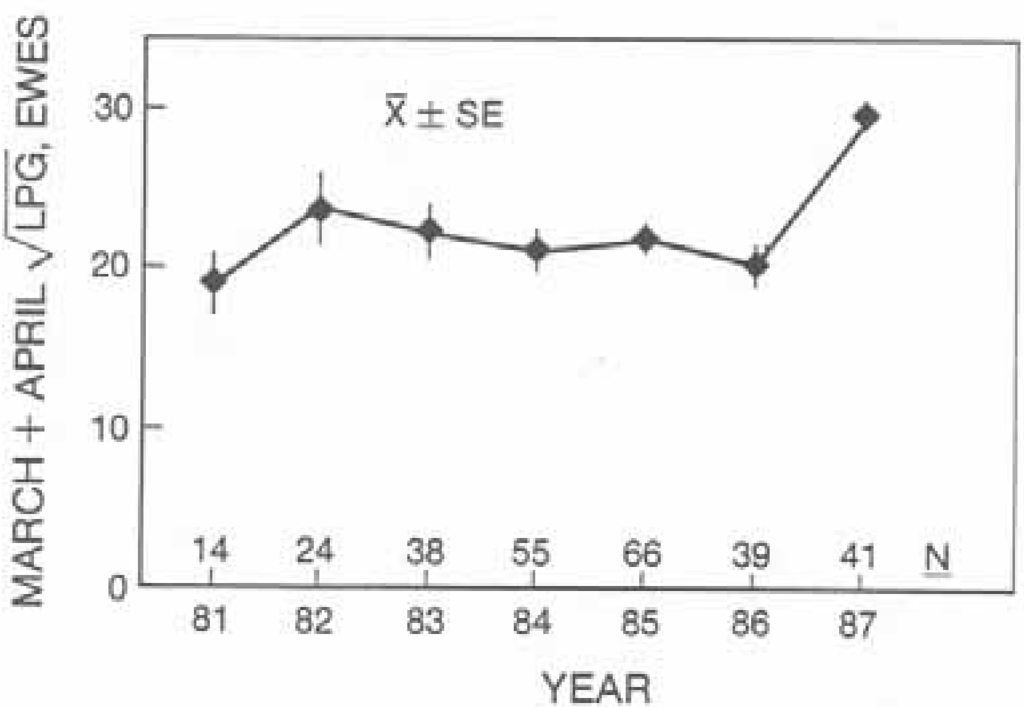

Figure 2. Average square-root transformed counts of first-stage lungworm larvae per gram of dry feces from fecal samples collected from marked resident ewes at Sheep River, Alberta, in March and April.

early autumn, but only at levels comparable to those seen in the previous 3 years.

The all-age die-off (Spraker and Hibler 1982) started in the second week of November. By the end of the month, 18 carcasses had been found, 1 apparently unhealthy female had been shot and a few more marked sheep were missing. At least 8 sheep died in December. Later, the rate of mortality declined, but sheep continued to die until early April. In total, remains of 37 bighorns were found, and a further 20 marked sheep disappeared. I estimated a total loss of 60-65 individuals, not counting the lambs that died before November. It is likely, however, that not all deaths were related to the epizootic.

Sheep of all sex and age classes died during the epizootic (Fig 3), except for yearling females and males older than 6 years. Only 1 of 8 tagged males 6 years of age and older died during the die-off. Yearling males were one of the sex-age classes most affected. In addition to the 6 tagged ones (Fig. 3), 4 untagged yearling males were recovered dead. Mortality among yearlings was significantly higher for males than for females (Fisher exact text, $\underline{P} = 0.01$). Only 7 of 53 lambs born in 1985 (13%, including the lambs born to the 2 remaining untagged females) survived to 1 year of age.

Of 11 carcasses necropsied, P. hemolytica type A was recovered from 7, and type T from 2 lambs. No signs of pneumonia were evident in at least 3 dead sheep from which type A was recovered, and cause of death could not be determined for 2 others. The dead sheep appeared in good condition, with no obvious evidence of malnutrition.

Ewes that died during the epizootic appeared to have had higher fecal counts of lungworm larvae in the previous March-April, but the difference was not significant (Fig. 4). Ewes that bred as yearlings were more likely to die during the epizootic (6 of 22) than females that had not bred as yearlings (none of 11) (Festa-Bianchet 1987).

DISCUSSION

External Sources of Stress

The winter range was subject to heavy grazing by livestock, road construction and other potential sources of stress. Cattle grazing occurred from mid-June to early October. In 1984 and 1985, 100 to 300 cattle were in the winter range for most of the summer. By September in both years the grass over the entire range was grazed down to less than 5 cm. Two to 5 horses wintered in the wildlife sanctuary, and the number of horses increased to 7-11 from May to October. Drought in 1984 and 1985 may have lowered the productivity of the range.

Road construction in 1982-1985 destroyed 10-12 hectares of winter range, and at times generated considerable dust pollution. Sheep were seen sneezing and rubbing their noses, which appeared irritated by dust. Dust has been implicated as a predisposing agent in other pneumonia epizootics (Spraker et al. 1984). Reclamation of the areas destroyed by road construction either did not begin or was unsuccessful until 1986.

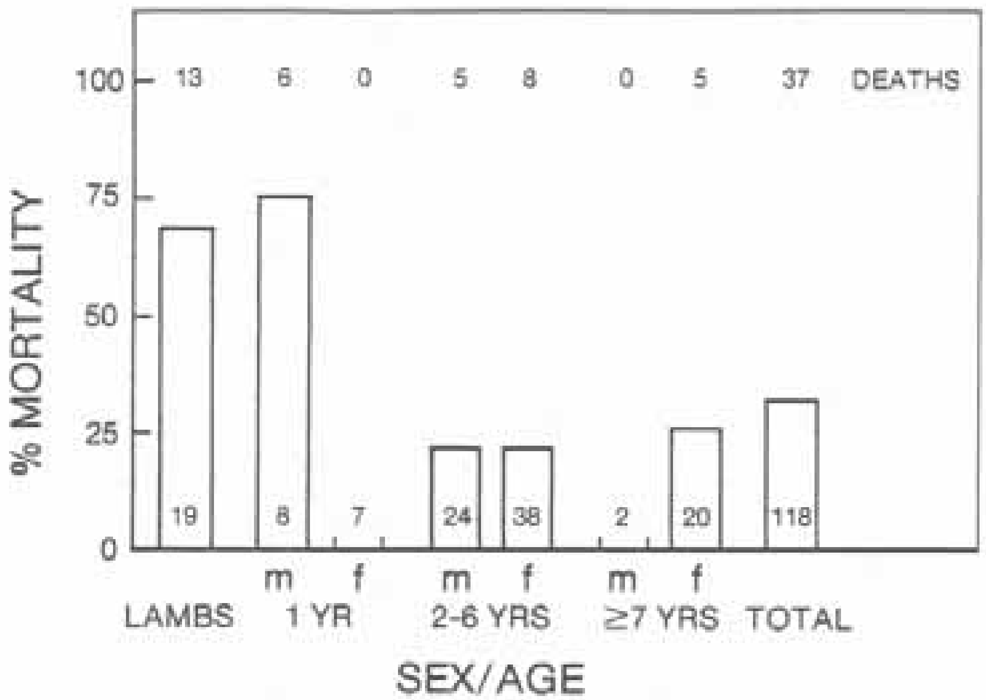

Figure 3. Tagged bighorn sheep that died during the 1985-1986 pneumonia epizootic at Sheep River, Alberta. Numbers in bars refer to marked sheep of each class alive at the onset of the epizootic. Percent mortality was calculated from this sample.

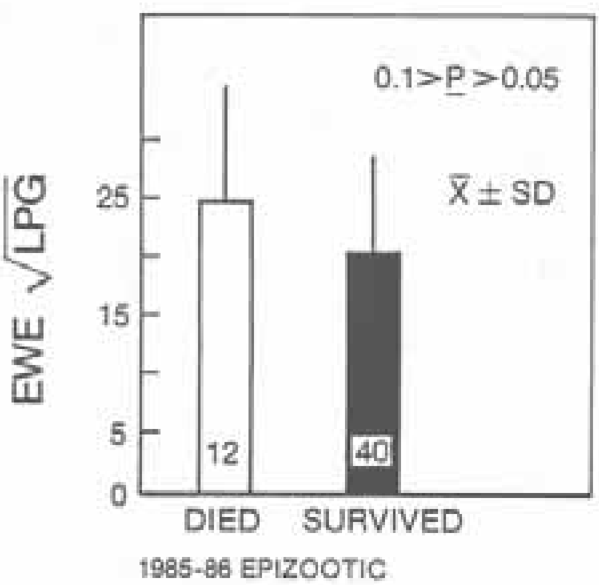

Figure 4. Average square-root transformed counts of lungworm larvae per gram of dry feces in March and April 1985 for ewes that died during the 1985-1986 pneumonia epizootic, and ewes that survived the epizootic. Numbers in bars indicate sample size.

The sheep were habituated to people in the wildlife sanctuary. Instances of harassment by tourists were rare, and almost always involved dogs or amateur photographers without telephoto lenses. The number of people residing in the wildlife sanctuary (mostly government employees) increased to about 12-20 in the summer and 6-8 in the winter. Two to 5 dogs were kept by these people, and several instances of sheep-chasing by dogs were observed. The sheep appeared to avoid areas near residences where dogs were kept unleashed. In late summer 1985, I was led by these circumstances to predict that a pneumonia die-off was imminent.

Possible Causes of the Die-off

The cause of this die-off cannot be determined with certainty. I believe that it was brought about by an increase in sheep numbers and abuse of the winter range. An important unanswered question is whether or not this die-off would have occurred without the human-related sources of stress.

Under normal circumstances, in a healthy bighorn population, the immune system can probably prevent invasion by pneumonia pathogens. The immune response, however, can be impaired by inadequate nutrition (Chandra 1972). Presumably, outside stresses that require the expenditure of metabolic energy have the same effect. Bighorns whose habitat is destroyed or overgrazed, and that are harassed or prevented by dogs or people from using parts of their range, are likely to suffer nutritional stress, which may in turn affect their immune system.

In the past, emphasis has been placed upon a causative role of lungworms in bighorn pneumonia (Forrester 1971). The term "lungworm-pneumonia complex" is widely used (Huschley and Worley 1986; Layne and McCabe 1986). There is, however, no clear evidence that lungworms cause pneumonia, except in the case of lamb mortality following transplacental infection (Spraker 1979). Most (possibly all) bighorns have lungworms (Uhazy et al. 1973; Festa-Bianchet 1987), but normally do not develop pneumonia. Lungworm parasitism is likely a source of metabolic stress, but other parasites may have a similar effect. "Stress-related pneumonia" (Spraker et al. 1984) is a better name for this disease. The difference in lungworm larval counts for females that died or survived the epizootic (Fig. 4) is difficult to interpret because it is not significant. Possibly, some individuals had a particularly ineffective immune system, and were at the same time unable to curb the reproductive performance of their lungworms (Wakelin 1984; Gibbs and Barger 1986) and unable to prevent invasion by pneumonia pathogens. Lungworm larval counts appear to correlate with body condition of individual sheep (Festa-Bianchet 1987).

Predictor Variables

Average larval counts for all females (Fig. 2) did not change from 4 years before to 2 years after the die-off, and the very high larval counts of March and April 1987 were not followed by pneumonia. Clearly, monitoring fecal counts of lungworm larvae is not a reliable way to predict pneumonia epizootics. This technique would be particularly ambiguous when samples are not collected from known individuals and when the raw data are analyzed with parametric statistics without transformation (Festa-Bianchet 1987, 1988b; Festa-Bianchet and Samson 1984).

Coughing is not always a predictor of pneumonia, but frequent and violent coughing bouts are not normal and warrant further investigation. Much more frequent and violent coughing than that observed in 1985 was seen in this herd preceeding the 1978 die-off (Wishart et al. 1980), and in the autumn of 1981, when no evidence of pneumonia was found. It would be useful to obtain data on prevalence of coughing bouts in other herds. Coughing is frequently reported before and during pneumonia die-offs (Feuerstein et al. 1980; Spraker and Hibler 1982; Onderka and Wishart 1984), but there is little information on its occurrence outside of pneumonia epizootics. It is also unclear whether individuals that cough frequently and violently are more likely to develop pneumonia than individuals that cough less.

Population parameters also failed to provide a clear warning of a deteriorating situation, with the possible exception of the increase in frequency of late-born lambs (Festa-Bianchet 1988c). Lambing dates, however, are difficult to determine. The prevalence of lactation among young females should have declined with the increase in population size (Jorgenson and Wishart 1986). Instead, it remained constant until after the die-off. Population dynamics after the epizootic, particularly lamb survival, may reflect lingering effects of the disease and therefore not show the expected density-dependent relationships (Wehausen et al. 1987).

The die-off described here differed from other pneumonia epizootics (Feuerstein et al. 1980; Onderka and Wishart 1984; Spraker et al. 1984). Pneumonia could not be diagnosed in some of the dead sheep, and mortality did not show the characteristic bias towards older males. There was no evidence that the pneumonia spread to neighboring herds, despite known contact with the Sheep River group (Festa-Bianchet 1986a,b).

Stelfox (1976) hypothesized that bighorn populations that increase in density will suffer die-offs before they reach a balance with their environment. Hoefs and Bayer (1984) convincingly argued that this hypothesis does not apply to Dall sheep (Ovis dalli). It may apply to some bighorn populations, possibly those that have been exposed to domestic livestock (Goodson 1982). Long-term studies of other populations are required to determine under what circumstances (other than exposure to domestic sheep) pneumonia epizootics are likely to occur among bighorns. The available evidence (Potts 1938; Feuerstein et al. 1980; Bailey 1986; this study) suggests that to avoid pneumonia management must be preventive.

Preventive Management

The ideal management strategy for bighorn sheep should include habitat protection and population control. Control would only be necessary when predation and other natural sources of mortality are low. It is difficult to establish what is a "safe" population size, but large increases in established populations should be avoided. Habitat protection must be an integral part of any management strategy for bighorn sheep. In the Sheep River case, political expediency and local incompetence overrode wildlife concerns, and may have caused the die-off. Hope-fully this case history can be used to prevent similar abuses of bighorn habitat in the future. Potts (1938) suggested that pneumonia can be avoided through habitat protection. Fifty years later, this basic principle of bighorn management is sometimes ignored by local authorities.

Unleashed dogs, heavy grazing by livestock, and extensive habitat destruction cannot be allowed in bighorn ranges if the goal is to preserve the sheep population. Bighorn sheep can habituate to human presence and because they occupy open habitat they can be easily observed. At Sheep River, bighorn harassment by tourists was uncommon and did not affect the behavior of the sheep, with a few unfortunate exceptions. In preparing programs to protect bighorn sheep ranges, managers must strike a balance between uses that should be tolerated or encouraged, and abuses that should be prevented. There is a strong need for more case reports, both of pneumonia epizootics and of circumstances when suspected outside stress did not result in pneumonia. These data are necessary to provide guidelines for managers in deciding how much stress is too much stress.

LITERATURE CITED

Bailey, J. A. 1986. The increase and die-off of Waterton Canyon bighorn sheep: biology, management and dismanagement. Bienn. Symp. North. Wild Sheep and Goat Counc. 5:325-340.

Chandra, R. K. 1972. Immunocompetence in undernutrition. J. Pediatrics, 81:1194-1200.

Festa-Bianchet, M. 1986a. Seasonal dispersion of overlapping mountain sheep ewe groups. J. Wildl. Manage. 50:325-330.

________. 1986b. Site fidelity and seasonal range use by bighorn rams. Can. J. Zool. 64:2126-2132.

________. 1987. Individual reproductive success of bighorn sheep ewes. Ph. D. Thesis, University of Calgary.

________. 1988a. Age-specific reproduction of bighorn ewes in Alberta, Canada. J. Mammal. 69:157-160.

________. 1988b. Nursing behaviour of bighorn sheep: correlates of ewe age, parasitism, lamb age, birthdate and sex. Anim. Behav. 36:in press.

________. 1988c. Birthdate and survival in bighorn lambs (Ovis canadensis). J. Zool. 214:653-661.

________ and J. T. Jorgenson. 1985. Use of xylazine and ketamine to immobilize bighorn sheep in Alberta. J. Wildl. Manage. 49:162-165.

________ and J. Samson. 1984. Lamb survival in relation to maternal lungworm larval output in bighorn sheep. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:364-371.

Feuerstein, V., R. L. Schmidt, C. P. Hibler and W. H. Rutherford. 1980. Bighorn sheep mortality in the Taylor River-Almont Triangle area, 1978-1979: a case study. Spec. Report No. 48, Colorado Div. Wildl., Denver.

Forrester, D. J. 1971. Bighorn sheep lungworm-pneumonia complex. Pp. 158-173 in: J. W. Davis and R. C. Anderson (Eds.), Parasitic Diseases of Wild Mammals. Iowa State Univ. Press, Ames.

Gibbs, H. C. and I. A. Barger. 1986. Haemonchus contortus and other trichostrongylid infections in parturient, lactating and dry ewes. Vet. Parasit. 22:57-66.

Goodson, N. J. 1982. Effects of domestic sheep grazing on bighorn sheep populations: a review. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:287-313.

Hoefs, M. and M. B. Bayer. 1984. Demographic and characteristics of an unhunted Dall sheep (Ovis dalli dalli) population in southwest Yukon, Canada. Can. J. Zool. 61:1346-1357.

Huschley, C. and D. E. Worley. 1986. Long-term effects of Ferbendazole on lungworm infections in transplanted bighorn sheep. Bienn. Symp. North. Wild Sheep and Goat Counc. 5:222-230.

Jorgenson, J. T. 1988. Environmental impact on the Mounta Allan bighorn sheep herd - the Olympics story. Bienn. Symp. North. Wild Sheep and Goat Counc. 6:(this issue).

________ and W. D. Wishart. 1986. Ram Mountain bighorn sheep project - Progress Report 1984 and 1985. Alta. Fish & Wildlife Div., Edmonton. 72 pp.

Layne, L. J. and T. R. McCabe. 1986. Use of Ivermectin to increase lamb survival in a herd of Rocky Mountain bighorn sheep. Bienn. Symp. North. Wild Sheep and Goat Counc. 5:207-221.

Onderka, D. K. and W. D. Wishart. 1984. A bighorn die-off from pneumonia in southern Alberta (1982-1983). Bienn. Symp. North. Wild Sheep and Goat Counc. 4:356-363.

Potts, M. K. 1938. Observations on disease of bighorn in Rocky Mountain National Park. Trans. North Am. Wildl. Conf. 3:893-897.

Samson, J., J. C. Holmes, J. T. Jorgenson and W. D. Wishart. 1987. Experimental infection of free-ranging Rocky Mountain bighorn sheep with lungworm. J. Wildl. Dis. 23:396-403.

Samuel, W. M. and J. B. Gray. 1982. Evaluation of the Baermann technique for recovery of lungworm larvae from wild ruminants. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:163-172.

Sokal, R. R. and F. J. Rohlf. 1981. Biometry. 2nd ed. W. H. Freeman and Co., San Francisco.

Spraker, T. R. 1979. The pathogensis of pulmonary protostrongylosis in bighorn lambs. Ph. D. Thesis, Colorado State University, Boulder.

________ and C. P. Hibler. 1982. An overview of the clinical signs, gross and histological lesions of the pneumonia complex of bighorn sheep. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:163-172.

________, ________, G. G. Schoonveld and W. S. Adney. 1984. Pathologic changes and microorganisms found in bighorn sheep during a stress-related die-off. J. Wildl. Dis. 20:319-327.

Stelfox, J. G. 1976. Range ecology of Rocky Mountain bighorn sheep. Report Series No. 39, Canadian Wildl. Service.

Uhazy, L. S., J. C. Holmes and J. G. Stelfox. 1973. Lungworms in the Rocky Mountain bighorn sheep of western Canada. Can. J. Zool. 51:817-824.

Wakelin, D. 1984. Immunity to Parasites. Edward Arnold, London.

Wehausen, J. D., V. C. Bleich, B. Blong and T. L. Russi. 1987. Recruitment dynamics in a southern California mountain sheep population. J. Wildl. Manage. 51:86-98.

Wishart, W. D. 1978. Bighorn Sheep. Pp. 161-171 in: J. L. Schmidt and D. L. Gilbert (Eds.), Big Game of North America. Stackpole Books, Harrisburg, PA.

________, J. T. Jorgenson and M. Hilton. 1980. A minor die-off of bighorns from pneumonia in southwestern Alberta (1978). Bienn. Symp. North. Wild Sheep and Goat Counc. 2:229-245.

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and Goat Council 6: 77 - 83

LUNGWORM SURVEILLANCE IN BIGHORN SHEEP: POSSIBLE APPLICATIONS FOR POPULATION DENSITY ESTIMATES AND RANGE USE ASSESSMENT

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Abstract: Population trends of certain wild ungulates (e.g., white-tailed deer) have been shown to be roughly proportional to the prevalence and intensity of the large stomach worm, *Haemonchus contortus*. Although comparable data on gastrointenstinal helminth levels in bighorn sheep seldom are available, information on lungworm (*Protostrongylus* spp.) infections frequently is accessible because of the assumed role of this nematode in the lungworm-pneumonia respiratory disease complex in *Ovis canadensis*. In addition to the direct application of lungworm prevalence data for herd health assessment, the possibility of utilizing *Protostrongylus* counts as an index for correlating herd densities and chronological fluctuations in population numbers warrants consideration as a possible management tool. In order to test this hypothesis, estimates of the size of bighorn herds on summer or winter ranges were examined in relation to fecal output of protostrongylid larvae and/or an appraisal of lung lesions and worm counts postmortem in 3 Montana herds ranging in size from less than 100 sheep to more than 800 animals. A retrospective assessment of the relevance of this technique for estimating population densities and evaluating range use relationships in bighorn herds suggested that fecal larval counts paralleled herd growth for a time in expanding populations, but failed to show consistent correlations as bighorn populations continued to grow. Postmortem worm counts showed a tentative relationship to degree of lung involvement, but were useful primarily to supplement fecal analysis data and relate respiratory tract lesions to specific types and numbers of adult parasites.

The role of disease in regulation of wild ungulate populations is recognized as a significant factor in certain instances, e.g. the lungworm-pneumonia complex in bighorn sheep (Buechner, 1960; Forrester, 1971). The well documented history of recurring respiratory disease problems in Rocky Mountain bighorn sheep and the consistent occurrence of protostrongylid lungworms in affected herds has led to the assumption that this parasite is involved either directly or as a predisposing agent in triggering outbreaks of respiratory disease (Uhazy and Holmes, 1971;

Lange, 1974; Schmidt et al., 1979). As a consequence, surveillance of lungworm incidence has become a common practice to monitor rates of infection and assess the risks that appear to be associated with high Protostrongylus levels.

Additional applications of lungworm prevalence data may emerge as indices reflecting fluctuations in herd densities and in effect could serve as an early warning system for identifying bighorn populations approaching critical levels, particularly in rapidly expanding herds. Previous efforts to relate parasite intensity to ungulate herd density have been described by Eve and Kellogg (1977) and Demerais et al. (1983), who demonstrated that correlations may exist between abomasal nematode counts (Haemonchus sp.) and the density of white-tailed deer herds in southeastern United States. Based on analysis of lungworm infection data from several Canadian bighorn herds, Holmes and Samuel (1974) postulated that Protostrongylus levels might reflect the condition status of mountain sheep populations because of implicit parasite involvement in the lungworm-pneumonia disease complex. In the present paper, the relationship between lungworm levels and population densities was evaluated to see if lungworm larval shedding rates and/or relative worm populations and lung lesions might serve as an analytical tool for estimating population densities and/or range status in 3 western Montana bighorn herds.

METHODS

Rate of excretion of lungworm larvae in bighorn feces was estimated with the Baermann technique (Thorne, 1983). Fecal samples collected on bedgrounds or around feeding sites at monthly or quarterly intervals were stored in paper bags at approximately 4°C until they were processed in the lab. Quantitative counts of larval output were based upon the number of first stage larvae isolated from 2-10 g. pellet groups after suspension in tap water for 12-18 hours at room temperature. Larval counts were expressed as larvae per gram of feces (LPG). These data were used to derive a lungworm index which was calculated by multiplying the percentage of infected sheep by the mean larval output for the group at each sample interval.

Supplementary data on lungworm infection intensity and species occurrence was based on postmortem examination of respiratory tracts from hunter-killed sheep, road kills, and individuals taken for research purposes. After the respiratory tract was removed intact, the pleural surfaces of the lung were examined for plaques, nodules, bullae or other lesions characteristic of infection with the parenchymal lungworm, Protostrongylus stilesi. The trachea, bronchi and major bronchioles were opened longitudinally with scissors and the epithelial surfaces were examined grossly for P. rushi adults. The entire tract then was chopped into approximately 1 x 2 inch pieces which were agitated in warm saline solution on a reciprocating shaker for 30-45 minutes in an attempt to recover larval or adult forms embedded in lung parenchyma. Worms recovered by this procedure were counted and identified to species where feasible, using the criteria of Honess and Winter (1956) and Thorne et al. (1983). Several bighorn foetuses also were examined to determine whether prenatal lungworm infections occurred in lambs born to infected ewes. Respiratory tracts from foetal lambs were removed intact, chopped into small pieces, and digested in pepsin-hydrochloric acid solution for 14-16 hours at 37°C to assay for the presence of larval or adult lungworms. The resulting tissue digests were washed on a fine mesh screen to collect Protostrongylus specimens recovered from infected tissue. A total of 806 fecal examinations and 40 necropsies performed on the Ural-Tweed, Thompson River and Sun River bighorn herds were analyzed retrospectively as the basis for this report. Previous data on lungworm prevalence and intensity in these herds are in Worley et al. (1976).

Estimates of herd size used for comparative purposes in this study were based on annual census data calculated from aerial and/or ground surveys made each year in mid- to late winter to include all age classes prior to lambing. A correction factor was employed in certain instances to compensate for the inability to verify total numbers in the Ural-Tweed and Thompson River herds where heavily forested habitat made accurate counts difficult. This was based on the assumption that only about 75% of the sheep present in the area were actually observed during each count. Hence, each estimate of total numbers was arbitrarily increased by 25%. A repetitive Lincoln-Index method utilizing marked animals was used during the early years of the Thompson River study to derive population estimates.

RESULTS

Ural-Tweed Herd

Prevalence and intensity of Protostrongylus infections were monitored via fecal analysis in this northwestern Montana herd at 5 intervals during the 11-year period from 1976 to 1987 (Table 1). The lungworm index doubled in the early years of the study during a period of static herd size ranging between 25 and 40 animals. Growth of the herd over the next 7-8 years roughly paralleled the rise in lungworm infection levels. During the next three years, herd size continued to increase, while the lungworm index decreased to negligible levels.

During this 11-year period the proportion of larval counts that exceeded 100 LPG paralleled the lungworm index curve closely, i.e. the fewest counts >100 occurred at the beginning and end of the period when counts were lowest and peaked in 1985-86 when lungworm prevalence and intensity were highest. A 212% increase in herd size was accompanied by a 19% increase in mean Protostrongylus counts, based on 505 sheep sampled during the 1976-87 interval. Total range area available to this herd was relatively constant at approximately 9477 hectares and did not vary seasonally.

Incidental findings derived from postmorten examinations on 6 sheep of either sex ranging in age from 1 1/2 to 6 years revealed extensive lung lesions suggestive of clinical lungworm-pneumonia syndrome in only 1 animal. The parenchymal lungworm (P. stilesi) occurred in a single sheep, whereas P. rushi was present in low to moderate numbers (1-44 worms) in 5 sheep. Concurrent infections with both lungworm species were seen in only 1 animal. The single sheep with clinically significant lung lesions was examined during the third year of the study prior to the rapid expansion of the herd.

Table 1. Relationship of lungworm larval counts to estimated size of Ural-Tween bighorn herd (1976-87).

Sampling period	% infected	Av. *Protostrongylus* count (L.P.G.)	% counts >100 L.P.G.	Herd Size
1976-77	80 (40/50)	5.3	0	25-40
1978	85.3 (204/239)	9.5	1.2	25-40
1985 - early 86	96.2 (75/78)	49.1	7.6	60-70
1986	78.5 (62/79)	26.1	7.5	80-90
1987	76.2 (45/59)	6.3	0	100
CHANGE:	-4%	+19%		+212%

Thompson River Herd

This herd occupies approximately 28,560 hectares of forest range adjoining the Thompson River in northwestern Montana. Prevalence and intensity of lungworm infections were monitored via fecal examinations at 4 intervals during the nine-year period between 1973 and 1982 (Table 2). Quantitative Baermann examinations based on 301 fecal samples indicated that lungworm larval shedding levels at the beginning of the study in 1973 increased about 427% by 1981. During the same period, total sheep numbers increased by 82%. The resident sheep population has continued to increase at about a 20% annual rate since 1982, with very limited postmortem data suggested that no major change in *Protostrongylus* infection levels has occurred concurrently.

Detailed postmortem analysis of 14 sheep between 1973-80 indicated consistently low adult lungworm populations throughout this period. Of 5 adult ewes, 3 rams and 1 yearling ewe examined at necropsy, 3 sheep were infected with *P. stilesi*, 2 with *P. rushi*, and 4 were negative for adult lungworms. Total worm burdens were less than 5 in all instances. Lungs of 2 sheep with *P. stilesi* and 1 with *P. rushi* had lesions consisting of raised plaques or nodular foci under the pleura. None of 5 near-term (March-May) foetuses from pregnant ewes with active lungworm infections showed evidence of prenatal *Protostrongylus* infections. No gross lesions were seen in respiratory tracts of these lambs.

Sun River Herd

Chronological changes in lungworm infection levels in Sun River sheep were monitored over a 13-year period in which major fluctuations occurred in the size of the herd (Table 3). The range occupied by these

Table 2. Relationship of lungworm larval counts to estimated size of Thompson River bighorn herd (1973-82).

Sampling period	% infected	Av. *Protostrongylus* count (L.P.G.)	% counts >100 L.P.G.	Herd Size
1973	73 (33/45)	26.6	8.8	241
1974	88 (136/155)	25.7	7.7	241
1981	62 (37/60)	140.4	5.0	438
1982	93 (38/41)	29.7	4.8	481
CHANGE:	+27%	+12%		+100

Table 3. Herd size in relation to lungworm levels in the Sun River bighorn population (1971-84).

Year	Herd Size	No. sheep infected / Total no. examined	Adult lungworms/sheep: *P. stilesi*	Adult lungworms/sheep: *P. rushi*	Lungworm larvae*
1971	589	4/4	0	13	<1
1973	880	4/5	4	3	<1
1976	1000	1/1	0	8	7
1984	600	5/9	only fragments recovered; total no. indeterminate	184	9

* Expressed as larvae/g of feces

sheep consists of approximately 80,862 hectares of reefs, cliffs and ridges interfacing with foothills grassland along the east front of the Rocky Mountain chain. Historically, this area has supported the largest bighorn herd in the region.

Baseline necropsy observations in 1971 indicated that the predominant lungworm species in a small sample of the herd was *P. rushi*, with pleural adhesions and fibrinous pleuritis present in some animals. Additional postmortem observations in 1973 demonstrated that *P. stilesi* was present in 3 of 5 adult ewes selected at random from a herd then numbering about 880. Two of the 3 sheep also had concurrent infections with *P. rushi*. Emphysematous areas in the diaphragmatic lobes of the lung and/or areas of patchy congestion were evident in 4 of 5 adult sheep examined.

Continued growth of the population during the next 6-8 years culminated in a herd of 1000-1200 sheep. Limited postmortem data during this period did not indicate that a parasite buildup was occurring. However, an extensive die-off apparently correlated with severe respiratory problems began in early 1984, following similar outbreaks in British Columbia and Alberta (Onderka and Wishart, 1984). Examination of 9 adult ewes and rams showing varying degrees of respiratory disease revealed a marked increase in *Protostrongylus* numbers in some animals, usually accompanied by signs of bronchopenumonia. Extensive areas of congestion were common in the diaphragmatic lobes, along with raised plaques under the pleura. Populations of 200-500 adult lungworms were observed in some sheep. A mortality rate of approximately 40% reduced the herd to about 600 animals within 3-6 months.

DISCUSSION

The ability to recognize fluctuations in lungworm infection levels and relate them to bighorn population trends appeared to have some application in both the Ural-Tweed and Thompson River studies, where a steady growth in both herds over an 8-9 year period was accompanied by a proportionate increase in lungworm indices. Increases in larval output and the proportion of infected Ural-Tweed sheep preceded an approximately 2-fold increase in herd size over a 7-year period (1978-85). In the Thompson River herd, fecal larval counts and herd numbers increased simultaneously over an 8-year period. In both herds, larval shedding rates decreased precipitously at this point while sheep numbers continued to increase. This suggests that herd immunity to lungworms may reach an effective level after adequate exposure occurs in a growing population to the point that it either actually reduces the prevalence of infection via a "self-cure" response (Stewart, 1955) or merely appears to do so by reducing fecundity of the existing lungworms. In either instance, it makes interpretation of lungworm larval counts more difficult and in general reduces the predictive value of fecal analysis data. Other biological criteria of value for judging overall herd health status, in conjunction with lungworm monitoring, include routine determinations of lamb/ewe ratios, field morbidity and mortality observations, and incidence of coughing and other signs of respiratory disease under field conditions.

Little or no opportunity existed during the present study to evaluate the feasibility of using lungworm larval discharge rates for anticipating overcrowding likely to trigger episodes of field mortality. Quantitative fecal analysis data collected at regular intervals appeared to be the preferred method for monitoring lungworm status of a herd. Postmortem findings can be a useful adjunct to relate lung lesions to specific numbers and types of *Protostrongylus* adults and to determine the extent of lung damage. However, the number of necropsy specimens required to estimate herdwide parasite loads accurately probably would be impractical to collect in most instances because of the large number of sheep required for examination to compensate for individual variability in worm numbers.

LITERATURE CITED

Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present, and future. Wildl. Monogr. 4. 174 pp.

Demerais, S., H. A. Jacobson and D. C. Guynn. 1983. Abomasal parasites as a health index for white-tailed deer in Mississippi. J. Wildl. Manage. 47:247-252.

Eve, J. H. and F. E. Kellogg. 1977. Management implications of abomasal parasites in southeastern white-tailed deer. J. Wildl. Manage. 41:169-177.

Forrester, D. J. 1971. Bighorn sheep lungworm-pneumonia complex. Pp. 158-173 in Parasitic Diseases of Wild Mammals, J. W. Davis and R. C. Anderson, eds. Iowa State Univ. Press, Ames.

Holmes, J. C. and W. M. Samuel, 1974. Surveillance study of the parasites of bighorn sheep in the mountain national parks. Typewritten Report, Dept. of Zoology, University of Alberta, Edmonton, 22 pp.

Honess, R. F. and K. B. Winter. 1956. Diseases of Wildlife in Wyoming. Pp. 182-188. Wyoming Fish and Game Commission, Cheyenne.

Lange, R. 1974. Cause and nature of mortality in bighorn sheep. Pp. 104-107 in Constan, K. J. and J. L. Mitchell (Eds.), Proc. Bienn. Symp. North. Wild Sheep Counc., Great Falls, MT 146 pp.

Onderka, D. K. and W. D. Wishart. 1984. A major bighorn sheep die-off from pneumonia in southern Alberta. Pp. 356-363 in E. T. Thorne (Ed.), Proc. Bienn. Symp. North. Wild Sheep and Goat Counc., Yukon Wildlife Branch, Whitehorse. 513 pp.

Schmidt, R. L., C. P. Hibler, T. R. Spraker and W. H. Rutherford. 1979. An evaluation of drug treatment for lungworm in bighorn sheep. J. Wildl. Manage. 43:461-467.

Stewart, D. F. 1955. Self-cure in nematode infestations of sheep. Nature 176:1273-1274.

Thorne, E. T. (ed.). 1982. Diseases of Wildlife in Wyoming. Second Edition. Wyoming Game and Fish Dept., Cheyenne. 353 pp.

Uhazy, L. S. and J. C. Holmes. 1971. Helminths of the Rocky Mountain bighorn sheep in western Canada. Can. J. Zool. 49:507-512.

Worley, D. E., S. T. Stewart and T. Komberec. 1976. Lungworm infection in Montana bighorn sheep -- A Re-examination. Pp. 83-88 in E. T. Thorne (Ed.), Proc. Bienn. Symp. North. Wild Sheep Counc., Wyoming Game and Fish Dept., Cheyenne. 165 pp.

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LUNGWORM LARVAE DISCHARGE LEVELS WITHIN THE URAL-TWEED BIGHORN SHEEP POPULATION

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Abstract: Seasonal and annual variation in lungworm (*Protostrongylus* spp.) infection and larvae shedding within a population of bighorn sheep indigenous to the coniferous forests of northwestern Montana are examined. Fecal samples were collected in 1976 to 1978 after a severe die-off and the bighorn population was at a low, and 1985 to 1987 after a period of population recovery. Lungworm prevalence for the 2 periods were similar, averaging 84.4% and 81.5% respectively. Larvae shedding was also similar with very low numbers of larvae per gram of sheep feces. Ninety percent of the fecal samples examined contained <30 larvae per gram of sheep feces. Significant variation between months was observed for both the prevalence and larvae output.

The potential role of the lungworm-pneumonia complex as an important mortality factor in Rocky Mountain bighorn sheep has long been recognized (Buechner 1960, Forrester 1971, Stelfox 1976). Monitoring and evaluation of both lungworm prevalence and levels of discharge of first-stage larvae (L_1) in the feces have become a regular part of bighorn sheep management programs and studies. Often these collections and associated analyses are of short duration or conducted only during a particular season. Two studies of the Ural-Tweed bighorn sheep population have provided yearlong collections of fecal material for analysis of lungworm levels within the population.

The Ural-Tweed bighorn sheep population, the only native herd remaining in northwestern Montana, occupies a long, narrow band of over-steepened, heavily-timbered terrain (9,470 ha) along the east shore of Lake Koocanusa between Libby and Eureka, Montana. This herd numbered approximately 150-200 sheep during the 1950s and early 1960s (Blair 1955, U.S. Dep. Inter. 1965). During the late 1960s and early 1970s, the population suffered a die-off and numbered 25-40 animals in 1978 (Brown 1979). Currently the population is undergoing steady growth and numbers approximately 100 animals (Yde, unpub. data). The first of the 2 studies was conducted by Brown from 1976 to 1978 at a time when the population was at a low level following the die-off. The second set of data was collected by Yde from 1985 to 1987 as the population started to recover. The information on lungworm prevalence and L_1 larvae discharge rates that has been collected will provide a baseline for comparison as the population continues to grow and responds to large-scale habitat treatments, which are being completed on the range.

The U.S. Army Corps of Engineers (Contract No. DACW67-76-C-0083) and Bonneville Power Administration (Contract No. 84-39) provided funding for the 1976-78 and 1984-87 projects, respectively.

METHODS

Fecal material was collected from known bighorn sheep defecations. From October 1976 through April 1977, a total of 50 fecal pellet groups were collected; 23 in 1976 and 27 in 1977. During 1978, 240 fecal pellet groups were collected at a rate of 20 samples per month. From May 1985 through December 1987, 3-34 samples were collected monthly, with the exceptions of October 1985, and March and June 1986 when no samples were collected. During the 1985-87 study period, direct observation of bighorn sheep defecations were made as conditions permitted. This resulted in classification of the fecal samples to bighorn sheep sex and age class. During both studies the individual samples were stored in paper bags at approximately 4°C until they were processed at the Montana Veterinary Research Laboratory, Bozeman, Montana. The Baermann technique (Baermann 1917) was used to determine the number of lungworm larvae per gram fecal material.

Postmortem examination of the respiratory tracts obtained from 8 sheep mortalities - road kills, predation, poaching and natural - provided supplementary data on the lungworm infection level within the population. Methods of examination are explained in Worley et al. (this publication).

RESULTS

A total of 556 of 672 fecal samples (82.7% were infected with lungworms during the 2 study periods. There was no significant difference ($P > 0.81$) among complete years (1978, 1986 and 1987). The data from all years were combined to illustrate the monthly and seasonal variation in the prevalence of infection (Fig. 1). This figure illustrates there were significant variations in prevalence between months ($P < 0.005$) and season ($P < 0.05$). Figure 2 illustrates the prevalence as determined for sex and age class of bighorn sheep during the 1985 to 1987 study period. Statistical analysis of the prevalence determined there were no significant differences between the rates for the 2 sexes ($n = 383$, $P > 0.89$), age class ($n = 311$, $P > 0.51$) and sex age class ($n = 311$, $P > 0.65$).

Figure 3 illustrates the frequency distribution of shedding rates (L_1 larvae/g fecal material -- hereafter designated LPG) observed during 2 periods of study. Low levels of larval output were observed throughout the 2 study periods, with more than 90% of the samples containing <30 LPG. Figure 4 illustrates the shedding rates by month, season and year. Analysis indicated there were significant differences in larval shedding rates between months ($P < 0.001$) and season ($P < 0.001$).

Postmortem examination of respiratory tracts from 8 bighorn sheep collected from the Ural-Tweed population was conducted (Brink 1941, Brown

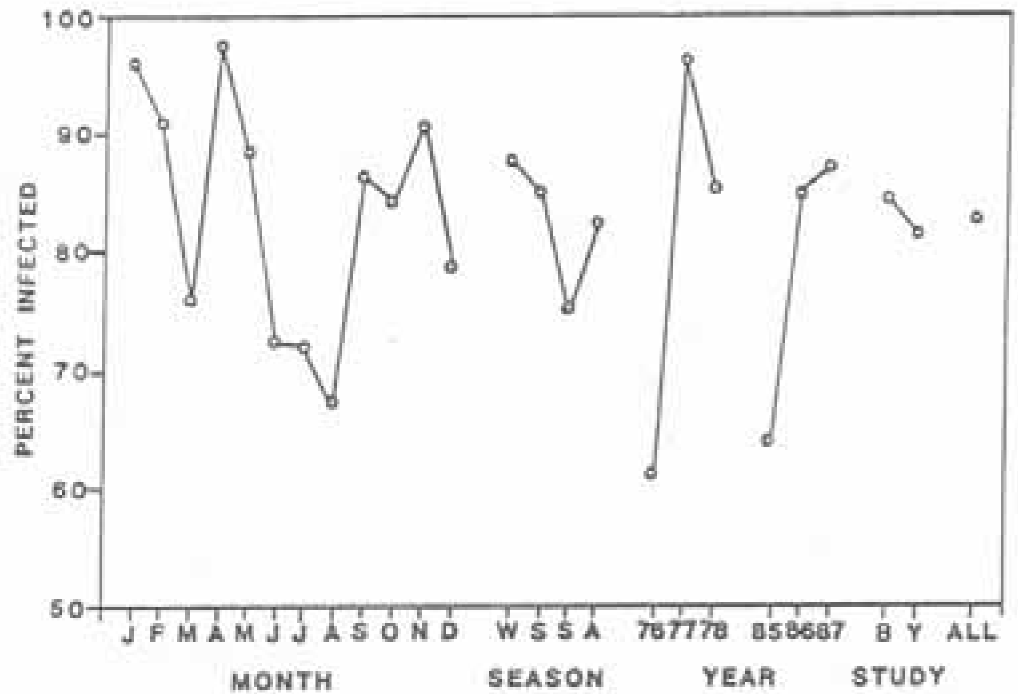

Fig. 1. Prevalence of lungworm infection for the Ural-Tweed bighorn sheep population, as determined by combining all fecal samples (n=672) collected from 1976-87. B=Brown; Y=Yde.

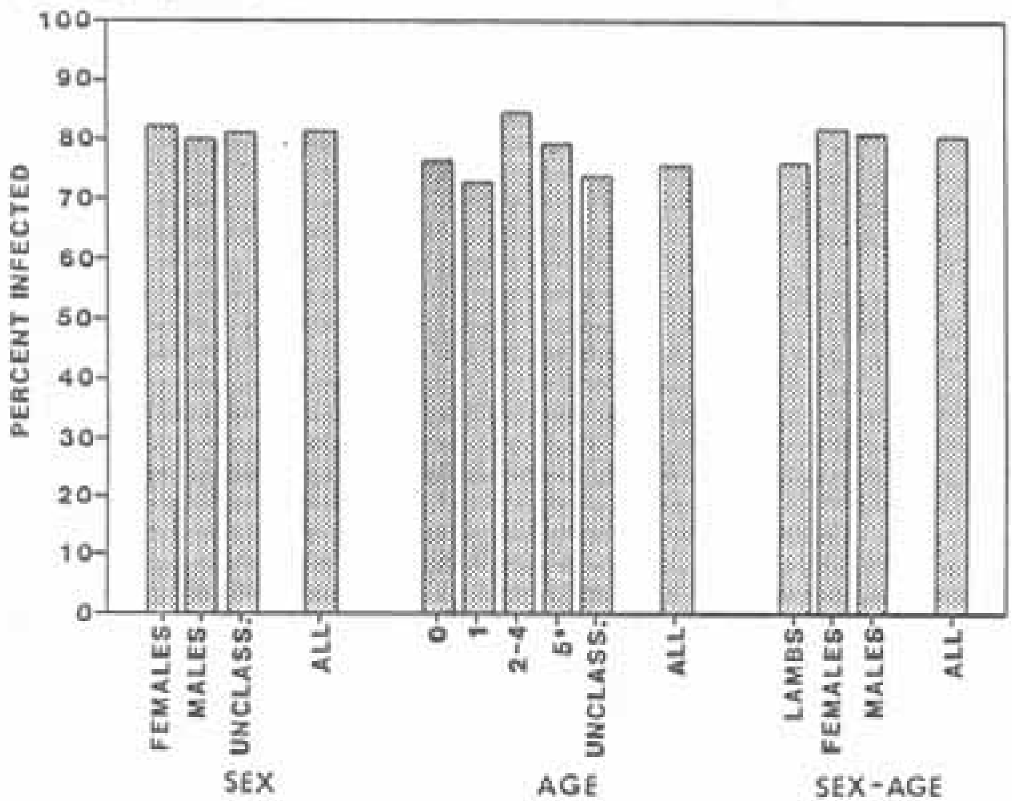

Fig. 2. Lungworm infection for sex, age and sex-age class of bighorn sheep, Ural-Tweed population, 1985-87.

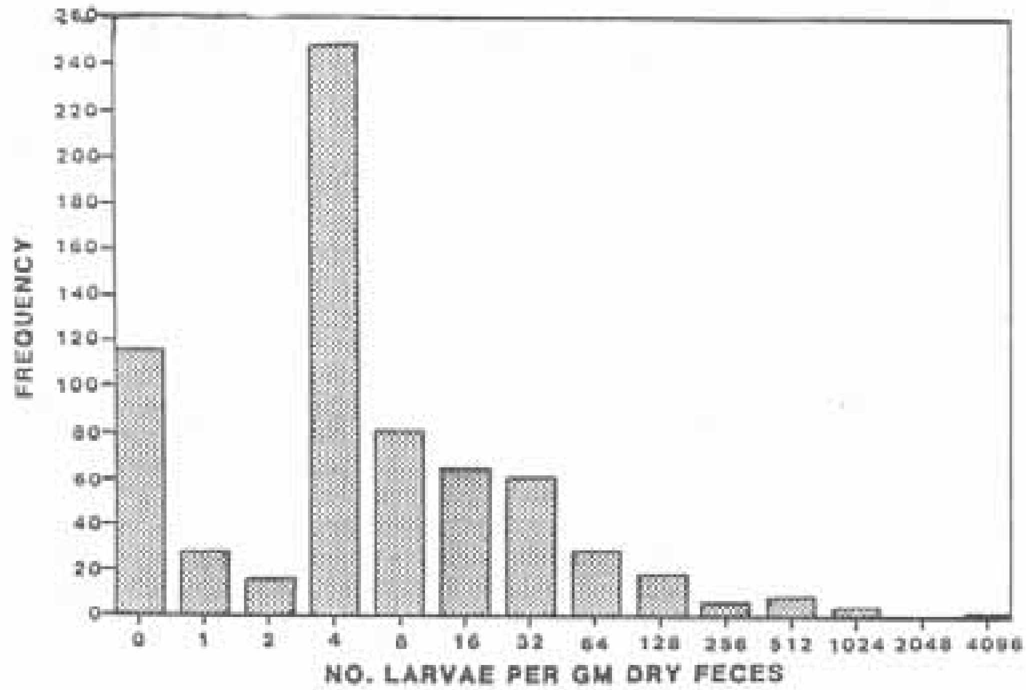

Fig. 3. Distribution of Protostrongylus spp. larvae in fecal samples for the Ural-Tweed bighorn sheep population, 1976-87.

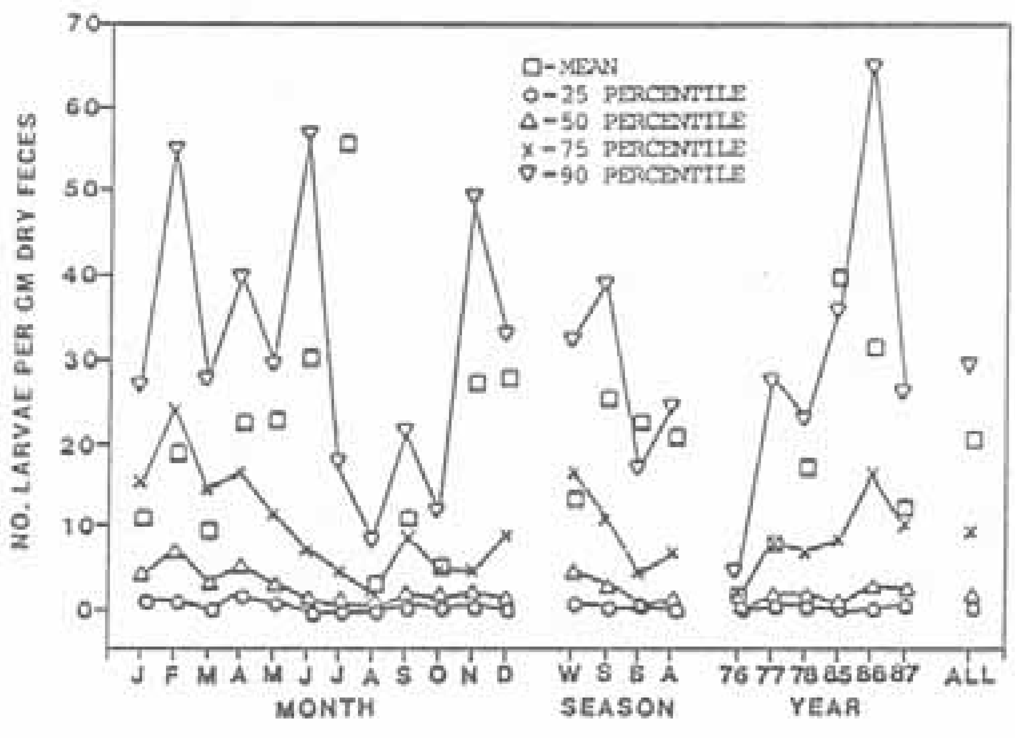

Fig. 4. Monthly, seasonal and annual variation in lungworm shedding rates for the Ural-Tweed bighorn sheep population, 1976-87. Mean and percentiles are illustrated by separate graphs.

1979, Yde, unpub. data). Seven adult bighorn sheep were infected with *Protostrongylus* spp. adults. Adult lungworms, identified as *P. rushi* werefound in 6 of the 8 respiratory tracts. Adult *P. stilesi* were found in conjunction with *P. rushi* in one animal (Brown 1979). Lungworms found in 1 of respiratory tracts were identified only to genus. One adult female bighorn infected by *P. rushi* carried a near full-term fetus, which was not infected by lungworms. Forrester and Senger (1964) reported that 5 hunter-killed Ural-Tweed rams examined from 1959 to 1962 contained both *P. rushi* and *P. stilesi* within the lung tissue.

DISCUSSION

The Ural-Tweed bighorn sheep herd is currently undergoing a population increase following a catastrophic decline in the late 1960s and early 1970s. The high prevalence of lungworms (84.4%) reported by Brown (1979) after the die-off has remained during the current period of population recovery. Similar levels of infection were previously reported for the Ural-Tweed population (Couey 1950, Forrester and Senger 1964), as well as the other bighorn populations (Couey 1950, Buechner 1960, Forrester and Senger 1964, Forrester 1971, Uhazy et al. 1972, Stelfox 1976). The high level of infection was found in all sex and age classes, including the lamb segment. The high prevalence among lambs indicates that lungworms are acquired at an early age, possibly even through transplacental migration. Postmortem examination of an adult female and associated near-term fetus indicated no transplacental migration of lungworms. This method of infection, however, has been documented for bighorn sheep (Forrester and Senger 1974, Hibler et al. 1972, 1974).

Lange (1974) reported there are often small areas of habitat that contain large concentrations of infected snails. Frequent use of these areas by bighorn sheep increases their exposure to the infected snails, thereby providing for the continued infection and reinfection of the population. Telemetry data collected by Brown (1979) and Yde (unpub. data) indicate the sheep utilize the entire Ural-Tweed range, concentrating in selected seasonal-use areas. Within these areas of seasonal concentration, there are sites preferred by the bighorn sheep. These preferred sites are routinely visited by bighorn sheep as they utilize or travel through a given area. The presence of 1 or more snail concentration areas, as described by Lange (1974), within these preferred sites would increase the likelihood of a particular sheep becoming infected with lungworms.

The continued high prevalence of infection within the population indicates the parasite is an integral part of the ecology of the Ural-Tweed bighorn sheep population. Because of the pattern of habitat use, any non-infected bighorn sheep have a high risk of being infected by the parasite. The prevalence level has remained high during a period of population growth. This indicates that unless a treatment of a bighorn sheep population for lungworm infection is completely successful, reinfection of a majority of the population will occur within a relatively short period of time.

Shedding rates for lungworm larvae were low: 90% of the fecal samples that were analyzed contained <30 LPG. This level of output is considerably below the level previously reported for the Ural-Tweed population (Couey 1950, Forrester and Senger 1964).

Significant seasonal variations in both the prevalence and larval output of lungworm were observed during the 2 studies. Peaks in prevalence were found in January, April and November (Fig. 1), while larval output peaked in February, June and November (Fig. 4). Monthly lungworm larval output from the Wildhorse Island, Montana, bighorn sheep population peaked in February and May (Forrester and Senger 1964). Uhazy et al. (1973) reported a similar peak from January through March. The peaks that have been observed correspond to periods of high stress, i.e., the rut, mid-winter concentration, and parturition. This may indicate a relationship between the life cycle of the parasite and they physiology of the host. The greatest level of larvae were shed on areas of bighorn sheep seasonal concentration, thus increasing the potential to reinfect the bighorn population. The spring increase in larval output may also be related to the shift to more succulent vegetation. Gevondyan (1958) found that such a shift increased the amount of *Muellerius capillaris* larvae shed by sheep.

The seasonal variation in the infection and larval output rates, indicate that caution should be utilized when considering the collection and analysis of lungworm related data. If the data are to be collected only from a short seasonal period, the collecting period should coincide with one of the peak periods of larval shedding. The mid-winter and spring periods appear to be the best periods to collect the fecal samples; the sheep are concentrated and the larvae output rates are maximized. Collection during these periods should produce the most reliable indicator of what the levels of infection and larvae output actually are. Additionally, data collected from a specific period should probably only be compared with the results from comparable periods.

LITERATURE CITED

Baermann, G. 1977. Eine einfache Methode zur Auffindung von Ankylostomum - (Nematoden) - Larven in Erdproben. Welteureden. Batavia. Geneesk. Lab. Feestbundel. Pp. 41-47.

Blair, R. M. 1955. Impact of the proposed Libby Dam upon the wildlife resources of Lincoln County, Montana. Mont. Fish and Game Comm., Wildl. Restoration Div. Proj. W-36-R, work plan X. Helena, 88 pp.

Brink, B. W. 1941. Summary report of the Ural-Tweed sheep project. October 15, 1940 to June 15, 1941. U.S.F.S. Rept., Kootenai Nat. For. 33 pp.

Brown, G. W. 1979. Ural-Tweed bighorn sheep investigation, October 1, 1976 - May 31, 1979. Mont. Dep. Fish, Wildl. and Parks, Wildl. Manage. Div., Proj. Comp. Rept., Helena. 94 pp.

Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present and future. Wildl. Mongor. 4. 174 pp.

Couey, F. M. 1950. Rocky mountain bighorn sheep in Montana. Mont. Dept. Fish and Game. Bull No. 2. Helena. 90 pp.

Forrester, D. J. 1971. Bighorn sheep lungworm-pneumonia complex in parasitic diseases of wild animals. Pp. 158-173 in J. W. Davis and R. C. Anderson (Eds.), Parasitic diseases of wild mammals. Iowa State Univ. Press, Ames. 364 pp.

________ and C. M. Senger. 1964. A survey of lungworm infection in bighorn sheep of Montana. J. Wildl. Manage. 28(3):481-491.

________ and ________. 1974. Prenatal infection of bighorn sheep with protstrongylid lungworms. Nature 201:1051.

Gevondyan, S. A. 1958. Effect of green forage on the latent form of muelleroisis in sheep. Pp. 119-128 in Contributions to helminthology. Kazakhskoe Gosudarstvennoe Izdatel'stvo. Alma-Ata. Translated from Russian by the Israel Program for Scientific Translations. Jerusalem, 1969.

Hibler, C. P., R. E. Lange and C. J. Metzger. 1972. Transplacental transmission of Protostrongylus spp. in bighorn sheep. J. Wildl. Dis. 9:389.

________, C. J. Metzger, T. R. Spraker and R. E. Lange. 1974. Further observations on Protostrongylus spp. infection by transplacental transmission in bighorn sheep. J. Wildl. Dis. 10:39-41.

Lange, R. 1974. Cause and nature of mortality in bighorn sheep. Pp. 104-107 in K. J. Constan and J. L. Mitchell (Eds.) Proc. Bienn. Symp. North. Wild Sheep Counc., Mont. Dep. Fish and Game, Helena.

Stelfox, J. G. 1976. Range ecology of Rocky Mountain bighorn sheep in Canadian national parks. Can. Wildl. Ser. Rept., Series No. 39. 50 pp.

Uhazy, L. S., J. C. Holmes and J. G. Stelfox. 1973. Lungworms in the Rocky Mountain bighorn sheep of western Canada. Can. J. Zool. 51:817-824.

U.S. Department of Interior. 1965. A detailed report on fish and wildlife resources affected by Libby Dam and Reservoir Project, Kootenai River, Montana. U.S.D.I., U.S. Fish and Wildl. Ser. Rept. Portland, OR. 51 pp + appendices.

Bienn. Symp. North. Wild Sheep
and Goat Council 6: 91 - 97

ASPECTS OF THE LIFE CYCLE OF *Protostrongylus stilesi* (Nematoda, Protostrongylidae) IN BIGHORN SHEEP WITH EMPHASIS ON ENVIRONMENTAL INFLUENCES ON EXCRETION OF LUNGWORM LARVAE IN FECES.

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Abstract: The effect of experimentally altered environmental conditions on excretion of first stage larvae (L_1) of *Protostrongylus stilesi* in feces of bighorn sheep (*Ovis c. canadensis*) was investigated. Bighorns brought into captivity maintained highly elevated but rather variable L_1 excretions compared to age-matched free-ranging sheep. Water and food deprivation of 2 sheep for 8 days resulted in no change in L_1 excretion, but water and food deprivation and crowding of 5 sheep in a 1.4 x 3 m pen for 15 days resulted in a 2.5 fold increase in fecal larval output above the pre- and post-stress levels. Four sheep (2 lungworm-free sheep born in captivity and 2 captive wild bighorns) were experimentally infected with *Protostrongylus* lungworms. Wild sheep were treated several times with ivermectin. Sixty-three days after the last treatment, third stage *Protostrongylus* larvae (L_3), grown in the snail (*Vallonia pulchella* were inoculated into the rumen. One sheep was infected with a mixture of *P. rushi* and *P. stilesi* while the other 3 received only *P. stilesi*. The prepatent period was 45 days for the mixed infection and 48, 51, and 54 days, respectively for *P. stilesi*. Quantitation of mature parasites in the lungs of two sheep 11 and 234 days post-patency indicated 10% and 30% of inoculated L_3 molted into adults.

Virtually all wild bighorn sheep are infected with *Protostrongylus* lungworms. From data of necropsies and quantitation of lungworms, it is apparent that larvae excretion in the feces does not reflect the extent of worm burden in the lung (Onderka and Wishart 1984). This suggests a host controlled regulatory mechanism, but besides seasonal variations, little is known about factors that influence excretion of lungworm larvae in bighorn sheep feces. Furthermore, the prepatent period for *Protostrongylus* lungworms is unknown in pure-bred bighorns.

This paper summarizes results of a study to influence fecal lungworm larvae excretion and to determine the prepatent period of *P. stilesi* in bighorn sheep.

We gratefully acknowledge the financial support of the Alberta Recreation, Parks and Wildlife Foundation. We thank J. Jorgenson and M. Festa-Bianchet for the capture of the sheep and the use of their field data of herds from which the animals originated. We also thank W. Wishart, W. Samuel and J. Holmes for advice and support.

METHODS

Animals

Seven bighorn lambs were captured at 3 locations in autumn in corral traps baited with salt or by the administration of 150 mg xylazine (Haver-Lockart Laboratories, Shawnee, Kansas) delivered by a projectile dart (Cap-Chur gun, Palmer Chemical and Equipment Co. Ltd., Douglasville, Georgia). They were transported to the laboratory in individual crates under xylazine sedation (4 mg/kg intramuscularly). They were housed individually on straw in wiremesh - covered indoor stalls measuring 1.4 x 3 m and 1.8 m high. The animals were each fed free-choice hay supplemented daily with 250 g of alfalfa pellets and 2 g cobalt-iodized stock salt sprinkled on the hay every other day. Four additional bighorn sheep were acquired from zoos.

Fecal Analyses

Fecal samples were collected from the rectum after the sheep have been blind-folded to keep them calm. The Baermann technique as described by Samuel and Gray (1982) was used to determine larvae per gram of dry feces (LPG). The same method was used to obtain LPG counts from the wild herds at the Sheep River Sanctuary and Mt. Allan in southwestern Alberta and from Cadomin in the northwestern Alberta Rocky Mountains from where the experimental sheep originated. Data were also compared with those of age-matched sheep from the Ram Mountain herd in westcentral Alberta.

Experiments

A. Environmental Influences on Fecal Larval Output

1. Captivity.--Two lambs from the Sheep River Sanctuary were held for two months indoors and were then transferred to an outdoor pen measuring 7 x 7 m where they remained from mid-October to mid-January. The temperatures were as low as -35C. Fecal samples were collected twice a month from each sheep. The number of samples from age-matched wild sheep at the Sanctuary varied from 1 to 11 per month.

2. Food and water deprivation.--Two male lambs from Mt. Allan and 1 male lamb from Cadomin were acclimatized to captivity from mid-June to the end of July. In August, the 2 Mt. Allan sheep were deprived of food and water for 8 consecutive days but remained on straw bedding. The third lamb served as control. The frequency of fecal sampling before, during and after the experiment is given in Figure 2. The degree of dehydration was assessed using packed cell volume determined on day 1, 5 and 8. Since no data were available from wild Mt. Allan sheep, LPG was compared to age-matched bighorn lambs from Ram Mountain. The number of samples from June through August were 23, 17 and 8, respectively.

3. Food and water deprivation with crowding.--Two wild female lambs from Cadomin were acclimatized to captivity from June to October before they were housed together with 3 male lambs used in experiment 2 in a stall measuring 1.4 x 3 m. All 5 sheep were deprived of food and water for 15 days, except for a little water on day 7. Only the 2 female lambs

were monitored. The frequency of fecal sampling before, during and after the experiment is given in Figure 3. Packed cell volume was determined on day 4, 8, 11 and 15. The LPG of age-matched wild sheep from Ram Mountain is the same as in experiment 2 except for October, which is based on only one sample.

B. Prepatency Period

Trial 1.--Two zoo born bighorn lambs found to pass no lungworm larvae in the feces were housed in separate indoor stalls on concrete floors covered with straw. One lamb was inoculated via a rumen tube with 1004 third stage larvae (L_3) of *P. stilesi* and *P. rushi* grown in 49 *Vallonia pulchella* snails as described by Samson and Holmes (1985). The other lamb was sham inoculated and served as control.

Trial 2.--A zoo born lamb found to pass no lungworm larvae in the feces was inoculated with 240 L_3 of *P. stilesi*, contained in 20 snails. To assure single genus infection, snails were infected with larvae extracted from typical *P. stilesi* nodules from lungs with no evidence of *P. rushi* after careful dissection of the airways.

Trial 3.-- The 2 Mt. Allan sheep used earlier in experiment A-2 and one zoo born male yearling sheep were used in this trial. All 3 sheep excreted lungworm larvae and had to be treated with ivermectin (Ivomec, Merck-Sharp-Dome, Kirkland, Quebec) given at 200 ug/kg subcutaneously in the neck. Several treatments were necessary before the sheep no longer passed L_1 in the feces. The zoo born sheep served as control while the other 2 received 222 L_3 and 575 L_3 of *P. stilesi* in 31 and 49 snails, respectively.

Rectal fecal samples were collected weekly up to 40 days post inoculation and from then on every 2nd day until patency was established. The sheep from trail 1 and 2 were euthanized 11 and 24 days post-patency, respectively, using an overdose of intravenous Pentobarbital (M.T.C. Pharmaceuticals, Mississauga, Ontario). To recover adult nematodes from the lungs, nodular tissue was minced and digested in a solution of 3.6 mg Papain in 50 ml water for 1.5 h at 22 C. For the recovery of larvae, the nodular tissue was further digested using .45 g pepsin and .7 ml 37% HCl in 100 ml water for 16 h at 37 C. A thin segment of tissue was fixed in 10% buffered formalin for histologic examination.

RESULTS

Excretion of Larvae

Excretion of lungworm in sheep feces increased dramatically when bighorn sheep were brought into captivity as compared to age-matched animals in the wild herds from which they were caught (Figure 1). The normal seasonal increase in LPG during the winter months was observed in the wild herds but not in captive sheep. Exposure of the lambs to severe weather conditions had no effect on the LPG. Stressors such as food and water deprivation had no appreciable influence on LPG (Figure 2), although it was reflected in a rise in packed cell volume and loss of elasticity of the skin. In a second experiment, when the sheep were crowded in addition

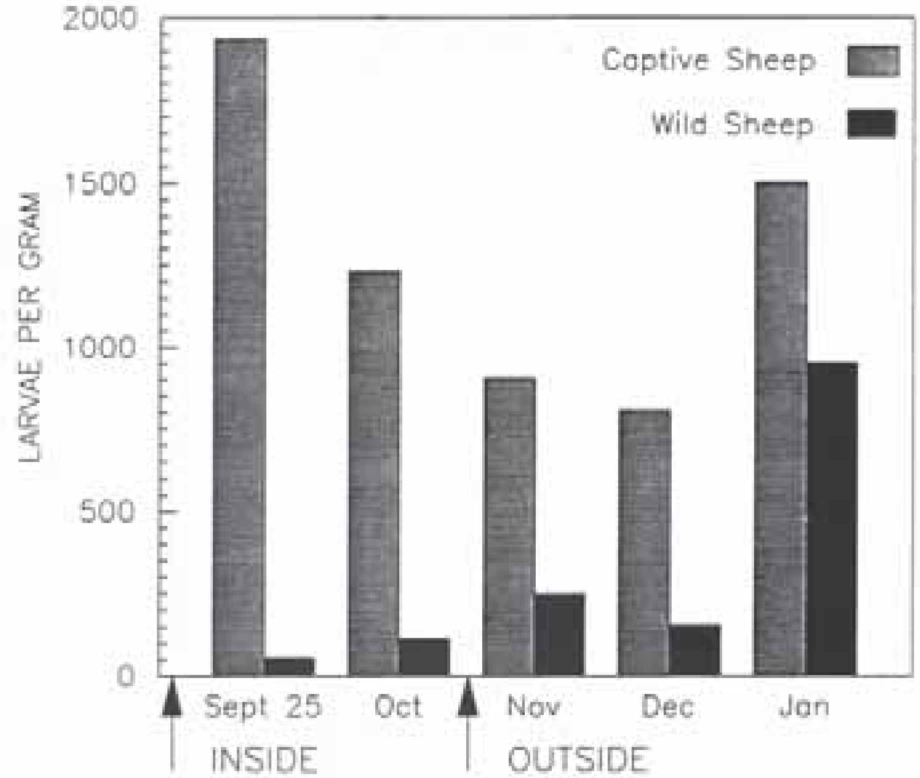

Figure 1. Mean lungworm larvae per gram in feces of two bighorns brought into captivity compared to age-matched wild sheep from the herd of origin.

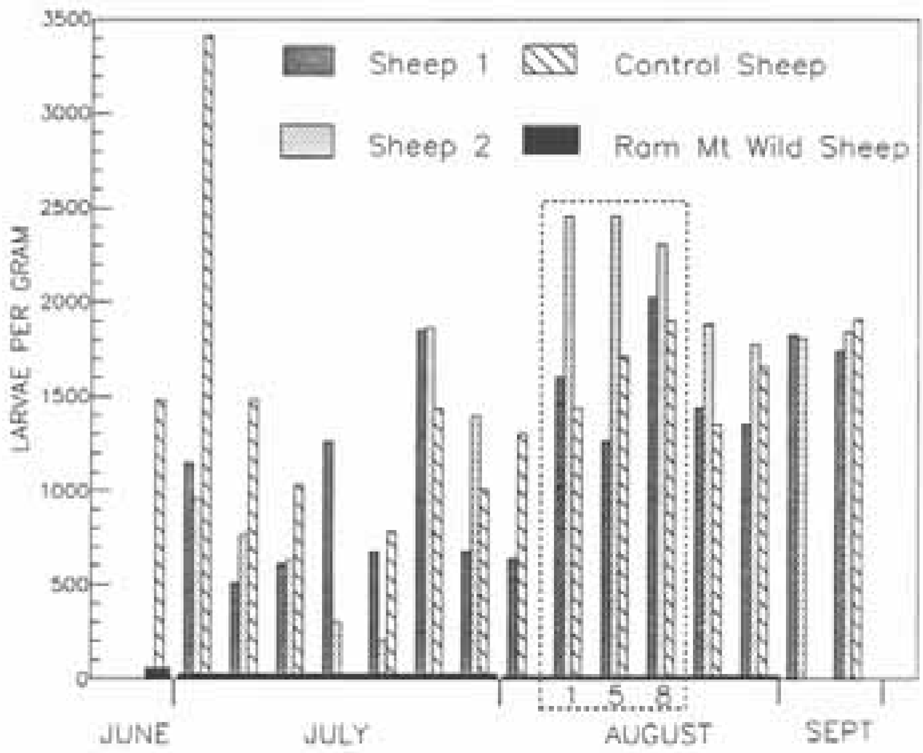

Figure 2. Mean numbers of lungworm larvae in feces of wild, captive bighorns compared to age-matched wild sheep. The time frame within the dotted lines refers to 8 days of food and water deprivation for sheep 1 and 2.

to a longer period of food and water deprivation, a distinct increase in LPG was noticed followed by a decline after the experiment was terminated (Figure 3).

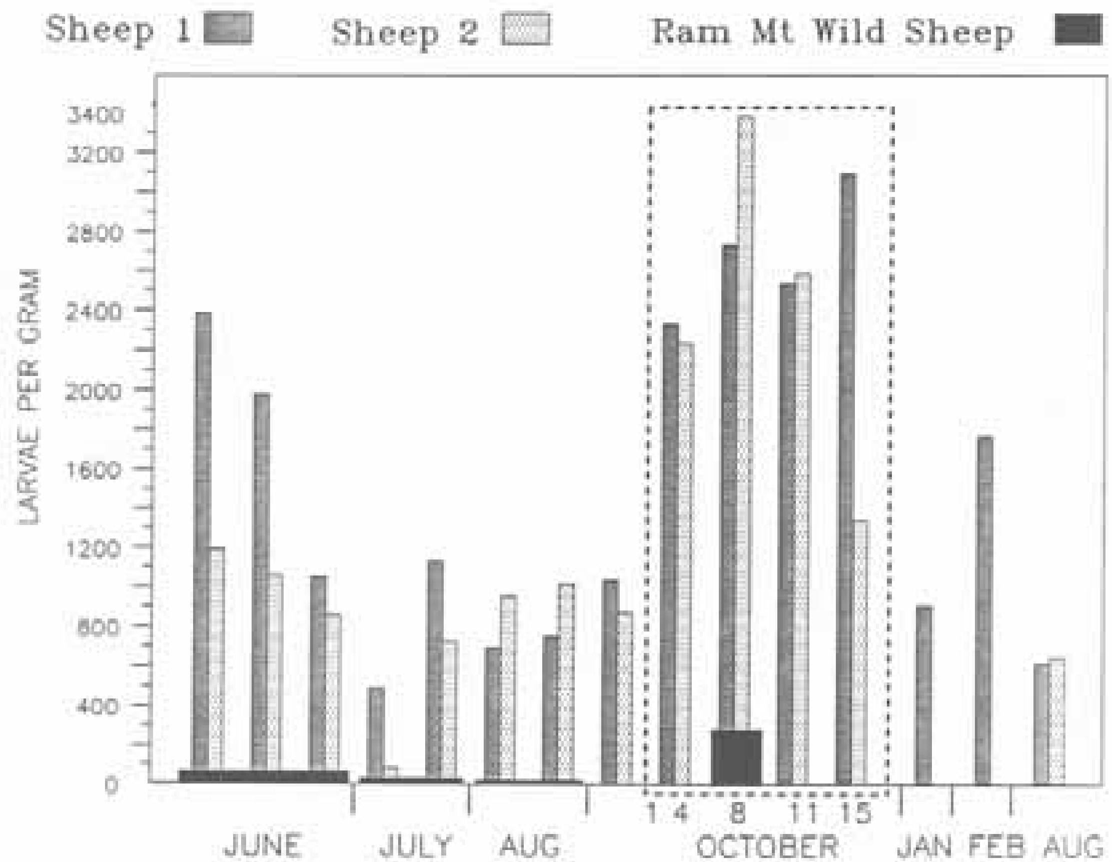

Figure 3. Mean numbers of lungworm larvae in feces of wild captive bighorns compared to age-matched wild sheep. The time frame within the dotted line refers to 15 days of food and water deprivation and crowding with 3 additional bighorn sheep.

Treatment Against Lungworms

A single injection (day 0) of Invermectin to 3 bighorns resulted in a 97% reduction of LPG after 23 days. A second treatment was given on day 43. At this time, one sheep had 0 LPG but from day 83 on (40 days after second treatment) all 3 sheep again excreted lungworm larvae. Six months later, these 3 sheep were again treated with ivermectin. Injections were given on day 0 and day 13. Fecal samples taken on day 119 were negative but a third treatment was given at this time. The sheep were monitored until day 182 (63 days after last treatment) when two of the animals were used for experimental lungworm infection. The third sheep served as control and maintained 0 LPG for over 260 days at which time the experiment was terminated.

Prepatent Period

The mixed infection of P. stilesi and P. rushi resulted in a prepatent period of 43 days. The prepatent period for the P. stilesi infection was 48, 51 and 54 days respectively. In the sheep inoculated with 1004 mixed species L_3, the LPG started very low with a steep rise to 950 after 11 days and 1200 after 24 days. At necropsy, 24 grey, raised, firm lungworm nodules consisting of adult nematodes, embryonating eggs, L_1 and lymphocytes contained 294 adults of P. stilesi (126 females and 168 males). In addition, there were 35 adult P. rushi in airways. This suggests that after 24 days 30% of L_3 developed into adults. The control sheep had no evidence of lungworms. The sheep from trail 2 was necropsied 11 days post-patency. It had received 240 L_3 of only P. stilesi. Six dark-red, firm nodules were found in the posterior margin of the caudal lung lobes. Microscopic examination showed a fairly acute reaction with hemorrhage, neutrophil and some eosinophil infiltrations in response to the reproductive activity of the lungworms. Twenty-two adult nematodes (10 females and 12 males) were found. The LPG was only 6 although an average of 15000 L_1 per female were found. At this time 10% of third stage larvae had developed into adults.

DISCUSSION

The dramatic increase of LPG in bighorns brought into captivity suggests that environmental changes have a marked influence on the excretion of lungworm larvae in feces. This could be further enhanced by crowding stress. These data support the value of long-term monitoring of LPG in bighorns to assess the stress level of a herd. It does not, however, reflect the actual extent of lungworm infection in individual animals.

Treatment of wild sheep with anthelmintics has been of interest in the management of small, poor doing herds. Our results, using ivermectin, show that at least two treatments 14 days apart are necessary for long term lungworm control. If the treatments were spaced further apart sheep again began to shed larvae. The interval between treatment and resumption of shedding was 40 days. This is similar to results reported by McCraw and Menzies (1986) in the treatment of Muellerius capillaris in goats. Our results agree with those of Miller et al. (1987) working with bighorns and Gregory et al. (1985) working with goats showing that ivermectin causes significant reduction of LPG even down to 0 but differ, in that in our study, long term monitoring showed resumption of fecal larvae excretion while in the other two studies follow up samples were obtained only for 29 days (Miller et al.) and 14 days (Gregory). The large difference in the number of L_3 developed into adults after oral inoculation between 11 days and 24 days post-patency lends support to suggestions by McGraw and Menzies (1986) that this development is gradual and ivermectin may only be effective against adult stages of lungworms.

The prepatent period of P. stilesi infection varied from 48-54 days. A shorter period was found when a mixed infection with P. rushi was given.

These data differ considerably from those reported for 3 bighorn sheep by Monson and Post (1972) (63,119 and 122 days). They likely used a mixed infection as their source of L_1 was fecal pellets from wild sheep that were inoculated into bighorn sheep-mouflon crosses.

The gradual development of L_3 into adults will be investigated further in view of the possible storage of L_3 in the lung of the ewe for transplacental transmission to the fetus.

LITERATURE CITED

Gregory, E. 1985. Efficacy of ivermectin and fenbendazole against lungworms. Vet. Med. 80:114-117.

McCraw, B. M. and P. I. Menzies. 1986. Treatment of goats infected with the lungworm Muellerius capillaris. Can. Vet. J. 28:287-290.

Miller, M. W., N. Thompson Hobbs, W. H. Rutherford and L. L. W. Miller. 1987. Efficacy of injectable invermectin for treating lungworm infections in mountain sheep. Wildl. Soc. Bull. 15:260-263.

Onderka, D. K. and W. D. Wishart. 1984. A major bighorn sheep die-off from pneumonia in southern Alberta. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:356-363.

Samson, J. and J. C. Holmes. 1985. The effect of temperature on rates of development of larval Protostrongylus spp. (Nematoda: Metastrongyloidea) from bighorn sheep, Ovis canadensis canadensis, in the snail Vallonia pulchella. Can. J. Zool. 63:1445-1448.

Samuel, W. M. and J. B. Gray. 1982. Evaluation of the Baermann technique for recovery of lungworm (Nematoda: Protostrongylidae) larvae from wild ruminants. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:232-243.

Bienn. Symp. North. Wild Sheep
and Goat Council 6: 98 - 105

BRONCHOALVEOLAR LAVAGE TECHNIQUE IN BIGHORN SHEEP: USE IN IMMEDIATE LUNGWORM DIAGNOSIS AND CELL FUNCTION TESTS

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Abstract: Segmental lavage was performed on 6 sedated Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) using fiberoptic bronchoscopy. Alveolar cells were recovered for characterization and function tests. Adult lungworms (*Protostrongylus* spp.) were observed during the lavage procedure in the lavage fluid recovered from 3 of 6 sheep. Microscopic observation of the lavage fluid revealed the presence of *Protostrongylus* spp. larvae and eggs in 5 of the 6 sheep. Alveolar cell viability was severely reduced in cases where larvae were numerous, and a direct correlation between numbers of larvae and cell death was observed ($r = 0.80$). The bronchoalveolar lavage technique is effective for immediate diagnosis of lungworms in bighorn sheep and may be more accurate than existing methods. In addition, bronchoalveolar lavage is a tool for collecting alveolar cells for the purpose of studying the defense mechanisms of the lung at the cellular level.

The pneumonia complex is a major mortality factor affecting bighorn sheep survival in North America (Potts 1937, Marsh 1938, Buechner 1960, Forrester 1971, Spraker et al. 1984). Its pathogensis is multifactorial and complex.

Several factors have been implicated in the role of predisposing bighorn sheep to opportunistic bacteria, of which *Pasteurella hemolytica* is the most deadly (Parks et al. 1972, Thorne et al. 1982, Onderka and Wishart 1984). The role of host defense at the cellular level is an area where little research has been focused to date. It involves investigation of alveolar cell types to understand their function in healthy animals, and to observe mechanisms involved in the impairment of their function during disease conditions.

The first line of defense for the lung is provided by the alveolar macrophage (Trigo et al. 1984, Liggitt et al. 1986). Macrophages function to phagocytize and kill bacteria and viral particles, and interact with lymphocytes to play a vital role in subsequent antibody production against foreign antigens. The alveolar macrophage can routinely be collected from the lungs using bronchoalveolar lavage technique. They can be maintained in tissue culture for at least 1 week, which enables an investigator to reconstruct parasitic, viral, or bacterial infections in tissue culture conditions, and to evaluate the effects on host defense parameters.

An area of active research in humans and domestic animals is the role of inflammatory chemical mediators in disease. Phagocytic cells release membrane-bound arachidonic acid and synthesize its metabolites in response to inflammatory stimuli. Different inflammatory cell types from various tissue sites and species generate characteristic profiles of arachidonic acid metabolites following cellular stimulation. These metabolites have critical lung defense roles when held in balance, yet can also result in tissue injury when that balance is lost (Taylor, 1986). This tissue injury can occur in the lung and predispose alveolar lining cells to viral and bacterial infection. The functions of the inflammatory mediators include chemotactic activity on neutrophils and eosinophils, thus providing one of the major stimuli for the migration of polymorphonuclear leukocytes into inflammatory lesions. They also play a role in causing several immune functions to become depressed and thus predispose a host to secondary infection. This is believed to be one of the mechanisms by which respiratory viruses such as parainfluenze-3 acts in the pathogenesis of the pneumonia complex (Laegreid et al. unpublished). The information gained from studying these mediators may suggest reasons for differences in species susceptibility to the pneumonia complex and may provide methods for prevention of compromised lung defenses in bighorn sheep. Understanding the role of inflammatory mediators has led to the development of such pharmacological agents such as corticosteriods or steriod-like products having anti-inflammatory action. An example of beneficial response from such agents is seen in the use of cyclooxygenase inhibitors to reverse the virus induced dysfunction of macrophages (Sestini et al. 1984, Rinaldo et al. 1985, Laegreid et al. 1988).

Parasitic infection is 1 of the factors which leads to impairment of host lung defense. This study confirms the role of Protostrongylus spp. in impairment of macrophage function by a toxic effect observed on macrophages obtained via bronchoalveolar lavage.

Contact between domestic sheep and bighorn sheep has proven to be detrimental under controlled experimental conditions (Foreyt 1988) and in some cases may have resulted in major die-offs, due to pneumonia, in wild bighorn herds (Foreyt and Jessup 1982, Coggins 1988). It is assumed that such contact resulted in a transfer of Pasteurella hemolytica from domestic sheep to bighorn sheep. The question to be answered is why bighorn sheep are so much more susceptible to the serotypes of Pasteurella hemolytica than are domestic sheep.

Identification of factors or circumstances leading to impairment of host lung defense would perhaps explain why bighorn sheep are more susceptible to pulmonary bacterial infections than domestic sheep. This would permit development of specific remedies which may be immunological, pharmacological or managerial.

METHODS

Pulmonary Phagocyte Collection And Processing

Alveolar macrophages were isolated from the lungs of 6 bighorn rams, 3-6 years old, following sedation with 50 mg of xylazine hydrochloride (Rompun, Miles Laboratories, Bayvet Division, Shawnee, KA 66201, USA) intramuscularly. The herd of bighorns used in the study was located on their winter range on Hall Mountain in northeast Washington. The trapping procedure involved minimal stress to the rams which were accustomed to being fed inside the trap enclosure. A fiberoptic bronchoscope (Machida, Orangeburg, NY, 10962, USA) with an insertion tube 145 cm long and diameter of 6 mm was gently lodged into the caudal lobe of the lung. Aliquots of sterile physiological saline, 60 cc, were infused and immediately withdrawn. A total of 300 cc of fluid was instilled of which 40-50% was recovered. This lavage fluid was placed in 250 cc centrifuge tubes and kept on ice for three hours prior to analysis at the lab. The alveolar cell population was characterized by staining a cytocentrifuge prepared slide with Dif-Quik stain. Total cell number and viability of each sample was obtained using a trypan-blue exclusion method in which 0.1 ml of cells were added to 0.1 ml of trypan-blue dye and counted on a hemocytometer. Dead cells stain blue due to their inability to exclude the dye. The cells were pelleted by centrifugation at 150 x g, and resuspended in nutritional media (RPMI) for use in various assays. A monolayer of adherent cells was obtained by placing them on plastic 6-well tissue culture plates.

Since cell viability was low from the 6 rams, we decided to use 4 captive bighorn ewes ages 2-6 located at Washington State University for a source of alveolar cells to use in phagocytosis and bactericidal assays. These animals were trapped and sedated in the same manner described above for the 6 rams, and the phagocyte collection and processing procedure was identical. No Protostrongylus adults or larvae were recovered during lavage of these 4 ewes.

We routinely administer antibiotics (5 ml LA-200) at the time of bronchoscopy as a preventative measure against potential infection caused by handling the animals. We reversed the effects of the xylazine by giving 10 mg of yohimbine hydrochloride (Antagonil, Wildlife Laboratories Inc., P. O. Box 8938, Fort Collins, CO, 80525, USA) intravenously.

Phagocytosis Assay

Alveolar cells (2 x 10^5) were suspended along with Staphyloccocus epidermidis at a ratio of 1:10. This suspension was incubated at 37 C for 1 hour to allow the cells to phagocytize the bacteria. The percent of alveolar cells with internalized bacteria were counted on Dif-Quick stained, cytocentrifuge prepared slides of the suspension.

Bactericidal Assay

The bactericidal assay measures the ability of phagocytes to kill bacteria. The method of Peck (1985) which is based on the ability of viable bacteria to reduce a tetrazolium dye, MTT, was used. Alveolar cells were allowed to adhere to 96-well tissue culture plates. To this monolayer was added a 10:1 ratio Staphyloccocus epidermidis. After 2 hours incubation at 37 C, the cells were lysed using the detergent saponin. This allowed the release into the supernatant of bacteria which may have been phagocytized but not killed by the cells. Nutrient broth was added to enhance growth of surviving bacteria for 4 hours. The number of live bacteria was then quantified by adding the tetrazolium dye MTT which was reduced by reproducing bacteria. The resulting color change wasmeasured by a Titertek plate reader, and data were communicated to an IBM-PC for analysis. Results were expressed as percent bacteria killed during the exposure to the alveolar cells.

Lungworm Larvae Numbers

Protostrongylus spp. larvae were observed in the tissue culture plates using an inverted microscope. The number of larvae were counted and expressed as total number of larvae per lavage. Once counted, the larvae were separated from the adherent alveolar macrophage population by washing the tissue culture plates with RPMI.

RESULTS AND DISCUSSION

Use of the bronchoalveolar lavage technique was successful in harvesting alveolar cells of the lower respiratory tract. The animals recovered rapidly from sedation after receiving yohibmine hydrochloride, and no adverse effects from the procedure were observed. An average of 44% of the fluid used in the lavage was recovered and contained an average of 7.9×10^6 cells (Table 1). As lavage fluid was being retracted, adult Protostrongylus spp. were observed grossly; eggs and larvae were observed microscopically on tissue culture plates. Direct observation plus the capability to quantify parasites in lavage fluid provided a more accurate assessment of pulmonary airway invasion by Protostrongylus than fecal examination methods.

Table 1. Summary data for alveolar cells and Protostrongylus recovered during lung lavage from 6 rams.

Tag #	Fluid Recovered (%)	Total Cells ($\times 10^6$)	Viability (%)	Protostrongylus Larvae	Protostrongylus Adults
Or-12	32.50	5.10	88	0	No
Y-15	51.67	7.75	84	10	Yes
Y-12	43.33	7.75	13	30	Yes
G-400	46.67	8.75	29	50	Yes
Y-11	40.00	12.50	10	30	No
Or-277	45.00	5.50	59	15	No
Mean $\pm$ SE	44.03 ± 2.0	7.89 ± 1.09	47.17 ± 14	22.5 ± 7.27	

The lavage technique can also be accomplished without a fiberoptic bronchoscope. A 145 cm plastic tube 6 mm diameter has been successfully placed in the lung of sedated bighorn sheep with the aid of a veterinary laryngoscope. The advantages of this method include greatly reduced cost of equipment, and elimination of the need for electricity. The fiberoptic scope however, offers the advantage of allowing visualization of the airways for the presence of parasites or other disease conditions.

A wide range of cell viability was observed using trypan-blue exclusion (10-88%). The percent of dead cells correlated with heavy loads of <u>Protostrongylus</u> larvae (r = 0.80) (Fig. 1). This suggests a toxic effect of the parasite on the alveolar cells which may be responsible for predisposing an animal to opportunistic bacteria commonly seen in the pneumonia complex.

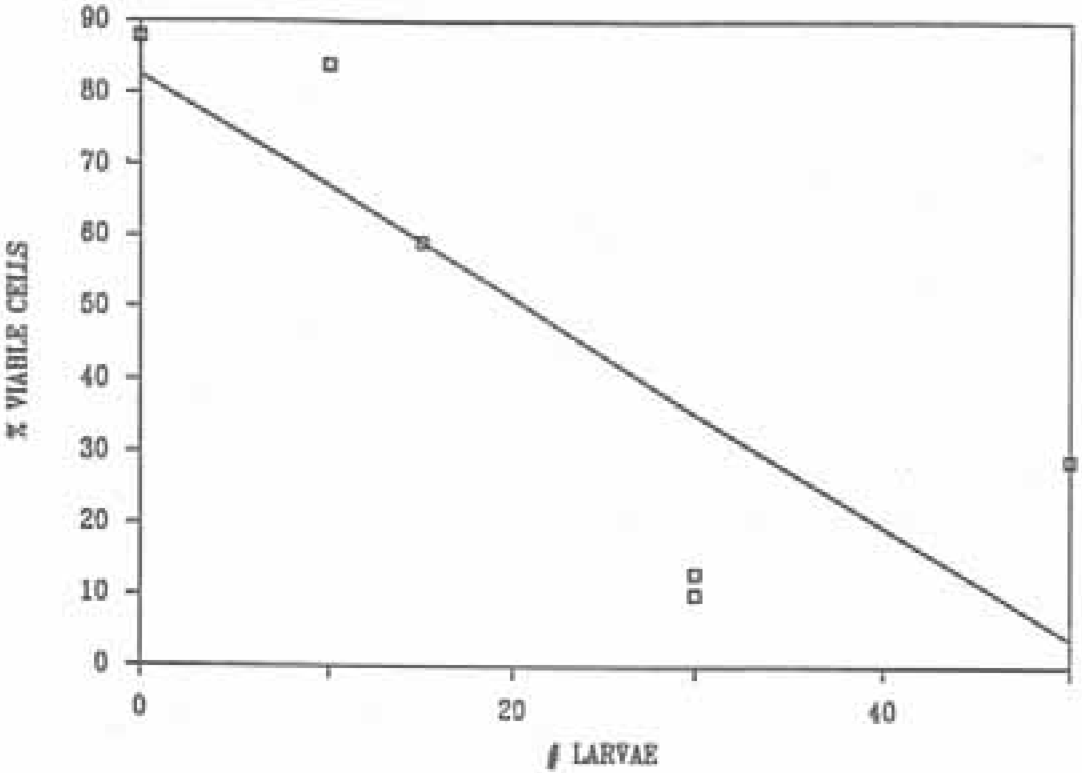


Figure 1. Correlation line (r = 0.80) showing effect of <u>Protostrongylus</u> larvae on alveolar macrophage viability (<u>n</u> = 6 rams).

The cell types present in the bighorn sheep lung were characterized and consisted of an average of 77% macrophages, 14% neutrophils, and 9% lymphocytes (Table 2).

Due to poor viability of alveolar cells from the 6 bighorn rams, the cells from 4 captive bighorns were analyzed for ability to phagocytize and kill bacteria. When bacteria were present at 10:1 bacteria per alveolar cell, 83% of the cells were considered actively phagocytic and 58% of the bacteria were killed in 2 hrs (Table 3).

Results from Table 3 indicate that the live cells are capable of functioning in the role of first-line defense against bacteria. However, when the total number of live cells is decreased by toxic agents such as

Table 2. Differential cell counts from alveolar cells recovered by lung lavage from 6 rams.

Tag #	Macrophages (%)	Neutrophils (%)	Lymphocytes (%)
Or-12	86	5	9
Y-15	82	11	7
Y-12	65	15	20
G-400	50	47	3
Y-11	98	2	0
Or-277	80	2	18
Mean ± SE	76.83±6.9	13.67±6.99	9.5±3.27

Table 3. Phagocytosis and bactericidal ability of alveolar cells from lung lavage of 4 captive ewes. No *Protostrongylus* were present in the lungs of these animals.

Tag #	Phagocytosis (%)	Bactericidal (%)
28	79.50	76.92
291	77.00	74.67
39	91.50	46.78
369	82.00	32.20
Mean ± SE	82.5 ± 3.17	57.64 ± 10.9

Protostrongylus, the ability of the host to defend against secondary organisms is seriously compromised.

By applying the technique of bronchoalveolar lavage in bighorn sheep, two major purposes can be accomplished: 1) alveolar cells can be obtained for in vitro studies relating to host defense mechanisms, and 2) immediate diagnosis of lungworms is possible by the observation of adults in the airways or retrieved fluid, or by examination of the fluid for eggs and/or larvae. Furthermore, the correlation of the effects of parasite load in the lung with cell function can be made. In addition, many more of the factors involved in the pathogenesis of the pneumonia complex can be studied in an in vitro environment, thus eliminating costly and destructive waste of valuable live animals necessary when in vivio experiments are performed.

LITERATURE CITED

Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present, and future. Wildl. Monogr. 4. 174 pp.

Coggins, V. L. 1988. The Lostine Rocky Mountain bighorn sheep die-off and domestic sheep. Bienn. Symp. North. Wild Sheep and Goat Counc.

Foreyt, W. J. and D. A Jessup. 1982. Fatal pneumonia of bighorn sheep following association with normal domestic sheep. J. Wildl. Dis. 18:163-168.

Foreyt, W. J. 1988. Fatal Pasteurella hemolytica pneumonia in bighorn sheep following direct contact with normal domestic sheep - an experimental study. Am. J. Vet. Res. (in press).

Forrester, D. J. 1971. Bighorn sheep lungworm-pneumonia complex. In J. W. Davis and R. C. Anderson (Eds.), Parasitic diseases of wild mammals. Iowa State Press, Ames, IO. Pp 158-173.

Laegreid, W. W., H. D. Liggitt, R. M. Silflow, J. R. Evermann, S. M. Taylor and R. W. Leid. 1988. Reversal of virus induced alveolar macrophage dysfunction by cyclooxygenase inhibition in vitro. (unpublished).

Liggitt, H. D., R. Silflow, L. Huston, J. Evermann and R. Breeze. 1986. The effect of bovine respiratory syncytial virus on pulmonary defenses of calves in vivo. Proc. 14th World Cong. of Dis. of Cattle 1:488-498.

Marsh, H. 1938. Pneumonia in Rocky Mountain bighorn sheep. J. Mammal 19:214-219.

Onderka, D. K. and W. D. Wishart. 1984. A major bighorn sheep die-off in southern Alberta. Bienn. Symp. North. Wild Sheep and Goat Counc. 1:356-363.

Parks, J. B., G. Post, E. T. Thorne and P. Nash. 1972. Isolation of parainfluenza virus from Rocky Mountain bighorn sheep. J. Am. Vet. Med. Assoc. 161:669-672.

Peck, R. 1985. A one-plate assay for macrophage bactericidal activity. J. Immunol. Meth. 82:131-140.

Potts, K. M. 1937. Hemorrhagic septicemia in the bighorns of Rocky Mountain National Park. J. Mammal. 18:105-106.

Rinaldo, J. E. and J. H. Dauber. 1985. Modulation of endotoxin-induced alveolitis by captopril and by hyperoxia. J. Leuk. Biol. 37:87-99.

Sestini, P., A. Tagliabue, and D. Boraschi. 1984. Modulation of macrophage suppressive activity and prostaglandin release by lymphokines and interferon: comparison of alveolar, pleural, and peritoneal macrophages. Clin. Exp. Immunol. 58:573-580.

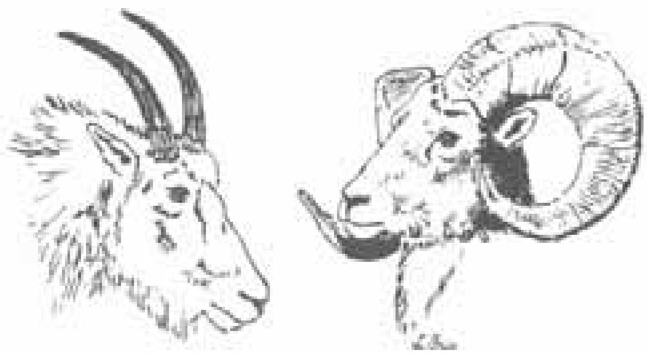
Spraker, T. R., C. P. Hibler, G. G. Schoonveld, and W. S. Adney. 1984. Pathologic changes and microorganisms found in bighorn sheep during a stress-related die-off. J. Wildl. Dis. 20:319-327.

Taylor, S. M., H. D. Liggitt, W. W. Laegreid, R. Silflow and R. W. Leid. 1986. Arachidonic acid metabolism in bovine alveolar macrophages: Effect of calcium ionophore on lipoxygenase products. Inflammation 10:157-165.

Thorne, E. T., N. Kingston, W. R. Jolley and R. C. Bergstrom (Eds.). 1982. Diseases of wildlife in Wyoming. 2nd edition. Wyoming Fish and Game Department, Cheyenne, WY, pp. 72-77 and 208-213.

Trigo, E., H. D. Liggitt, R. G. Breeze, R. W. Leid and R. Silflow. 1984. Bovine pulmonary alveolar macrophages: ante-mortem recovery and in vitro evaluation of bacterial phagocytosis and killing. Am. J. Vet. Res. 45:1842-1847.

Development Impact



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SEASONAL AND SPATIAL DISTRIBUTION OF BIGHORN SHEEP AT AN OPEN PIT MINING SITE IN THE ALBERTA FOOTHILLS

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Abstract: Mining activity at Cardinal River Coals Ltd., an open pit mining site in the Alberta foothills, drastically changed the landscape from a closed canopy coniferous forest to open terrain consisting of reclaimed meadows in proximity to unreclaimed pit walls. A population of approximately 200 bighorn sheep which had been using the mine lease was studied during the year 1985-86. Ranges for the prerut, rut, winter and spring seasons were variously located on the lease area, as well as features such as lambing walls and mineral lick sites. High walls of exhausted pits were used for escape terrain and travel routes. Recommendations were made to the Alberta Land Conservation and Reclamation Council regarding maintenance of high walls in association with reclaimed meadows as integral components of bighorn sheep habitat. This site-specific wildlife study should be invaluable for mine planning and reclamation efforts.

In 1985, Cardinal River Coals Ltd. (CRC) initiated a population study of a herd of bighorn sheep (*Ovis c. canadensis*) that had been using their mine lease site for several years. CRC is an open pit coal mining operation that is situated in the foothills of west central Alberta approximately 50 km south of the town of Hinton. CRC began mining activities in 1969 and reclamation work in 1971. Disturbed areas of the mine lease are being reclaimed for wildlife habitat and recreation opportunity according to requirements specified in The Coal Development Policy for Alberta (Department of Energy and Natural Resources, 1976). Wildlife habitat was chosen as the end use because viable wildlife populations were present in the vicinity of the mining lease and reclamation costs were less than returning the disturbed land to timber production. Wallis and Wershler (1979) developed guidelines for reclaiming the CRC lease to bighorn sheep, mule deer, elk and moose habitat. Since that time, however, bighorn sheep have become the common species using the mine lease.

The purpose of this study was to obtain baseline data on the population of bighorn sheep of CRC in order to establish a long term monitoring program. The work was undertaken by the author as part of a Master's Degree Program at the Faculty of Environmental Design, University of Calgary during the year 1985-86. This paper discusses a portion of that work, concentrating on seasonal and spatial distribution of the bighorn sheep on the mining site and the implications this use has for reclamation procedures. Descriptive techniques will largely be used in the discussion of this work, because research is not quite finished.

I wish to thank W. D. Wishart for providing critical review throughout the duration of this study. G. B. Acott helped to initiate the work and has provided continual support. Dr. V. Geist and Dr. M. Bayer also contributed to the study and reviewed this manuscript. Financial support for this project was supplied by CRC and the Recreation, Parks and Wildlife Foundation of Alberta.

STUDY AREA AND POPULATION

The study area is defined by CRC's Mineral Surface Lease #5972 located in TWP 47 and 48, Rge 24, W of the 5th Meridian. As of December 31, 1986 a total of 43.9% or 1250 ha (3,088.6 acres) of the lease area had been disturbed, of which 504.3 ha (1246.1 acres) were in some stage of reclamation (Acott et al. 1987). The mineral surface lease is bounded on the west side by Gregg River, the north by Mary Gregg Creek, the east by tributaries of Luscar Creek and on the south by the front ranges that encompass Whitehorse Creek. The mine is bisected by Hwy 40 (Figure 1).

In 1986, CRC moved 2,094,054 raw short tons of coal and 14,219,574 bank cubic yards of rock (Acott et al. 1987). They produced 1.64 million clean short tons of medium volatile metallurgical coal for export to Japan. Mining operations are carried out in two 12 h shifts, 7 days a week. The operation employs a truck/shovel technique to mine multiple open pits. Shovels with 15 and 30 cubic yard bucket capacity are employed in conjunction with 100 and 170 ton trucks.

The area has a Cordilleran climate characterized by cold winters and cool summers (Strong and Leggat, 1981). Meteorological data collected at the CRC lease for the years 1977-1987 indicate that the annual mean temperature is 2.4 C. The mean daily maximum is 8.0 C while the mean daily minimum is -3.2 C. The mean maximum temperature for the 11 years is 28.6 C while the mean minimum temperature for the same period is -35 C. The area receives an average of 744 mm of precipitation annually, 69.8% of which falls between May and September.

The study area is classified as Subalpine (Corms and Annas, 1986) and is typified by rolling topography and steep slopes of uplifted Mesozoic shales and sandstones. Elevation of the mine ranges from 1680 to 1860 m a.s.l. (5512 - 6102 feet) (Acott, 1981). Prior to mining, the study area was almost entirely forested with a closed canopy spruce/fir forest. Forest areas are dominated by hybrid spruce (Picea glauca x engelmannii), lodgepole pine (Pinus contorta), fir (Abies lasiocarpa) and black spruce (Picea mariana). Aspen (Populus tremuloides) occurs on exposed, warm, south-facing slopes. Most timber within the lease area is non-merchantable (<15.2 m (50 ft) high, <20.3 cm (8 in) dbh, <4 per ha (10 per acre). Soils of the study area are generally orthic gray luvisols on fine textured materials or eluviated brunisols on coarser textured parent materials.

The mining sequence involves site preparation by first salvaging or removing the timber resource. The topsoil and upper regolith layers are then salvaged and stockpiled for use later in the reclamation program. Finally, overburden is removed from the pit and used to backfill an

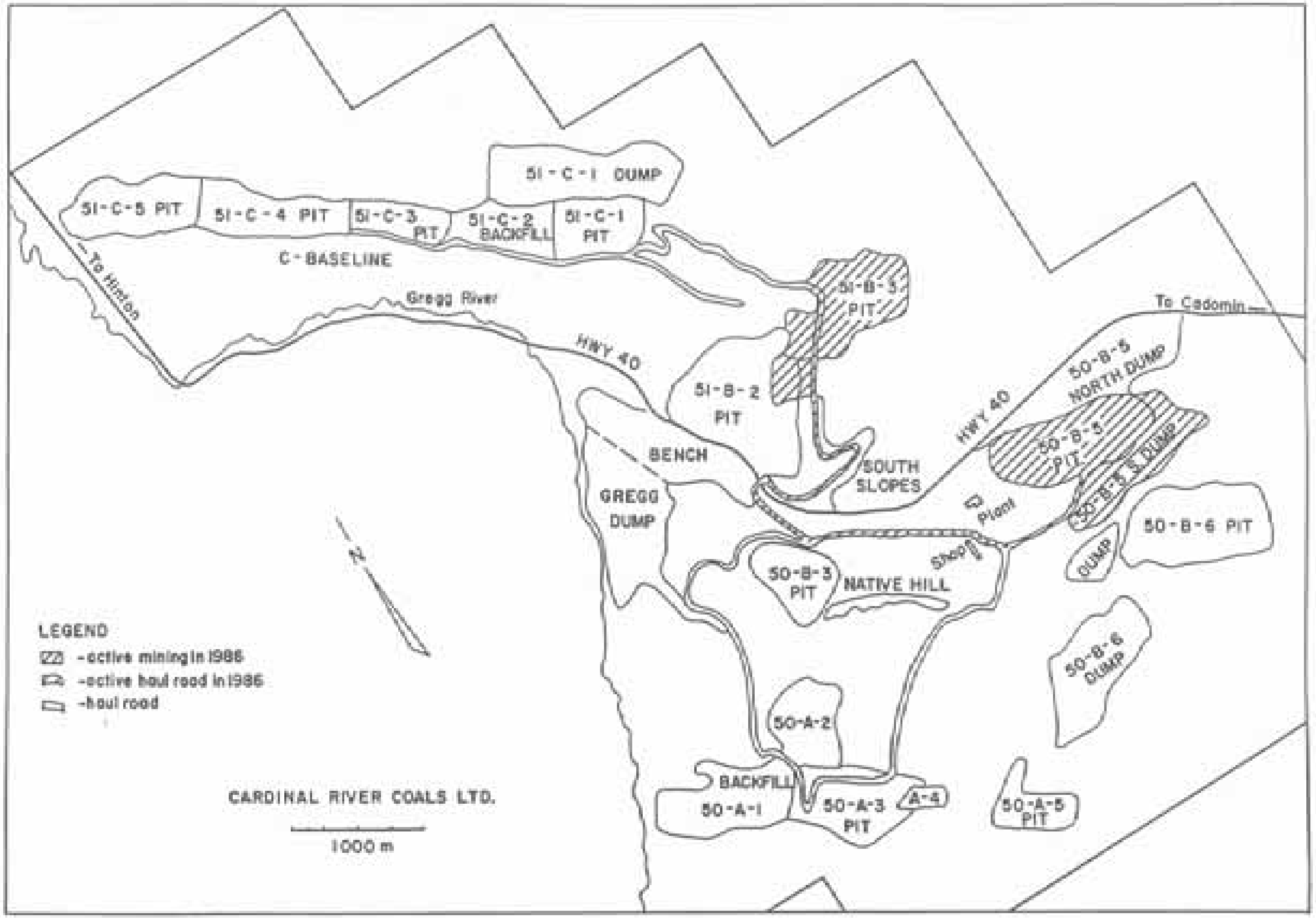

Figure 1. Location of pits, dumps and backfills at Cardinal River Coals Ltd., 1986.

existing pit or dumped externally onto an area where no previous mining activity has occurred.

Following the mining activities, the dumped or backfilled overburden is graded and recontoured to a slope angle of 27° or less. Regolith is placed over the entire surface to a depth of 15 cm (5.9 in), and topsoil islands are placed in favourable locations. The whole area is then seeded and fertilized and finally reforestated in appropriate locations. Figure 1 illustrates the location of the various pits, dumps and backfills that have been developed at CRC.

Revegetation is carried out using agronomic species in roughly a 50-50 grass/legume seed mixture. Grasses used are a combination of sod-forming and bunchgrasses - streambank wheatgrass (Agropyron riparium), smooth brome (Bromus inermis), red fescue (Festuca rubra), Canada bluegrass (Poa compressa), Kentucky bluegrass (Poa pratensis), crested wheatgrass (Agropyron pectiniforme), orchard grass (Dactylis glomerata), Russian wild ryegrass (Elymus junceus), tall fescue (Festuca arundinacea), hard fescue (Festuca ovina), and timothy (Phleum pratense). Legumes used are cicer milkvetch (Astragalus cicer), rambler alfalfa (Medicago media), sweet clover (Melilotus spp.), sainfoin (Onobrychis viciifolia) and alsike clover (Trifolium hybridum).

Approximately 200 bighorn sheep currently use the lease site from late summer to late spring. The sheep use reclaimed areas for foraging and the high walls of exhausted pits for escape terrain and travel routes. Sheep travel over non-reclaimed overburden and through active mining sites to gain access to forage areas. Some reclaimed areas located at distance from high walls are not used for forage, while some pits surrounded by coniferous forest or non-reclaimed overburden are not used for travel or escape.

A limited non-trophy sheep hunt was held in the fall of 1984, 1985 and 1987 on a reclaimed portion of the lease area. In addition, the Alberta Fish and Wildlife Division uses this site for capturing sheep for various purposes. A total of 84 sheep have been removed by hunting or other methods over the 4 year period ranging from 1984 - 1987. Eighty-two percent of these animals have been mature females.

Prior to the current mine development, rams were known to use old mine workings in the vicinity of the 50-A-3 pit for mineral licks. Surveys conducted by the Alberta Fish and Wildlife Division (Lynch 1972, Cook et al. 1978, Cook 1982) indicate that sheep were sighted on alpine ranges adjacent to the mine lease as well as on the 50-A-2 backfill. By 1979, large numbers of sheep of all age classes were frequenting reclaimed areas on the mine lease adjacent to timberline and were using the reclaimed south-facing slopes above Hwy 40 (G. Acott, CRC, pers. commun.).

METHODS

Animal observations in the field were made by direct ground counts from a fixed census route. Counts were begun September 17, 1985 and continued weekly until September 1, 1986. During each count, the location of each individual or group of sheep was marked on acetate overlays on a

1:4,800 base map. In addition to plotting locations, notes were made on the age class and activity of each individual within the group. Eight age classes described by Geist (1971:54) were identified. They were: lambs, yearling females, adult females, yearling rams, class I (2 yr) rams, class II (3-5 yr) rams, class III (6-7 yr) rams and class IV (8+ yr) rams. A total of 11,933 individual sightings from 138 census trips provided the data base for describing seasonal and spatial distribution of the sheep. Maximum counts of each age class were used to estimate population size for use in depicting seasonal fluctuations of the sheep herd on the lease.

Field data were computerized by coding and digitizing observation locations and by generating a corresponding database containing the numbers, age classes and activities of sheep associated with each location. Maps of data subsets and their locations that depict the cumulative frequency of observations per time period were then generated using the "nmap" program developed by the graphics laboratory at the Faculty of Environmental Design. A grid system with a cell size of 402 x 402 m (1320 x 1320 ft) or 16.2 ha (40 acres) was overlaid on the study area to assist in quantitative and visual analysis of the data. Cell size was arbitrarily selected. Data from the eight age classes were groups into 2 categories - nursery herd (lambs, ewes, female and male yearlings and class I rams) and older rams (class II, III and IV rams). Class I rams were associated both with the nursery herd and the older rams; however they were placed with the nursery herd for purposes of displaying and analyzing spatial distribution.

RESULTS

Seasonal Distribution

Four major movements were observed for the rams that used the CRC lease. These movements focussed on the following events:

Prerut or fall congregation.--Rams had already congregated on the lease by the time the study was initiated on September 17, 1985. During this period, they were largely segregated from the nursery herd. They occupied portions of the C-baseline and the Gregg dump bench above HWY 40. In early November, most rams moved onto the rutting area, which was also the ewe prerut range.

Rut.--This was defined as the period when rams and estrous ewes were observed. Large rams from off the lease began to be sighted on the rutting range (50-A-1 and 50-A-2 backfill and 50-A-3 pit) on November 15. The first successful copulation was observed November 20, 1985, and the last was observed January 18, 1986. The peak of rutting activity occurred during the second week of December, 1985.

Winter.--This is the period when the rams separated from the ewes leaving them on the rutting range. The rams occupied a native south-facing slope that is centrally located on the lease. The rams alternately used this slope and the south-facing slopes above HWY 40 until they began to leave the lease in late May. These latter slopes were also used by the nursery herd as alternate winter range.

Summer.--This is the period when no rams were present on the lease except the occasional individual or small group. Groups of rams were sighted during the summer in alpine areas, travelling along the mountain ranges.

Four major movements were also observed for the nursery herd that occupied the CRC lease:

Prerut, rut and early winter.--The nursery herd had already congregated on the lease when the study began in September, 1985. In early fall they used the slopes above HWY 40 and the Gregg dump bench in addition to the rutting range located closer to timberline. Some emigration by ewes was observed during this time. During the rut the ewes were concentrated entirely on the rutting range. After the rut, the prerut range (with the exception of the Gregg dump bench) was used as early winter range.

Late winter/spring.--This period was characterized by half of the nursery herd leaving the lease to winter elsewhere. This reduction in numbers was observed over two years. Ewes remaining on the lease continued to use the same areas frequented during the fall and early winter, however, 2/3 of the observations were made on the rutting range.

Lambing.--This period was defined when the first new lambs of the year were sighted (May 28 in 1986 and May 24 in 1987). This period also included the time when ewes focussed their activity around salt availability. Most lambing occurred off the lease; however, in May 1986, 6 ewes lambed on the east wall of the 51-B-2 pit. In May of 1987, 5 ewes were observed to lamb on this same wall. The nursery herd regrouped in alpine meadows immediately southwest of the lease, but during the remainder of June, ewes made daily trips to the 50-A-3 pit. The many seeps on the walls of this pit were used as a mineral lick. No grazing on the reclaimed areas was done by the ewes at this time as they returned daily to the higher alpine meadows.

Summer.--During this period the nursery herd did not frequent the lease. Two ewe groups used the drainages southwest of the lease. These two groups represented only a portion of the nursery herd that congregates on the lease in the late summer. As the summer progressed, these two nursery groups moved higher into the headwaters of the drainages. By mid August, ewes began the prerut congregation on the lease.

When the above movements for both ewes and rams were combined, 6 activity periods were identified. These time periods were as follows:

Prerut	- September 17 to November 14, 1985
Rut	- November 15 to January 18, 1986
Winter	- January 19 to February 14, 1986
Spring	- February 15 to May 27, 1986
Lambing	- May 28 to June 30, 1986
Summer	- July 1 to August 10, 1986

Of the 11,933 individual sheep observations made between September 17, 1985 and August 10, 1986, 73% were lambs, ewes or yearlings of either sex, 5% were of class I rams and 22% of older rams (Table 1). Sheep were concentrated on the lease from the prerut through to the beginning of lambing season, a period of 256+ days for the 1985/86 season (Figure 2). The prerut period for the 1986/87 season began August 11 when the first large numbers of ewes, lambs, yearlings and class I rams began to appear on the lease. Older rams (class II, III and IV) did not congregate in large numbers for the 1986/87 prerut season until a few weeks later, in early September.

Table 1. Number of observations of bighorn sheep by class at Cardinal River Coals Ltd. for the year 1985-86.

Season (# counts)	Lambs, ewes and yearlings	Ram I	Ram II, III, IV	Total
Prerut (23)	2435 (80%)	96 (3%)	506 (17%)	3037 (26%)
Rut (26)	2421 (74%)	179 (6%)	651 (20%)	3251 (27%)
Winter (14)	1370 (74%)	109 (6%)	364 (20%)	1843 (16%)
Spring (38)	1835 (63%)	191 (7%)	880 (30%)	2906 (24%)
Lambing (20)	466 (72%)	27 (4%)	151 (24%)	644 (5%)
Summer (17)	214 (84%)	7 (3%)	32 (13%)	252 (2%)
Year (138)	8740 (73%)	609 (5%)	2584 (22%)	11933 (100%)

Spatial Distribution

Aproximately 1/3 of the observations for the nursery herd for the year 1985/86 were made within 32.4 ha (80 acres) of the 50-A-1 and 50-A-2 backfill (Figure 3). Another 1/3 of observations were made within an additional 32.4 ha of the 50-A-2 backfill and within 48.6 ha (120 acres) of the south slopes and valley bottom adjacent to HWY 40. The last 1/3 were scattered over 696 ha (1720 acres) of the lease. The total area used by the nursery herd for grazing, security, mineral licks or travelling within the lease boundaries was 809.4 ha (2000 acres).

Observations of the older rams indicated that 1/3 of these animals were sighted within 32.4 ha of the 50-A-1 and 50-A-2 backfill, plus a 16.2 ha block of the native hill and a 16.2 ha block of the south slopes above HWY 40 (Figure 4). The next 1/3 of observations were scattered over 113.3 ha (280 acres) located on the 50-A-2 backfill, on the slopes adjacent to HWY 40, and on a topsoil stockpile located on the C-baseline ridge. The last 1/3 of observations were located on the C-baseline ridge. The last

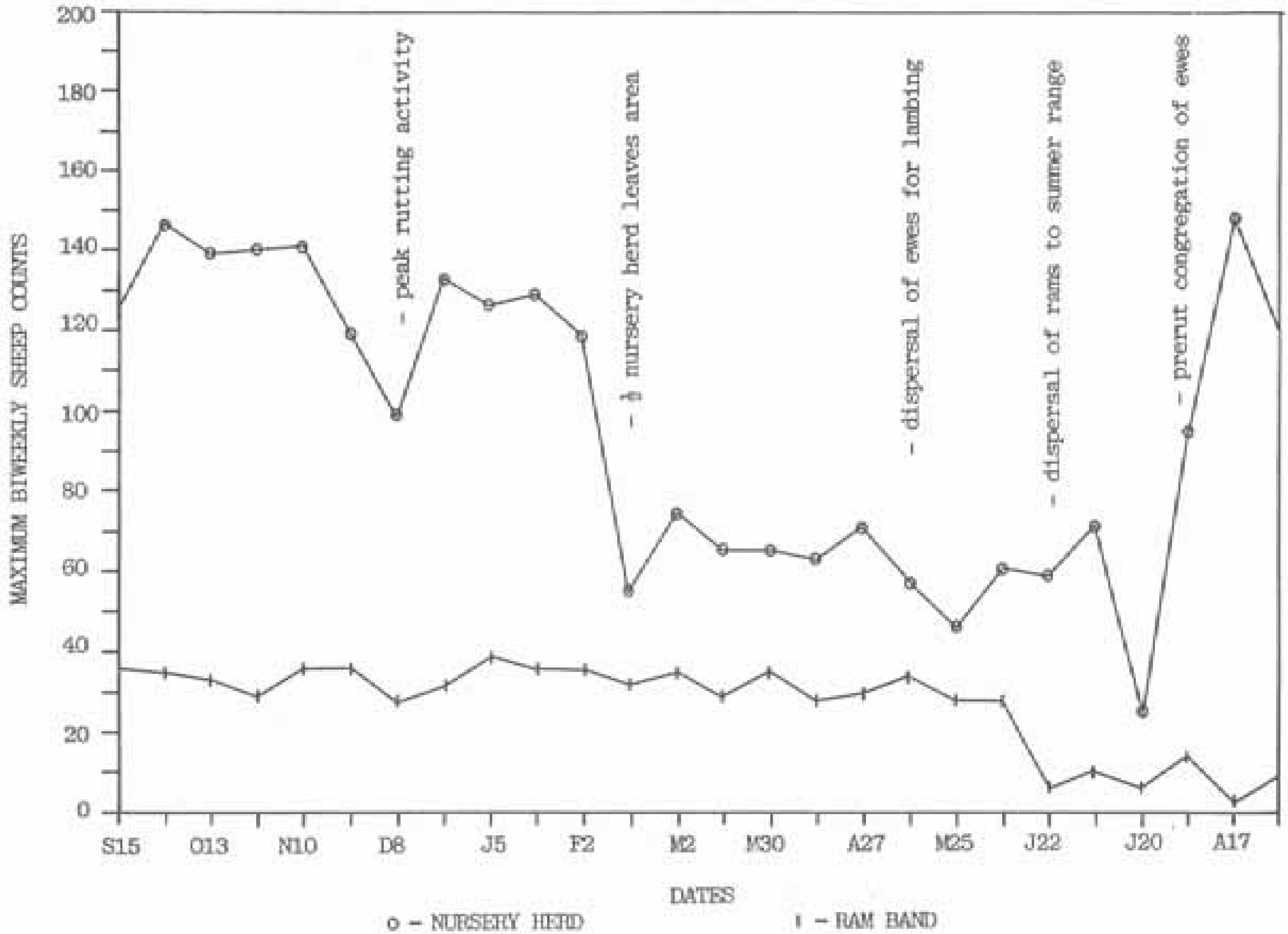

Figure 2. Seasonal use of the Cardinal River Coals Ltd. mining site by bighorn sheep from September 15, 1985 to September 19, 1986.

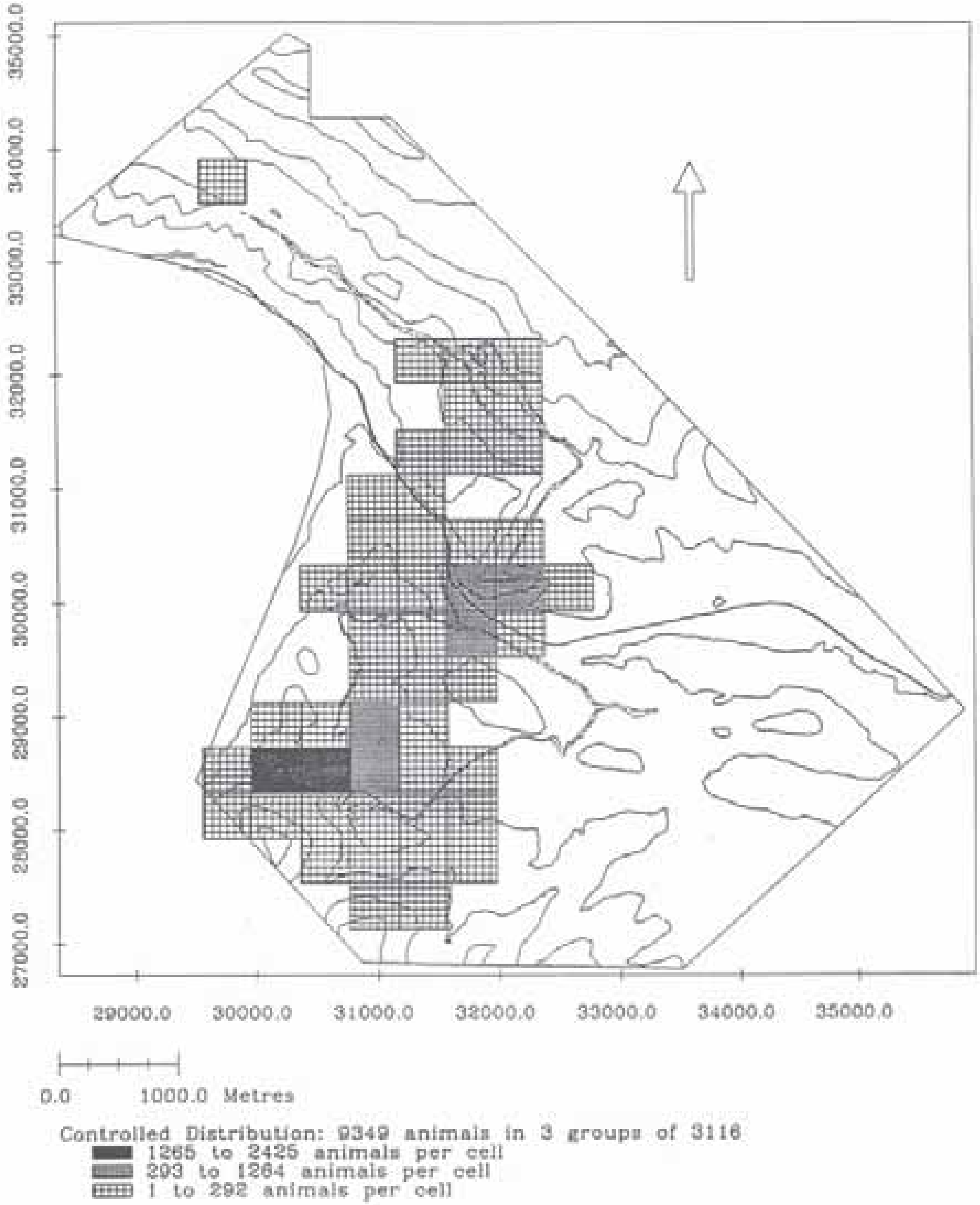

Figure 3. Intensity of use by lambs, ewes, yearlings and class I rams from September 17, 1985 to August 10, 1986.

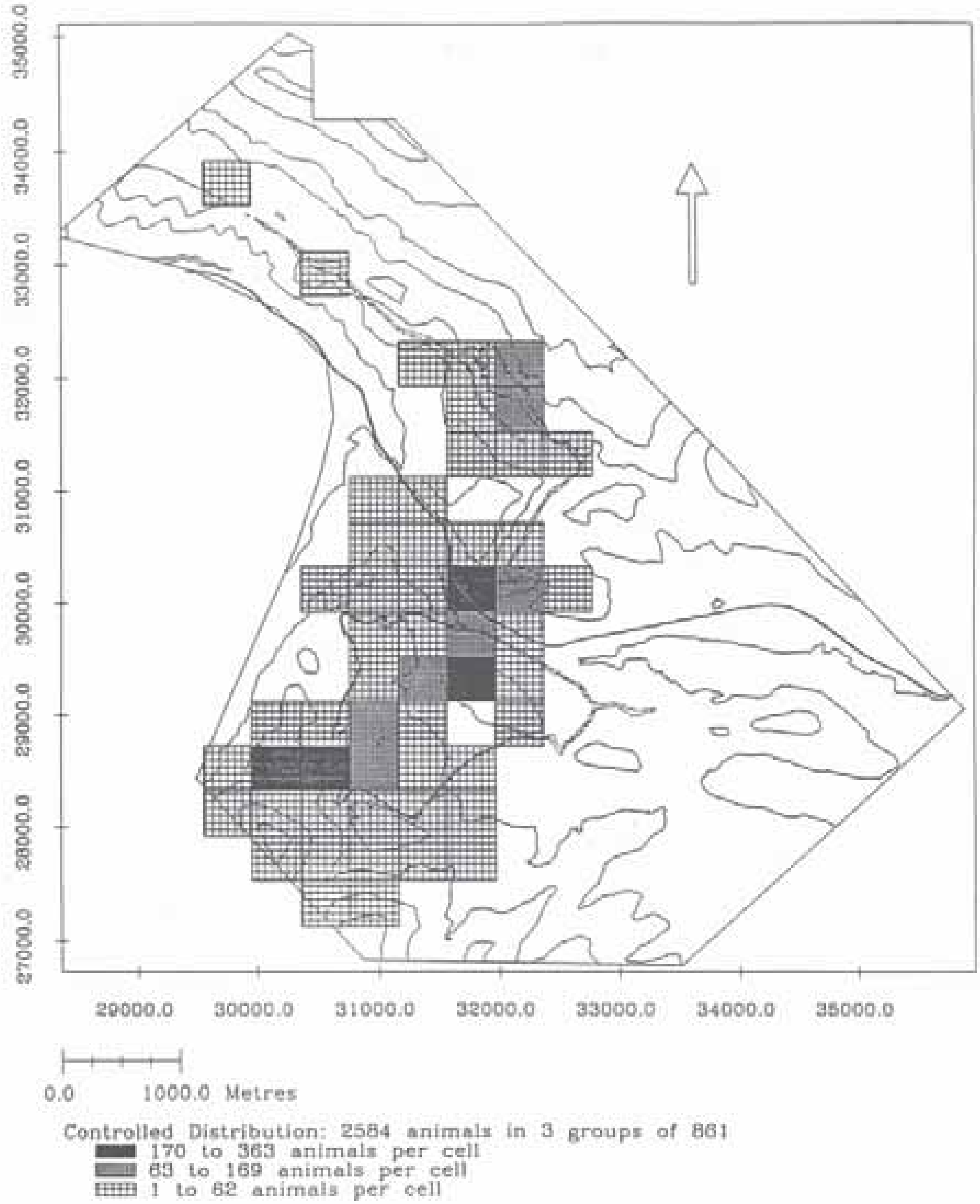

Figure 4. Intensity of use by class II, III and IV rams from September 17, 1985 to August 10, 1986.

1/3 of observations were located on 696 ha of the lease. The total area used by the older rams was 874 ha (2160 acres).

From the above description it is apparent that the most important area used by the sheep is focussed on the 50-A-1 and 50-A-2 backfill. This area was reclaimed in 1977, 1978 and 1979 and is used for grazing by the nursery herd during the prerut, rut, winter and spring seasons. Rams congregated here during the rut (Figure 5) during which time the high walls of the adjacent 50-A-3 pit were used heavily by ewes escaping rams and by rams attending receptive females. The benched walls of this pit were used as escape sites, bedding areas, and in May and June the seeps from the walls were used as mineral licks by the nursery group (Figure 6) that used the Luscar Creek valley immediately west of the lease. This daily movement was a response to the need for minerals as virtually no grazing took place on the mine at this season.

The sheep also made moderate to heavy use of the native grassed slopes of the large hill that is centrally located on the mine lease. This south-facing slope was used primarily by rams during the winter and spring period when they had segregated from the nursery herd (Figure 5). Heaviest use of this hill was on the NW corner which lies adjacent to the 50-B-3 benched pit wall. This slope and pit wall were used by the nursery herd chiefly as a travel route connecting the 50-A-2 backfill with the HWY 40 area.

The nursery herd used the south-facing slopes and valley bottoms adjacent to HWY 40 heavily in the prerut and spring seasons, while the rams used this area heavily in the winter and spring. This area was seeded in 1976. The east wall of the nearby 51-B-2 pit was used as escape terrain by the sheep when they frequented this area. In May 1985 and May 1986, 6 and 5 ewes, respectively, lambed on this wall. In 1986, these lambing sites were within a few hundred metres of an active dump site. Most lambing, however, took place off the lease.

Moderate use of the large bench and slopes of a portion of the Gregg dump was made by the nursery herd during the prerut (Figure 6). This part of the Gregg dump was reclaimed in 1972 and 1979/80.

Rams also used a topsoil dump located on the C-baseline (Figure 4). This area received heavy use during the prerut. A powerline located on the C-baseline was reclaimed in 1978 while the topsoil island was reclaimed in 1983. Rams have been observed on the C-baseline by mine personnel since 1970.

DISCUSSION AND CONCLUSION

Mining activity at CRC has resulted in a drastically changed landscape. The closed canopy coniferous forest of the central portion of the lease has been replaced by open terrain composed of reclaimed areas, active and abandoned pits and non-vegetated regolith material. Interspersed throughout are patches of the original coniferous forest and native grasslands. The common feature of bighorn distribution, (the presence of rocky escape terrain in proximity to quality forage) has been reproduced through the process of mining development and reclamation.

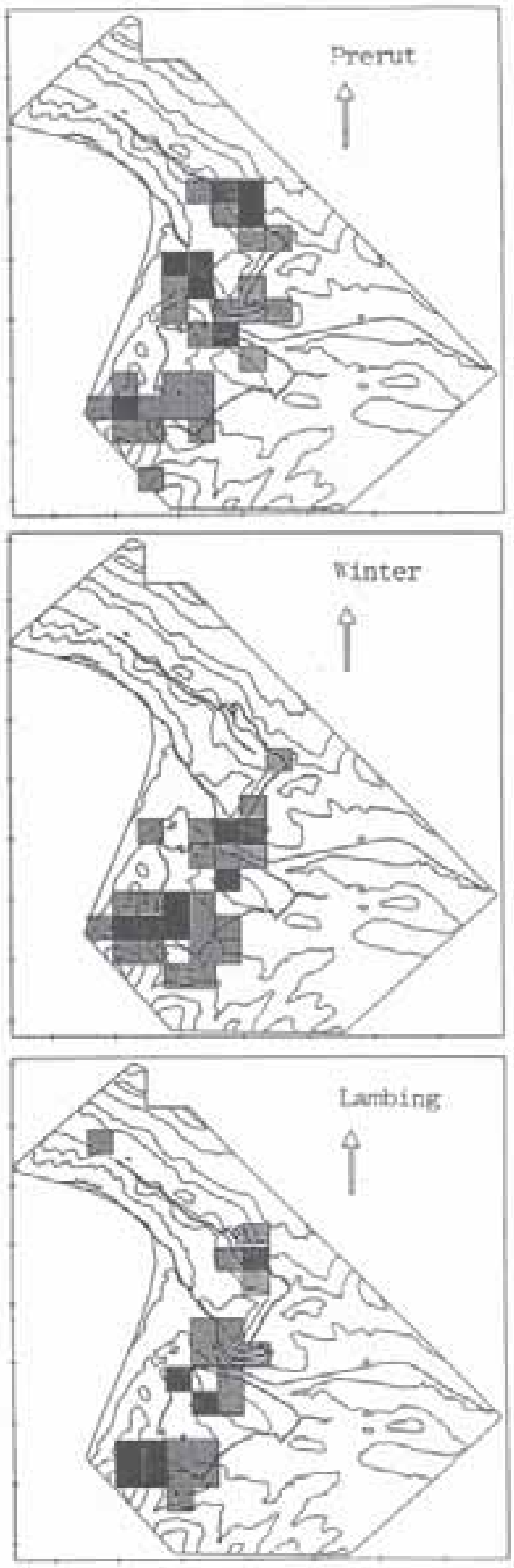

Figure 5. Seasonal use by class II, III, and IV rams of Cardinal River Coals Ltd. from September 17, 1985 to August 10, 1986. ▬ = heavy use; ▬ = moderate use; ▬ = light use.

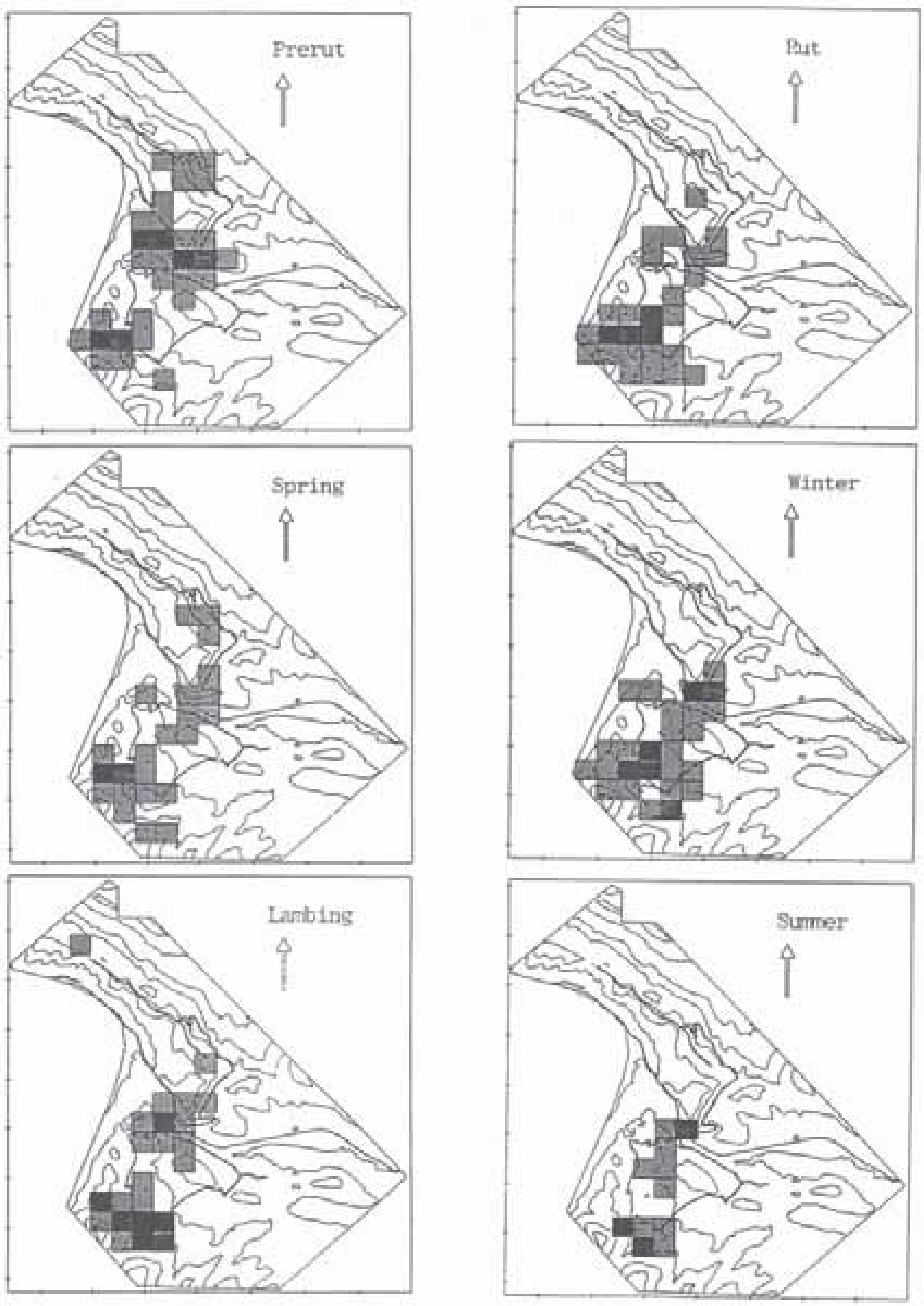

Figure 6. Seasonal use by lambs, ewes, yearlings and class I rams of Cardinal River Coals Ltd. from September 17, 1985 to August 10, 1986. ▬ = heavy use; ▬ = moderate use; ▬ = light use.

Every area on the lease used heavily by the sheep for foraging was adjacent to high walls of exhausted pits. These high walls served as escape terrain for the sheep, as bedding sites, as travel routes, and as sources for mineral licks. Some lambing occurred on benches of the high walls. Sevety-five percent of all sheep observations for the year 1985/86 occurred within 360 m (1181 feet) of escape terrain.

In addition to creating a usable habitat for bighorn sheep, other conditions that exist within the mine lease created a secure environment which was used opportunistically by the sheep. Coyotes were observed frequently on the sheep ranges, however, no predation was observed. Grizzlies travelled through the mine seasonally, but did not linger on the reclaimed areas. Wolf tracks were observed on the peripheral edges of the lease but never in the central portion or on sheep ranges. Cougar sign was not observed. It is thought that while the sheep were on the lease, mortality from predators was minimal.

CRC has been active an coal mining operation since 1969. During the 1985/86 season, 2 pits were active (51-B-3 and 50-B-5). Dumping, grading, regolith and topsoil placement, reseeding and refertilizing activities all took place in areas utilized by the sheep. For the most part, however, these activities occurred in a predictable fashion, or in areas not yet used for forage, or in the summer when there was minimal use of the lease by the sheep. Once a reclaimed area was established on the lease, little activity actually took place on the site. There were no tourists, trail bikes, hikers or skiers. Hunters have been active only recently on the same ranges that are important to the sheep. This hunt is very controlled and represents less harassment than what occurs during the hunting season outside the mine site where both trophy and non-trophy sheep are legal.

Bighorn sheep are modern ice-age mammals that have developed a high capacity for learning. Bighorns historically used the areas adjacent to the CRC lease prior to its development. Once a usable habitat was developed by mining activity, the sheep were well equipped to take advantage of the predictable, secure environment offered by the mining site.

A significant population of bighorn sheep has developed seasonal and spatial use patterns on the CRC lease. Several factors must be considered and explored further to ensure that this use is sustained in the long term to be of benefit to other developments with similar potential. The significance of the high walls as part of bighorn habitat was not recognized by the Alberta Land Conservation and Reclamation Council (ALCRC) until this study was conducted. Recommendations on maintaining high walls of significance to sheep have been made (Acott, 1986) to the ALCRC and were accepted. Further recommendations on the wall characteristics and placement in relation to foraging areas will be forthcoming. Future land management must recognize that sheep use of this site in part depends on a secure and predictable environment. Reclamation efforts designed specifically for human recreation activities may not be compatible with sheep use of the area if they are poorly placed in relation to habitat developed for sheep. Each sheep population and mine operation have their own characteristics. This site-specific wildlife study has proven to be invaluable for mine planning and reclamation efforts.

LITERATURE CITED

Acott, G. B. 1981. Cardinal River Coals Ltd. reclamation status annual report 1980. Cardinal River Coals Ltd., Hinton, AB. 28 pp.

Acott, G. B. 1986. Proposal to reduce costs at Cardinal River Coals Ltd. Cardinal River Coals Ltd., Hinton, AB. 17 pp.

Acott, G. B., M. T. O'Toole and F. J. Munn. 1987. Cardinal River Coals Ltd. reclamation and mining status report - 1986. Cardinal River Coals Ltd., Hinton, AB. 26 pp.

Cook, A. R. 1982. Aerial bighorn sheep census of designated winter ranges within the Edson district of the east slopes region. Alberta Energy and Natural Resources, Fish and wildlife Division, Edmonton, AB. 57 pp.

Cook, A. R. and W. K. Hall. 1978. Aerial sheep survey of the Edson, Red Deer and Calgary regions using the revised winter range technique. Alberta Recreation, Parks and Wildlife, Fish and Wildlife Division, Edmonton, AB. 100 pp.

Corms, I. G. W. and R. M. Annas. 1986. Field guide to forest ecosystems of west-central Alberta. Northern Forestry Centre, Canadian Forestry Service, Edmonton, AB. Rept. # F042-86 / 1986E. 251 pp.

Department of Energy and Natural Resources, Government of Alberta. June 15, 1976. A coal development policy for Alberta. Edmonton, AB. 38 pp.

Geist, V. 1971. Mountain sheep, a study in behaviour and evolution. The University of Chicago Press. 383 pp.

Lynch, G. M. 1972. Red Cap sheep; their movements and migrations (1972 progress report). Alberta Fish and Wildlife Division, Edson, AB. 18 pp.

Strong, W. L. and K. R. Leggat. 1981. Ecoregions of Alberta. Alberta Energy and Natural Resources, Resource Evaluation and Planning Division. ENR Tech. Rept. #T/4, Edmonton, AB. 64 pp.

Wallis, C. and C. Wershler. 1979. Literature review of considerations for reclaiming lands as wildlife habitat. Report prepared by Cottonwood Consultants Ltd. for Cardinal River Coals Ltd., Hinton, AB. 43 pp.

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ENVIRONMENTAL IMPACT OF THE 1988 WINTER OLYMPICS ON BIGHORN SHEEP OF MT. ALLAN

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Abstract: For 2 years prior to the 1988 Winter Olympics on Mount Allan, data were collected on distribution, productivity, survival, lungworm output and activity budgets of bighorn sheep, (*Ovis c. canadensis*). During 1986/87, the ski area was first opened for public skiing and 2 pre-Olympic downhill races were held. From 1986 to 1987 the population declined by 18% due in part to an intentional increase in the non-trophy sheep hunting permits. Lower lamb survival also contributed to the decline. Lamb production in 1986 was higher (48 lambs per 100 ewes) than in 1985 (29 lambs per 100 ewes). Production in 1987 was 37 lambs per 100 ewes. Range abandonment occurred in 1986/87 on a small portion of the winter range immediately below "the ladies downhill start area". This abandonment was due to human activities on the ridge top, snowmaking, helicopter flights, and avalanche blasting. Numbers of lungworm larvae in sheep feces increased significantly in 1986/87, but they also increased at the control area and at Sheep River. During 1987-88, larval outputs had returned to pre-1986-87 levels. Steps were taken to control helicopter activity and sheep-human interaction above the ladies downhill start for the 1988 Olympics. Co-existence of this sheep population and skiers can probably be maintained provided that no further encroachment on sheep winter range occurs.

In February, 1988 the winter Olympics were held in Calgary, Alberta with the alpine events taking place on Mt. Allan. For those events, a new recreational ski development, Nakiska, was built on the same mountain that winters a large herd of Rocky Mountain bighorn sheep (*Ovis c. canadensis*). Considerable controversy erupted over the choice of Mt. Allan as the site with much of that concern centering on the effects this development was going to have on the well being of the bighorn herd.

A monitoring program began in spring 1985, and continued until April 1988. Construction of the facility occurred during 1985-86 and the area was first opened for public skiing during 1986-87. Several World Cup downhill races were held that first season as Olympic test races and provided the opportunity to measure sheep response to activities related to normal skiing operations as well as an Olympic equivalent. Based on the results, mitigation would be enacted and its effectiveness measured during the Olympics themselves. The objective of this paper is to report on the impact that first year of operation had on the population, what mitigation was implemented and how the bighorns responded during the Olympics.

The author would like to thank P. Balagus, M. Badry, L. Stegenga, M. Raine, P. Paul and O. Pall for exceptional field work. B. Kuzyk conducted the lungworm and crude protein analysis. W. Wishart and H. Carr provided valuable advice on the study design. I would like to thank the Kananaskis Environmental Research Center for the wonderful accommodation. Tremendous cooperation was received from the Nakiska Ski Area (R. Farwig) and OCO '88 without which this data would have been far more difficult to collect. This study was funded primarily by the Olympic Secretariat of the Alberta Recreation and Parks Department.

STUDY AREA

Mt. Allan is located approximately 90 km west of Calgary, Alberta at the northern end of the Kananaskis Range (50° 58' N, 115° 12' W). The Nakiska ski area occupies predominantly conifered northern and eastern exposures that provide limited protection from the effects of solar radiation and the strong prevailing westerly winds. These warm winds (chinooks) regularly blow during winter and have a significant modifying effect on the severity of winter. A majority of ski runs are concentrated between the base area at 1495 m and tree line at 2350 m, however, an additional lift (Platter Lift) was constructed to increase the length of the Mens Downhill ski run. This lift extended the ski area into the alpine zone to 2415 m. At 2460 m is the ridgeline above all of the ski runs. The south and southeast facing slopes below this ridge are open alpine and sub-alpine vegetation zones with tree line at about 1750 m.

While most of the upper ski runs radiate from the top of the Gold Chair Lift, 1 run (Women's Downhill) begins further east and at a point lower in elevation. The start of this run is accessed by a narrow catwalk which traverses a conifered slope for approximately 1 km before emerging from the trees onto a ridge at the top of the Women's Downhill. This ridge overlooks the Nakiska ski area to the north and an open alpine slope to the south.

METHODS

Between November and April of each year, data on population size, structure, survival and distribution were collected through direct ground observation with occasional supplementation by aerial observations. Monthly surveys were conducted over the entire Mt. Allan-Wind Ridge winter range with a helicopter being used to census the more inaccessible portions. Due to varying survey conditions, the maximum count obtained from any one monthly census for that year was used. Sheep were classified as to adult ewe, lamb, yearling ewe, yearling ram, 1/4 curl ram, 1/2 curl ram, 3/4 curl ram, and 4/5 curl ram.

Productivity estimates were obtained from ground censuses conducted during the summer. During these censuses, we attempted to travel as much of the summer range as possible in 1 to 2 days in order to reduce duplication. The maximum number of ewes, lambs and yearlings observed during these surveys was used to calculate a summer lamb/ewe ratio. Similarly, a winter ratio was obtained during the winter counts. Total spring cohort size was estimated by taking the maximum number of sheep comprising each cohort found during the previous winter and assuming no additional mortality until spring. The number of viable lambs present was estimated using the lamb/ewe ratio for that summer and the known number of ewes which were around in late winter. The differences between the spring counts and the following winter counts provided survival estimates.

To determine range use intensity, the study area was divided into grids by vertical projection each approximately 2.5 - 3.0 hectares. Major ridges, creek drainages and cliff bands were used wherever possible as grid boundaries. The area was travelled regularly throughout winter along designated routes, however, because of weather constraints it was not possible to observe all grids with equal intensity. Area use was therefore calculated as number of sheep observed/grid/census trip. Low, medium and high use grids were arbitrarily distinguished using 0-1, 1.1-2.5, and 2.6+ sheep/grid/census respectively as criteria.

Fecal samples were collected monthly from January to April on Mt. Allan and analyzed for Protostrongylus spp. larvae (Samuel and Gray 1982). In addition, monthly samples were also collected from Wind Ridge and used as a control since these sheep were approximately 11 km from the Nakiska ski area. Because of the non normal distribution of larval counts, square root transformations were required of all counts before statistical analysis could be performed.

Additional data were collected incidentally on helicopter activity around Nakiska, snowmaking activities, recreational skiing activities and any other activity with the potential to interact with sheep.

RESULTS

Population Size

The Mt. Allan bighorn winter population increased since 1973 to a high of 297 animals in 1986 (Figure 1). Prior to 1983, estimates were based on a single census, but since 1983, estimates have been the maximum count obtained from an average of 4.4 (range 3-6) surveys per year. Following 1986, the population declined by 18% and remained at that level after the 1988 Olympics.

Survival Rates

Based on differences in cohort numbers from spring to late winter, survival of all cohorts except rams in 1986-87 was lower than that in 1987-88 (Table 1).

Hunting of both trophy rams (4/5 curl restriction) and non-trophy (ewes and lambs) sheep from the Mt. Allan herd occurred, therefore, survival rates include hunting and natural mortality. The number of rams harvested in 1986 and 1987 was 21 and 7, respectively, based on compulsory registration. In 1986, 90 permits were issued for non-trophy sheep with the harvest consisting of 47 ewes and 1 lamb. Permits were reduced to 50 in 1987 and resulted in a harvest of 14 ewes and 1 lamb. One collared ewe was killed in an avalanche and 2 lost to cougar predation. Other predators such as coyotes, bears and wolves are known to frequent the study area, but contribute an unknown level of mortality.

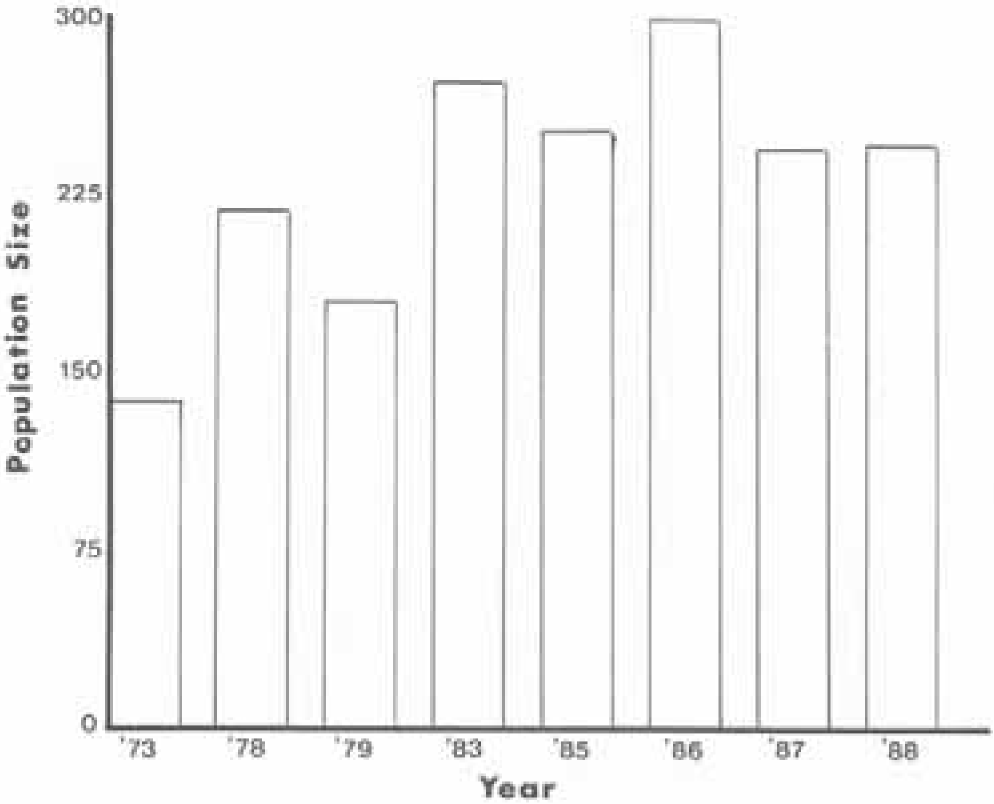

Figure 1. Winter population size of Mt. Allan herd, 1973-1988.

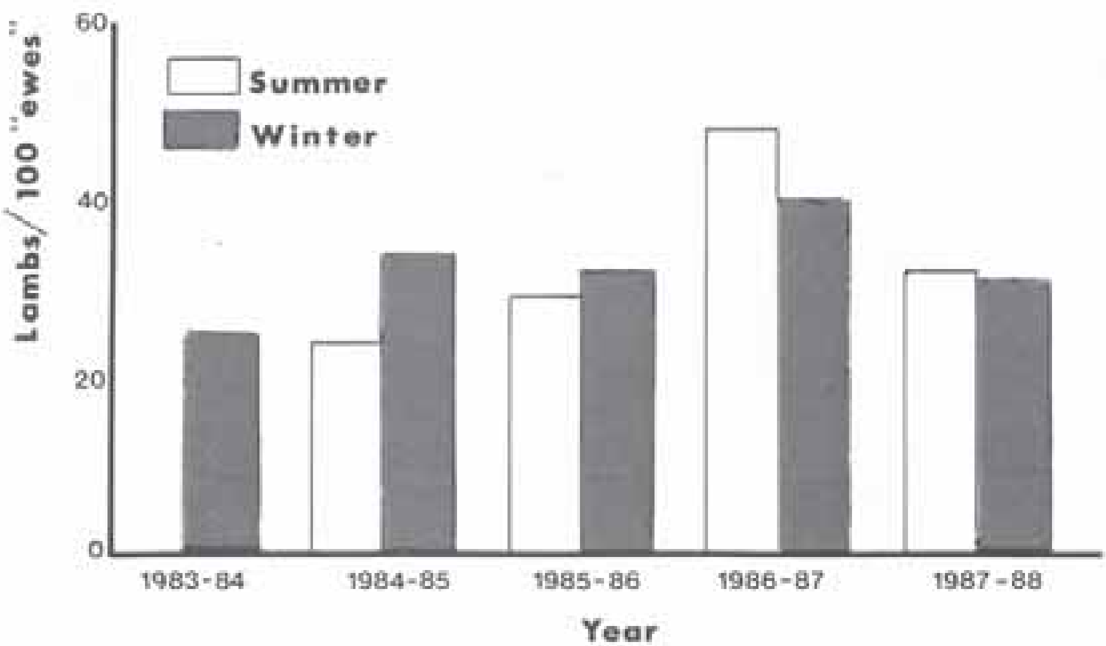

Figure 2. Summer and winter productivity on Mt Allan, 1983-1988.

Table 1. Estimated survival rates of bighorn sheep in the Mt. Allan herd from spring to late winter 1986-1988.

Year	Survival Rate			
	Adult Ewes	Lambs	Yearlings	Adult Rams
1986 to 1987	.62 (155)[a]	.58 (85)	.45 (56)	.78 (91)
1987 to 1988	.92 (112)	.79 (56)	.82 (49)	.67 (94)

[a]( ) = size of cohort in spring

Productivity

Winter lamb/"ewe" ratios (includes yearlings and 2-year old and adult ewes) averaged 32.4 (range 25 - 40) each year since 1983-84 with the highest ratio observed during summer 1986 (Figure 2). Summer values tended to be slightly lower ($\bar{x}$ = 33.2 vs. 34.2) than winter. In 1986-87 that trend was reversed indicative of the poor lamb survival previously seen. The hunting of ewes influenced the winter ratios and could explain the differences observed from summer to winter. A disproportionate number of ewes were harvested with less than 10% of the total consisting of lambs (Harvest statistics, Alberta Fish and Wildl. Div.).

Distribution

In winter, approximately half the herd concentrated on Wind Ridge while the balance extensively utilized the south and southeast facing slopes of Mt. Allan. Greatest use was made of those grids in the basin located to the southwest of the ridge above the Nakiska ski area. Sheep did however, make use of areas immediately above the Men's Downhill run and adjacent to the Ladie's Downhill run. To examine area use on a yearly basis, the study area was divided into 3 areas based on their proximity to the ski area (Figure 3) with Area 1 being on the same face or adjacent to the ski area, and Area 3 being farthest from the activity.

Area 2 received the greatest use throughout the winter and in all years with Area 1 receiving the least (Figure 4). Use of Area 1 was greatest in early winter while Area 3 was used mostly in late winter. Compared to 1985-86, Area 1 usage in 1986-87 declined to nil after December and remained negligible for the rest of the winter. In December 1986, the ski area first opened to public skiing and downhill test races were held in March. With the decline came an increase in Area 3 usage. In 1987-88, Area 1 appeared to receive similar usage to that seen in 1985-86. Also in 1987-88, the percentage of sheep using Area 3 remained high and was actually higher than Area 2 during February.

Lungworm Analysis

Compared to 1986, 1987 fecal lungworm outputs increased significantly

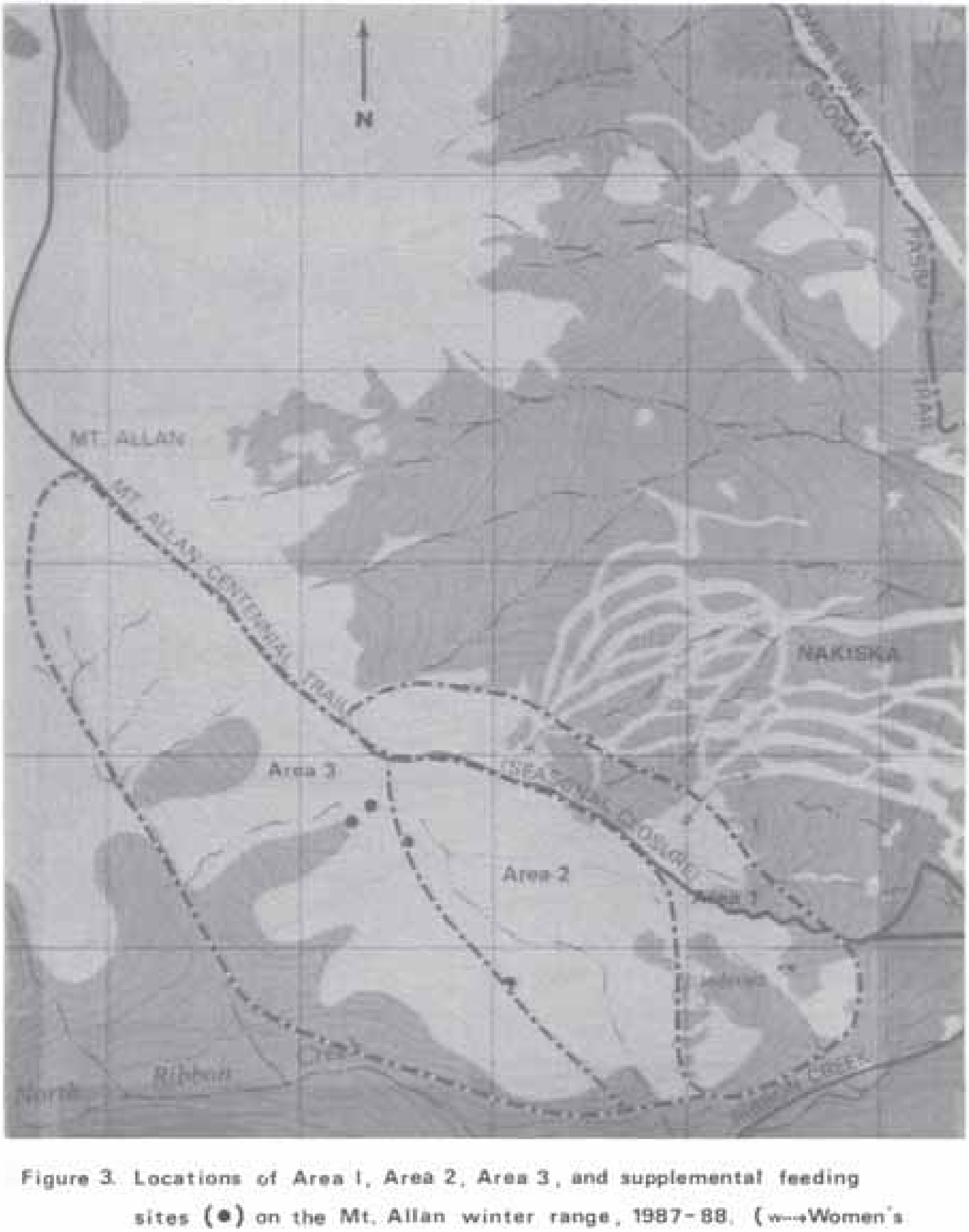

Figure 3. Locations of Area 1, Area 2, Area 3, and supplemental feeding sites (●) on the Mt. Allan winter range, 1987-88. (w--→Women's downhill, м--→Men's dowhill)

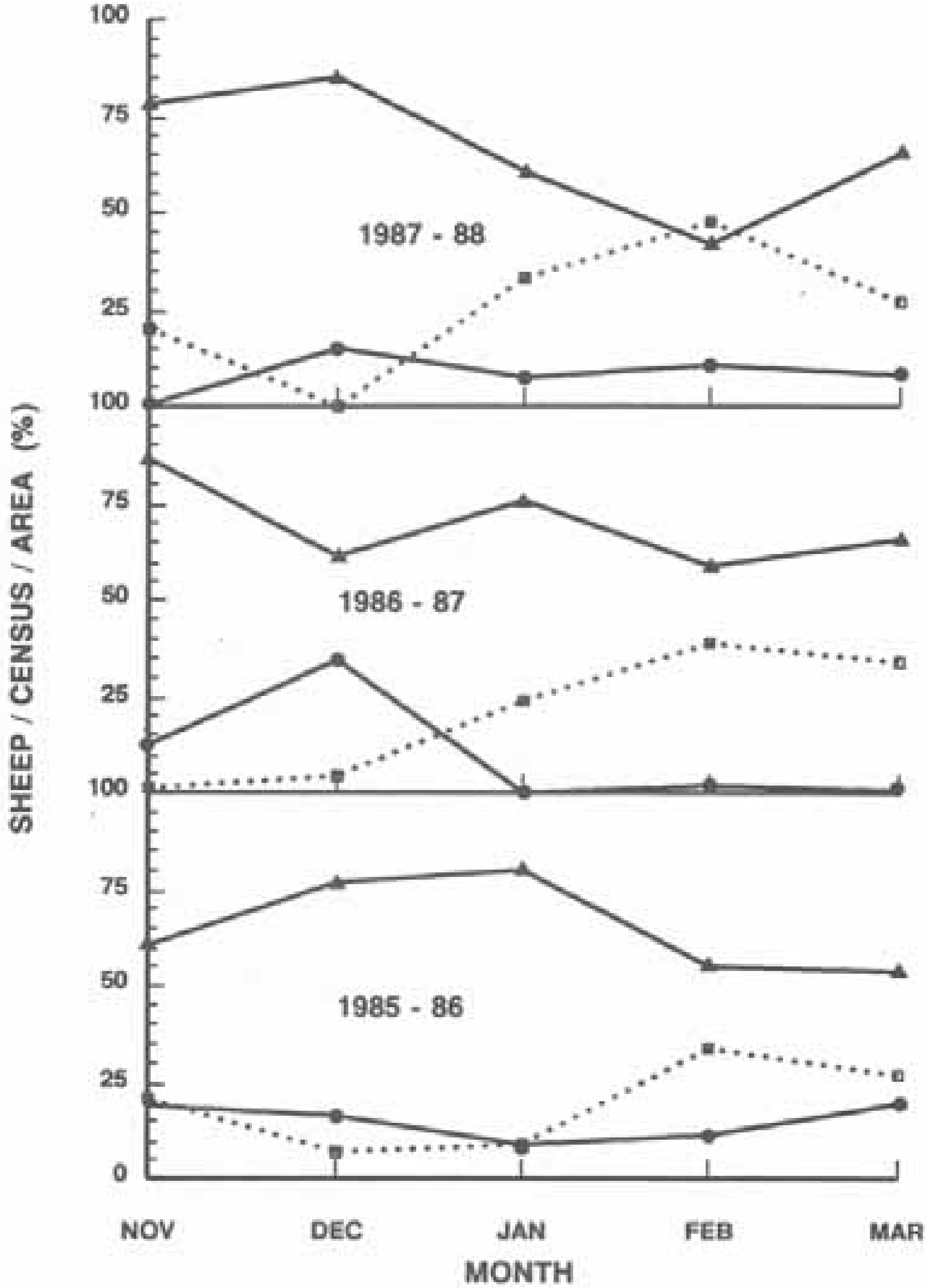

Figure 4. Area use of Mt Allan winter range 1985 to 1988.
(●) area 1; (▲) area 2; (□) area 3.

($P < 0.01$). These increases occurred at both Mt. Allan and Wind Ridge (Figure 5). In 1988, larval outputs decreased to levels comparable to 1986.

Associated Activities

During the World Cup races in March 1987, helicopter activity in the Nakiska area was high. During the 2 week period, helicopters were flying above Nakiska every day except 2 bad weather days. Helicopters being used for race-related functions were not considered a problem because they stayed at or below treeline and to the northeast of the ridge. A majority of the helicopters were chartered by media groups and they did fly west of the ridge over the winter range. Film footage of bighorns taken from the air did appear on 2 television networks covering the races. Sheep predictably fled when the helicopters came overhead usually at an altitude of less than 150 m.

Snowmaking and avalanche blasting occurred during the 1986-87 and 1987-88 ski seasons. Snowmaking guns are extremely noisy and an individual cannot stand next to one for long without ear protection. While most of the snowmaking guns at Nakiska were used at lower elevation, one gun at the top of the Ladie's Downhill caused momentary disturbance to the sheep grazing on the slopes below the ridge. Their reaction upon start up of the guns was to bolt a short distance and then gradually leave the area. This reaction was noted on several consecutive days until the sheep stopped using that slope. Sheep were not seen in any area that coincided with avalanche blasting. Such blasting was done with a cannon type system and occurred on slopes near both the Men's and Ladie's Downhill courses.

People were not observed outside the ski area boundaries climbing the mountain to gain access to viewpoints. Security patrols also did not occur outside the boundaries during either the World Cup or Olympic events. Considerable human activity did occur on the ridge above the Ladie's Downhill. Such activity was related to maintenance, course preparation, officials, media, coaches and racers. During the World Cup as many as 100 people were in the vicinity of the ridge top sightseeing and picture taking. Sheep did not stay during such times. After the World Cup races, public skiing was permitted on the Ladies course with a resulting high percentage of skiers skiing onto the ridge.

Mitigation

Supplemental feeding program.-- To lessen the impacts of the Olympics and future recreational skiing activities at Nakiska, several mitigative steps were taken. A supplemental feeding program was initiated to supply sheep with a higher than normal protein diet during the Olympic winter. Its purpose was to improve body condition that theoretically would enhance an individual's ability to counter any increased stress. Additionally it would act as a lure to keep sheep in areas away from human activities. Hay bales (timothy/brome/alfalfa mix) were flown by helicopter in November to 4 sites (Figure 3). Approximately 110 bales were stacked, wrapped in plastic fencing, and covered. Beginning in November, bales were removed

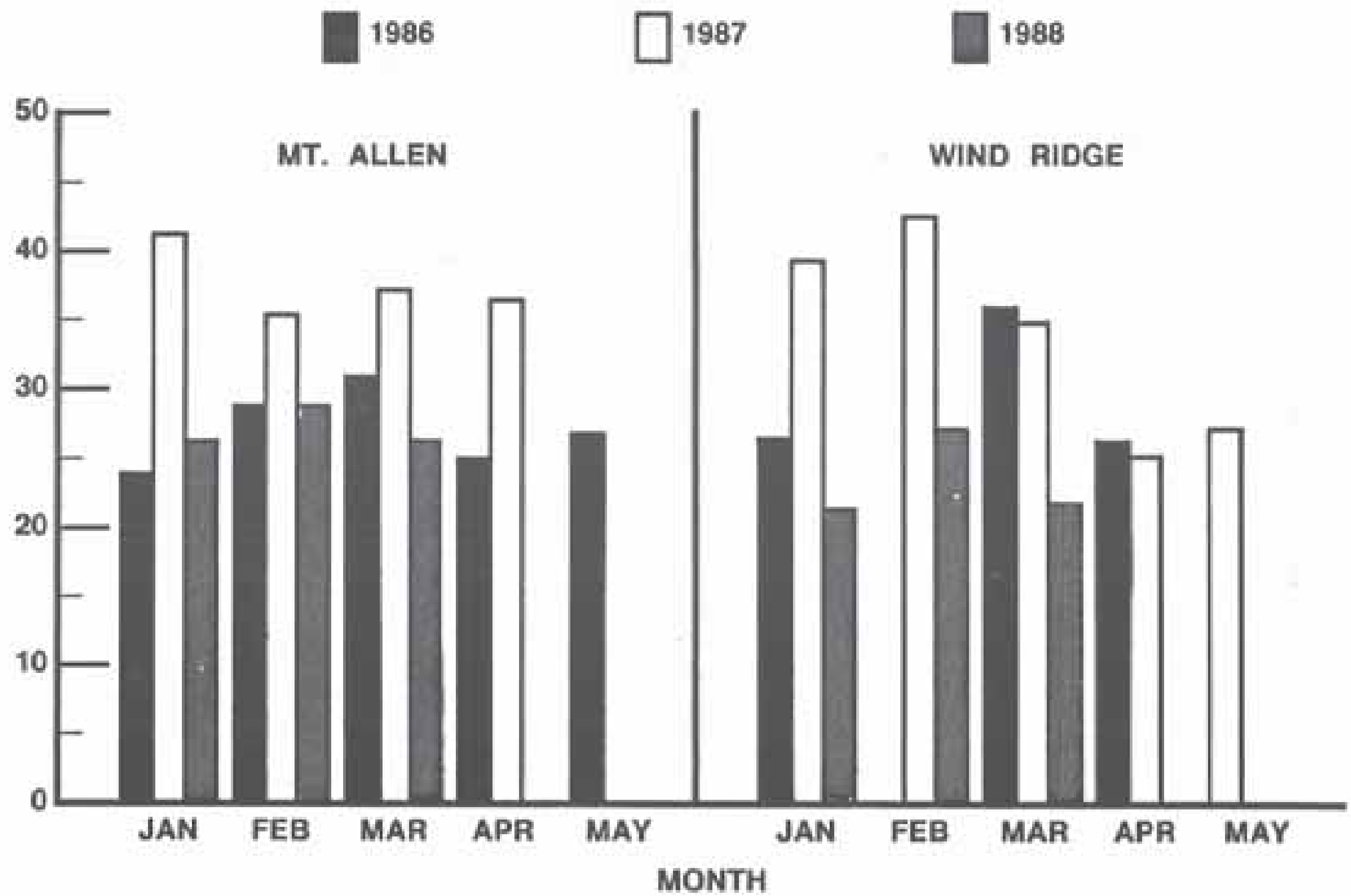

Figure 5. Mean monthly larval output from Mt Allan and Wind Ridge, 1986 to 1988.

and made available to the sheep. The amount available was slowly increased until February when hay was continually available.

Although on traditional winter range, sheep exhibited little inclination to consume the hay until the first cold temperatures (-20°C) and snowfall in January. From then until late February sheep were observed feeding at at least one of the sites whenever we were in a position to see them. During the first week of the Olympics, sheep were feeding on the hay daily often with all 4 sites receiving use. Once the weather turned mild, however, sheep only occasionally fed at the sites. By April, slightly more than half the feed had been consumed.

Helicopter restrictions.-- To alleviate helicopter harassment during World Cup events, voluntary flight guidelines were established restricting aircraft from flying west of the ridgetop above the ski area. These guidelines were distributed to all local charter companies and major media organizations. This system proved ineffective as the guidelines were ignored on several occasions. Requests to film sheep from a helicopter were received from 2 television stations and 2 stations did show film footage of bighorns prior to their broadcast of the race.

The potential for higher air traffic during the Olympics prompted the need for more effective regulations. In cooperation with the Ministry of Transportation, a NOTAM (Notice to Airmen) was put in place from January 30-March 2. Such aircraft restrictions were required for security and safety reasons anyway but were refined to accommodate our requests. Movements within the restricted airspace by accredited aircraft only, were strictly monitored and violators faced loss of licence. This regulation proved most effective. Three aircraft did fly west of the ridge during the Olympics with 2 of those being brief security flights (not required to adhere to air space restriction). The third incident involved a disoriented pilot flying from the west passing over the winter range at an altitude of about 2700 m.

Women's downhill start area.-- Attempts were undertaken to alleviate the problem of people congregating on the ridge area. Recontouring of the slope was done to prevent the funnelling of skiers onto the ridge and instead channel them downslope. In addition, a fence was erected above the start building to block access to the ridgetop. The fence proved difficult to maintain due to the high winds and proved only marginally effective. People were still able to find a way around or over the fence. Spectators were not allowed access to the upper part of the ski run, which helped in keeping the volume of people down, but there were still many officials, course workers, coaches, competitors, and media people in the area. The media were the worst offenders. During the actual competition, all attention was focused on the race and people did not have time to wander. Both before and after the Olympics the Women's course was closed to recreational skiers.

Population reduction.-- The sheep population was intentionally reduced the year before the Olympics to reduce the threat of added stress on the population due to overcrowding. This was achieved through an increase in the non-trophy sheep permits from 60 in 1985 to 90 in 1986. For 1987, permits were reduced to 50. Following the 1986 hunting season, a reduction of 18% was observed in the winter population. This represented a decline from about 309 animals to 251. Of the difference from 1985-86 to 1986-87 in the population age and sex structure, 61% was due to a decline in adult ewes. The 48 sheep (47 ewes, 1 lamb) shot in 1986 represented a harvest rate of 16% of the 1985-86 winter population. Taking into account the recruitment of yearling ewes from the winter of 1985-86 into the 1986 summer adult ewe population, the 90 non-trophy permits issued in 1986 contributed to less than half of the observed decline in adult ewes. The previously noted low survival of yearlings and lambs contributed more to the observed population decline.

DISCUSSION

During the first year of ski area operation, the Mt. Allan herd experienced a decline in population size, low survival rates, higher than previous lungworm levels, and some range abandonment. The following spring, a drop in lamb production was evident. The decline in numbers was directly the result of poor survival of all cohorts except rams and to an intentional increase in hunting permits. Hunting could account for most of the observed declines in adult ewes and rams. The reason for poor survival of lambs and yearlings was unknown. Survival rates the following year however, were very high and comparable to the high quality population on Ram Mountain (Jorgenson and Wishart 1986). Had high mortality in 1986-87 been stress related then that same stress was no longer affecting survival in 1987-88. Sheep may have acclimatized to the new disturbances.

While low lamb:ewe ratios followed 1986-87, they were similar to those observed the 3 years prior to 1986-87. It is known that lamb:ewe ratios from Ram Mountain have ranged from 34 to 55 in a herd with pregnancy rates averaging 90% (Jorgenson and Wishart 1986). Since Mt. Allan values fall at the low end of that range, nothing can be inferred about pregnancy rates but recruitment has obviously been low for 4 of the last 5 years. Such low ratios could indicate high levels of neonatal mortality, high lamb predation or low pregnancy rates.

The increased lungworm shedding rates recorded in 1986-87 were alarming and may have indicated high stress levels, but the same high levels were also found in sheep from Wind Ridge. Outputs also increased at Sheep River, a foothills population 51 km southeast of Mt. Allan, in 1986-87 (Festa-Bianchet pers. comm.) suggesting an environmental factor unrelated to Nakiska was involved. While tempting to attribute these parameter changes to the new activities on Mt. Allan, it was not possible to establish any definite link.

It is possible, however, for increased stress levels to have caused the observed changes. In responding to stress, unnecessary energy expenditures can negatively affect production in Dall sheep (Bunnell 1978, Nichols 1978) and lower the quality of individuals in all populations of wild sheep (Shackelton 1973, Heimer and Smith 1975). Loss of range could have increased crowding, which has often been cited as contributing to disease outbreaks (Lance 1980, Festa-Bianchet 1988), increased parasite loads (Stelfox 1976), and to decreased productivity (Murphy and Whitten 1976). Initial stress of captivity and food - water deprivation together with crowding caused increased larval shedding in captive bighorns

(Fougere-Tower and Onderka, 1988). In addition, an indirect relationship between poor body condition and high fecal larval output has been demonstrated in bighorn ewes by Festa-Bianchet (1987).

That sheep on Mt. Allan were affected by certain activities on the ski area was only definitely shown in the abandonment of that portion of their winter range below the ridge above the Women's downhill run. This area was vacated after December 1986 and not used the rest of that winter. At the same time, there was a increase in sheep use of Area 3 - that farthest from the activity suggesting these new activities were forcing sheep to move as far as possible from the disturbance. People congregating on the ridge, snowmaking, avalanche blasting, and helicopter activity were all contributing factors. Except for the occasional helicopter flight, these activities did not carry over to the larger part of the winter range. Sheep seen in the vicinity of the ski area often displayed signs of being disturbance and were often displaced but would retreat to the undisturbed backside of the mountain. This abandonment was not observed the following winter. While use of the area remained little, there was not the total lack of use seen the previous year. This again suggests that there may have been some acclimatization to activities in the ridge area.

The potential for increased stress during the Olympics prompted the need for mitigation to separate skiing activities from sheep. The supplemental feeding program certainly attracted sheep and probably kept them in the vicinity of the feeding sites but whether sheep would have utilized range nearer the skiing activity without the hay is unknown. The higher than normal usage of Area 3 during January and February, 1988 was probably due to the attraction of the 2 feeding sites in that area. The other 2 sites were in Area 2 along the boundary between Areas 2 and 3. All four sites began to see heavy use in January. Sheep did not begin eating the hay until the area received snow and cold temperatures. As long as these conditions remained, the feed was consumed but once mild weather returned, sheep use dropped. Lack of snow and mild temperatures also resulted in a migration off the winter range to higher elevations. Such movements were observed during all three winters and suggests a natural response to the availability of higher quality forage at higher elevation. The additional crude protein available from the supplemental feed may not have been great enough to act as a strong lure. Timothy and brome grasses made up more than 50% of the feed. A higher alfalfa content may have been stronger incentive.

Aircraft restriction only proved effective when rigidly enforced with heavy penalties for violation. The voluntary guidelines issued for the World Cup races were ineffective and often ignored by media chartered helicopters. The NOTAM issued for the Olympic period was more effective with officials willing to amend the restrictions to consider harassment to sheep by low flying helicopters. It must be noted that our requests did not interfere or restrict the operations or running of the competitions and therefore may have aided in the ease of implementation. The major reason for the NOTAM was for security and safety and may have been more difficult to implement had the reasons been solely sheep related.

Efforts to keep people off the ridge above the Women's downhill were generally ineffective. While closure of the area to spectators alleviated the greatest threat, there were still enough accredited people in the area that bypassed the fence to cause a problem. It was not practical to erect an effective people-proof barrier. Even with our enforcement efforts, the media and certain officials chose to ignore them. Such problems would only arise during competitions provided this ski run remains closed to the skiing public as stated in the operational guidelines of the lease with the ski area.

While the construction of the ski area and the holding of the Olympic games did not appear to have had a major impact on the bighorn herd at present, unavoidable harassment and disturbance has occurred at some locations. The current level of disturbance does not appear to have been great enough to affect their health and reproductive status. There is no question that bighorns can exist on ranges exposed to much higher levels of disturbance than that on Mt. Allan (Morgantini and Worbets 1988, MacCallum 1988) but disturbance can also combine with other factors to result in stress related die-offs (Festa-Bianchet 1988). The Mt. Allan herd does not have a history of die-offs and may not have had exposure to the pathogens isolated from dead sheep during other die-offs in North America.

That the population has not been negatively affected by the recent activities associated with Nakiska does not mean they will not be in the future. Monitoring of this herd should continue for at least 2 more years. It is currently felt that co-existence with the ski area can be maintained provided skiing activities do not encroach upon the winter range. At present, the winter range is isolated on the south side of the mountain and sheep can retreat to an undisturbed area. Mitigation currently implemented must remain to ensure that abandonment of any portion of the winter range does not occur. During future competitions, steps are required to control helicopter movements and human activities in areas likely to disturb wintering sheep.

LITERATURE CITED

Bunnell, F. L. 1978. Horn growth and population quality in Dall sheep. J. Wildl. Manage. 42:764-775.

Festa-Bianchet, M. 1988. A pneumonia epizootic in bighorn sheep with comments on preventative management. Bienn. Symp. North. Wild Sheep and Goat Counc., 6 (In Press).

________. 1987. Individual reproductive success of bighorn sheep ewes. Ph.D. thesis, Univ. of Calgary. 229 pp.

Fougere-Tower, B and D. K. Onderka. 1988. Studies of the lungworm lifecycle in bighorn sheep and the host-parasite interactions. Bienn. Symp. North. Wild Sheep and Goat Counc. 6 (In Press).

Heimer, W. E. and A. C. Smith. 1975. Ram horn growth and population quality - their significance to Dall sheep management in Alaska. Alaska Dept. of Fish and Game, Technical Bulletin No. 5. 41 pp.

Lance, W. R. 1980. The implications of contagious ecthyma in bighorn sheep. Bienn. Symp. North. Wild Sheep and Goat Counc. 1:262-268.

MacCallum, B. 1988. Seasonal and spatial distribution of bighorn sheep at an open pit mining site in west-central Alberta. Bienn. Symp. North. Wild Sheep and Goat Counc. 6 (In Press).

Morgantini, L. E. and B. Worbets. 1988. Bighorn sheep use of a gas well site during servicing and testing; a study case of impact mitigation. Bienn. Symp. North. Wild Sheep and Goat Counc. 6 (In Press).

Nicholls, J. 1978. Dall sheep reproduction. J. Wildl. Manage. 42:570-520.

Samuel, W. M. and J. B. Gray. 1982. Evaluation of the Baermann Technic for recovery of lungworm (Nenatoda, Protostrongylidae) larvae from wild ruminants. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:232-240.

Shackelton, D. M. 1973. Population quality and bighorn sheep (Ovis canadensis Shaw). Ph.D. Thesis, Univ. of Calgary, Calgary.

Stelfox, J.G., 1976. Range ecology of Rocky Mountain bighorn sheep. Can. Wildl. Ser. Rpt. No. 39, Ottawa. 234 pp.

Bienn. Symp. North. Wild Sheep
and Goat Council 6: 135 - 140

ATTRACTION OF BIGHORN SHEEP TO WELLSITES AND OTHER MAN-MADE MINERAL LICKS ALONG THE EASTERN SLOPES OF ALBERTA: A MANAGEMENT CONCERN.

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Abstract: Bighorn sheep (*Ovis canadensis canadensis*) were attracted to salty deposits found on gas wellsites and on other disturbed areas in the Panther River region along the eastern slopes of the Rocky Mountains of Alberta. During the study on movements and distribution, it was determined that sheep frequently used 5 man-caused mineral licks within 45 km^2 of mountain terrain. The use of these sites was observed during all seasons and frequently involved long range movements. The concentration of bighorn sheep on these sites, their habituation to people and vehicular traffic, and their increased exposure to legal and illegal hunting, are reasons for concern and are discussed in this paper.

Wildlife use of wellsites and other industrial locations has been previously reported and the attraction has been related to the presence of sodium and other minerals spilled on the soil during operations (Jones and Hanson 1985, Morgantini and Worbets 1988). However, until recently (Morgantini and Worbets 1988), the extent to which some species may use these sites was little appreciated.

During the 1960s and 1970s, numerous gas wells were drilled along the eastern slopes of the Rocky Mountains in Alberta. They are located in a variety of habitat types from low elevation muskegs and black spruce forests to upper-subalpine pine and spruce forests, and open slopes. Over the years, incidental observations by hunters and biologists indicated that some of the sites were used as mineral licks by bighorn sheep, elk, deer and moose. Unverified reports warned that, because of easy vehicular access, animals on these sites were frequent victims to unregulated hunting (poaching and native hunting). Nevertheless, the use of wellsites by wildlife was not believed to be a reason for major concern.

This paper reports on the results of a 3 year study on bighorn sheep movements and distribution along the eastern slopes of the Rocky Mountains in west-central Alberta (Morgantini and Worbets 1988, Morgantini unpubl. data).

ATTRACTION OF BIGHORN SHEEP TO GAS WELLSITES

In the Panther River region of west-central Alberta, bighorn sheep were attracted to 4 wellsites and one seismic shothole found within 45 km^2 of mountainous terrrain (Table 1).

Table 1. Approximate linear distance (kilometers) between wellsites used as mineral licks by bighorn sheep in the eastern slopes of Alberta's Rocky Mountains.

	Canterra 5-23	Panther 1	Panther 3	Panther 7	Shothole
Canterra 5-23	0				
Shell Panther 1	3	0			
Shell Panther 3	6	3	0		
Shell Panther 7	9	7	9	0	
Shothole	3	6	8	6	0

The animals that frequented these wellsites were part of a population that ranged over 400 km^2, inside and outside Banff National Park. As of 1988, the wellsites were capped and not in production. Until recently, motorized access on all-weather roads was possible.

The wellsites were found in different environments. Two were located in the upper foothills, within dense pine and spruce forests, 3 and 6 km distant (linear) from sub-alpine and alpine spring-summer ranges. One wellsite was located in a mature spruce forest at the base of a sub-alpine open slope used as early-winter range. The last wellsite was in the upper-subalpine within spring-summer ranges. The shothole was found in a mature spruce forest along a creek that separated winter from spring-summer ranges.

The wellsites were used, at one time or another, by all the animals in the region. However, the season and the level of use differed (Table 2), reflecting distance from seasonal ranges and the presence of escape terrain.

While the use of 3 wellsites had never been continuously monitored, data collected with time-lapse cameras (one frame every 3 1/2-4 minutes during daylight hours) on Canterra 5-23 and Shell Panther 7 (Morgantini and Worbets 1988, Morgantini unpubl. data) were considered representative for the entire region, particularly for the months of May and June (Table 3). The cameras only monitored the mineral lick and did not record the numerous instances when bighorn sheep were forced off site by vehicles or people taking pictures.

The strong attraction of bighorn sheep to wellsites was evident not only during the servicing and testing of Canterra 5-23 (Morgantini and Worbets 1988), but also in June 1987, when bighorn sheep detected the presence of an open sump on Shell Panther 1, a wellsite that previously did not have any lick on site. A herd of 18 young rams took over the

Table 2. Season and level of use of 5 wellsites by bighorn sheep, 1984-1987.

	Season	Time	No. animals at one time	Sex-age
Canterra 5-23	Spring-summer-fall	Almost everyday	up to 50	rams-ewes-lambs
Panther 1[a]	Spring-?-	Almost everyday	up to 20	rams
Panther 3	Spring-summer-fall	Almost everyday	up to 30	ewes-lambs
Panther 7	Winter-spring-(summer)	Periodic	up to 15	rams
Shothole	Winter-spring-summer-fall	Almost everyday	up to 50	rams-ewes-lambs

[a] The attraction to this wellsite developed as a result of well testing in the fall of 1986. In spring, when bighorn sheep started using the site, the area was fenced off with a 2 m high pagewire fence.

Table 3. Use of Canterra 5-23 and Shell Panter 7 wellsites by bighorn sheep as measured through time-lapse cameras.

	Total no. of frames	No. of frames with animals	Total no. of animals counted
Canterra 5-23:			
May 1-31, 1985	5,582	2,779	16,098
May 16-June 27, 1986	10,317	2,021	8,974
Shell Panther 7:			
June 11-July 19, 1986	5,817	387	570

site, did not want to leave in spite of the use of numerous scaring devices by the senior author. After a 2 m high pagewire fence was erected, the young rams attempted to jump over it or to knock it down.

On all wellsites, bighorn sheep licked and ate soil containing minerals used during gas well drilling and testing. Sodium appeared to be the major attraction. In some instances, the lick was localized to a specific site. For instance, on Canterra 5-23 and Shell Panther 3 the mineral lick was represented by water seeping through old sumps. On Shell Panther 7, water seeped upward through the sump. However, in most cases, each lease area (approx. 10,000 m^2) had turned into a mineral lick following bulldozer work to recontour the site. The mineral lick at the siesmic shothole was associated with minerals brought up by a flowing spring.

MANAGEMENT CONCERNS

The presence of these artificial mineral licks and their heavy use by bighorn sheep are reasons for concern: 1) crowding and range depletion, 2) altered distribution, 3) tameness, 4) toxic chemicals, and 5) hunting (recreational, poaching, subsistence). These concerns are discussed in order.

Large numbers of bighorns concentrate and remain for a long time on small areas trying to eat soil and dirt. Dominance interactions with body contacts among all sexes and ages are frequent. Abrasion of the skin by the soil creates ideal conditions for the development of contagious ecthyma (Samuel et al. 1975, Karstad 1981). Associated crowding allows it to spread, as well as spreading of any other infectious disease. In 1986, 2 lambs showing the initial stages of contagious ecthyma were found on 2 wellsites. One ram, with its face badly scarred by secondary infections, was observed on another wellsite, and later was taken by a hunter. The continuous use of wellsites also leads to overgrazing conditions on the limited adjacent range.

One of the wellsites is located in the upper foothills, within a black spruce forest. The animals forage on grasses growing in the cleared area. The proximity of a ravine offers some escape terrain. Another wellsite is also located in what would be considered marginal bighorn sheep habitat. It could be suggested that these wellsites are beneficial to bighorns because they actually expand the range of the population. However, increased vulnerability to predation, increased energy expenditures for travel, and foraging on suboptimal ranges may be ultimately deleterious to the long term health of the population.

The over-riding attraction to mineral licks, association with motorized vehicles, and the frequent presence of industry personnel and recreationists can ultimately lead to the habituation of bighorn sheep to people. This modified behaviour detracts from the bighorn's image as a wilderness alpine species and predisposes them to exploitation and risks.

There is no evidence that mineral licks on the wellsites at the present contain toxic chemicals. Canterra 5-23 wellsite was drilled in 1961 and, since then, bighorn sheep have been using the seepage through the old sump. The site might have been toxic at that time. However, the existence of a well established set of trails in the area, and the presence of an apparently healthy animal population, indicate that the site has not been toxic for a significant period. The same line of reasoning can be applied to the other wellsites. Nonetheless, in view of the large array of chemicals which are used during well operations, the dynamic nature of drilling research, and considering that historically all chemicals used to be dumped in sumps, the potential for toxicity is present.

The bighorn's stubborn use of wellsites despite efforts to chase them off (Morgantini and Worbets 1988), increases their susceptibility to hunters. Vehicular access on all-weather roads further compound the problem. Reports of up to 20 ewes and lambs taken from Canterra 5-23, and of unknown numbers from the vicinity of the seismic shothole, could not be verified. However, the recent slaughter of some 35 ewes and lambs by natives at an easily accessible natural mineral lick in the same drainage, indicates the potential management problem.

MITIGATION

Unless a need for an adjacent mineral lick at a new wellsite can be demonstrated (to provide essential compounds and elements), bighorn sheep should be denied access to the salt impregnated soil of wellsites. Wellsites are by their nature difficult to keep free of contaminants. The number of people on site, their frequent shift changes, the recruitment of new workers, adverse weather conditions and heavy dependency on short term contractors, make the regulation of spillage very ineffective. The economics of waste disposal, use of heavy equipment and temporary storage of large volumes of fluids and chemical compounds, make sump pits and spillage on wellsites unavoidable. After drilling, reclamation is of limited value. The drilling muds, circulation fluids, detergents, rig wash, and lubricants used at wellsites can have very high concentrations of salts and other chemicals. Bulldozer work will stir the soil and turn the entire area into a mineral lick. In the Panther River region, bighorn sheep were attracted on reclaimed wellsites with sodium concentrations as low as 40 ppm (0.004%).

On some sites (very dry, well drained), it may be possible to bury the sump pit and wellsite with overburden that will remain free of leached and waterborne contaminants. At most sites in the rugged terrain occupied by bighorn sheep, this is ineffective or economically aesthetically unacceptable. The only recourse is to erect a permanent fence around the entire site. Reclamation and denial of vehicular access to the wellsite are usually desirable to prevent further habitat degradation.

Seismic shotholes that turn into mineral licks should be dealt with in the same way as a wellsite. In most cases, the access trail will be easier to close to traffic.

If reclamation and physical blockage of vehicle access are not feasible, legislation that will reduce human use of the site even if only for part of the year may be required. The creation of a Wildlife Sanctuary or Wildlife Control Zone may also be advisable.

LITERATURE CITED

Jones, R. L., and H. C. Hanson. 1985. Mineral licks, geophagy, and biogeochemistry of North American ungulates. The Iowa State Univ. Pres, Ames. 301 pp.

Karstad, L. H. 1981. Miscellaneous viral infections. Pp. 202-210 in J. W. Davis, L. H. Karstad, and D. O. Trainer (Eds.), Infectious diseases of wild mammals. (2nd Ed.). The Iowa State Univ. Press, Ames. 446 pp.

Morgantini, L. E., and B. W. Worbets. 1988. Bighorn sheep use of a gas wellsite during servicing and testing: a case study of impact mitigation. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 6 (in press).

Samuel, W. M., G. A. Chalmers, J. G. Stelfox, A. Loewen, and J. J. Thomsen. 1975. Contagious ecthyma in bighorn sheep and mountain goat in western Canada. J. Wildl. Dis. 11:26-31.

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and Goat Council 6: 141 - 158

BEHAVIORAL RESPONSE AND HABITUATION OF MOUNTAIN GOATS IN RELATION TO PETROLEUM EXPLORATION AT PINTO CREEK, ALBERTA

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Abstract: Two programs of experimental habituation were conducted to condition a wild population of mountain goats (*Oreamnos americanus*) to noise stimuli representative of petroleum exploration activities. The habituation programs achieved an increase in the goat's awareness of introduced acoustic stimuli and human presence without causing adverse responses. Goats exhibited a tolerance of increased levels of indirect and persistent noise, but continued to investigate any initial or novel sounds. Goats habituated to predictable, continuous stimuli, but were disturbed by sudden, unpredictable stimuli. Nannies were sensitive to stimuli of all kinds during the kidding and post-kidding seasons.

Human-caused disturbance of large mammals is a concern for wildlife managers (Geist 1978, Shank 1979). Disturbances associated with industrial and recreational activities, hunting or other situations can cause modifications in the behavior of animals with repercussions on their physiology, distribution, habitat use, fecundity and population health (Geist 1971). Smith (1982) examined the potential impact of a proposed natural gas well on the forest-dwelling mountain goats of Pinto Creek, Alberta and concluded that habituation might be the only behavioral alternative if the goats were to survive.

Mountain goats have inhabited the Pinto Creek area at least since 1945 (Kerr 1965). Population size appears to have remained fairly constant and probably never consisted of more than 12 animals from 1942 to 1962 (Stelfox and Kerr 1962). Classified counts in recent years show the herd size has varied from 17 animals in 1965 to 7 animals in 1982 (Table 1). During the present study the herd size fluctuated from 7 to 14 animals.

The Pinto Creek herd is considered to be atypical of goat populations and is the longest term example of a goat herd known to reside in a forested area in Alberta. The goats have successfully colonized a restricted river valley habitat that is separated from the main Rocky Mountain goat ranges by 38 kilometers of dense conifer forest.

This paper examines the results of three investigations on the behavioral response and habituation of mountain goats in relation to proposed and completed petroleum exploration activities at Pinto Creek between 1981 and 1987.

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Table 1. Numbers of goats by age and sex cohorts in the Pinto Creek population.

Source	Date	Kid	Yrl.	2-yr old	Adult female	Adult male	Unclass-ified	Total
Stelfox & Kerr(1962)	June'62	1	2	-	3	1	5(Ad)	12
Kerr(1965)	Jul'62	2	3	3	5	4	-	17
Bibaud & Hall(1976)	Jan'76	1	1	-	-	-	7(Ad)	9
Bibaud(1977)	------	2	1	-	-	-	6(Ad)	9
Penner & Jalkotzy (1984)	Mar-Apr'81	1	2	-	3	2	-	9
	May-Dec'81	3	1	2	3	2	-	11
	Jan-Mar'82	3	1	2	3	1	-	10
	Apr'82	2	1	2	3	1	-	9
	May'82	2	2	1	4	2	-	11
	Jun'82	4	2	1	4	2	-	13
	Aug'82	4	1	1	4	2	-	12
	Oct'82	2	1	1	3	1	-	8
	Nov-Apr'83	2	0	1	3	1	-	7
	May-Jul'83	1	2	0	3	2	-	8
Smith(1984)	Jun'84	2	1	2	3	2	-	10
Penner(1986)	Nov'84	1	1	2	3	2	-	9
Taggart(1985)	Aug'85	3	1	1	3	?	1	9
Taggart et. al. (1986)	Jun'86	3	2	-	4	?	-	9
Penner(1988)	Nov'86-Mar'87	3	2	-	4	2	-	11
	May'87	3	3	2	4	2	2[a]	14

[a] Includes 2 goats reported from Hightower Creek (W. Berry, Local Trapper, pers. comm).

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STUDY AREA

The study area, which encompasses the Pinto Creek Mountain Goat Reservation, lies on the eastern slopes of the Rocky Mountain Foothills (Figure 1). The gently rolling forested plateau is dominated by lodgepole pine (Pinus contorta) and white spruce (Picea glauca). Pinto Creek valley is deeply incised through several high, rounded hills, thus exposing the shale and sandstone bedrock. Total relief varies less than 110 m throughout the study area (1112 - 1220 m elevation). Goat habitat is centered on a series of discontinuous bedrock exposures along the slopes of the Pinto Creek valley and along Wroe and Hightower Creeks, near their confluence with Pinto Creek. Thirty-four discrete cliff units have been identified within the 15 kilometers of river valley normally used by the goats. The majority of goat habitat use, however, is centered on three of the largest cliff complexes located in the northern, central and southern portions of the range. The many small bedrock and soil exposures along the valley slopes provide some additional foraging habitat and escape terrain for goats during travels between the larger cliff units. The vegetation of the area is classified as the Upper Foothills Section of the Boreal Forest Region (Rowe 1972). The upland forest is dominated by lodgepole pine and white spruce on well drained sites and black spruce (Picea mariana) and tamarack (Larix laricina) in poorly-drained muskeg areas.

METHODS

Behavioral studies on mountain goats at Pinto Creek were done in response to three petroleum exploration programs:

1. January, 1981 to July, 1983. A natural gas well was proposed and would be located within 400 m of a main goat trail between core cliff complexes. The study included monitoring baseline conditions and experimentally conditioning goats to noise stimuli. The proposed drilling program was not initiated.

2. November and December, 1984. Mountain goats were habituated to noise disturbance prior to a seismic program that would pass about 600 m from the herd's traditional winter range.

3. October, 1986 through May 1987. An exploratory natural gas well was drilled about 2100 m from the winter range. The goat's response to the potential disturbance was monitored.

Monitoring Procedures

Field trips during the three study programs were mostly on a monthly basis, each lasting for about 5 to 10 days. On each trip the goats were

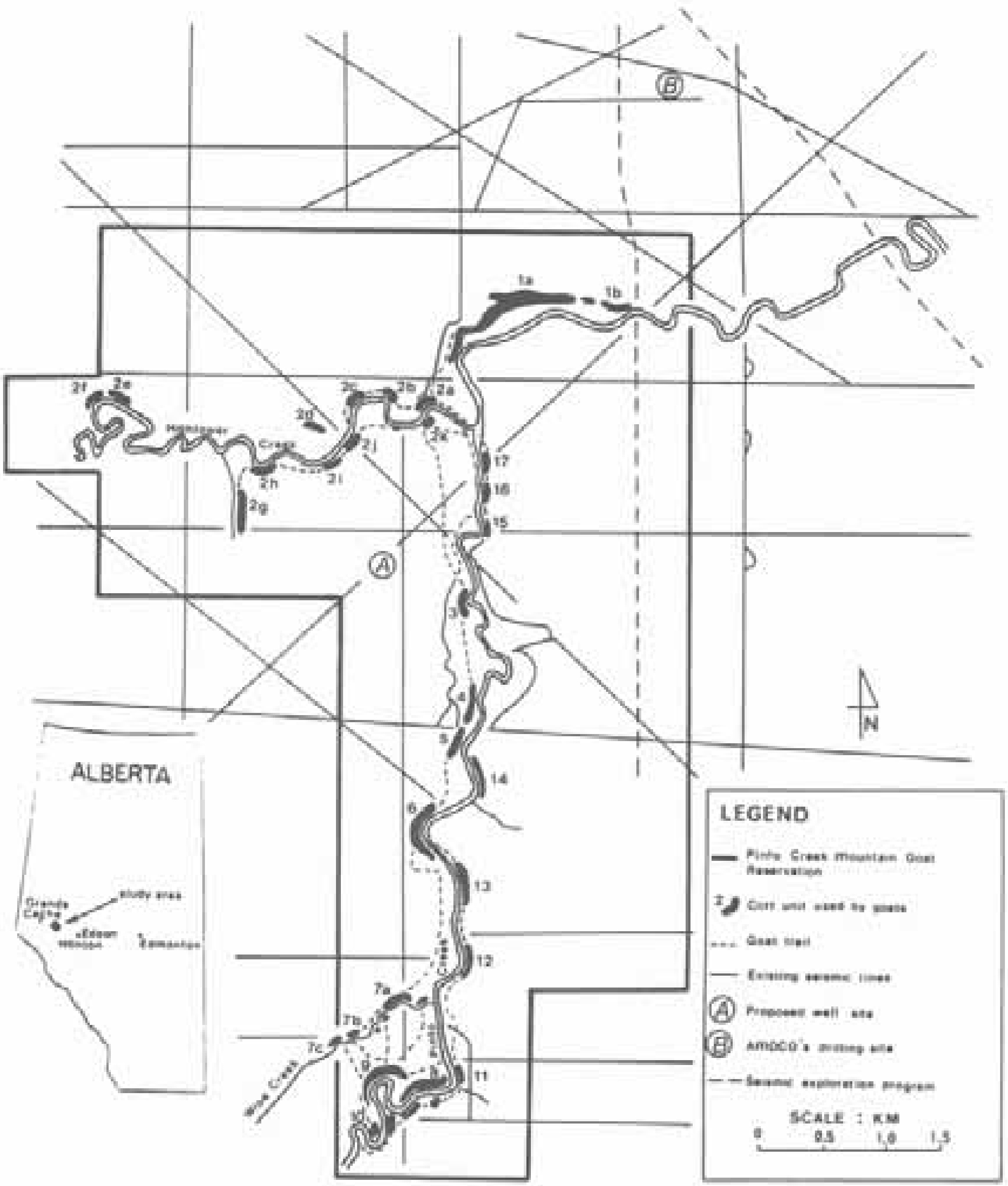

Figure 1. Study area of Pinto creek mountain goat herd.

located (or at least the nursery herd) and main cliff units and trails were examined to document recent habitat use. The main aggregation of goats were monitored from dawn to dusk whenever possible and most consistently for the times between 0800 and 1800 hours. Goats were observed from across the valley at a distance of 400 to 600 m. Observations were made with the aid of a 20 - 60X spotting scope and 8 X 40 binoculars. Individual goats were identified on the basis of body size (kid, juvenile or adult), sex, and horn size and configuration.

Goat activity and habitat use was documented using the observation-interval technique, adapted from the instantaneous scan method (Altmann 1974). At each 15 minute interval, goats were observed intently for about 3 minutes and the dominant activity, the habitat zone in which it occurred and the behavior of each individual determined and recorded. The activities recorded were: feeding, bedding, standing, moving, playing and intraspecific interactions. The behavior of goats to their surroundings was recorded as an index of increasing levels of awareness, alertness and alarm responses based on overt behavior (adapted from Hicks and Elder 1979) (Table 2). Within the 15 minute interval, the goat herd was monitored to note changes in their distribution on the cliff unit, major changes in activity patterns and especially to document any directional or alarmed behavioral response (i.e. R3-or-greater) to environmental stimuli. Goat behavioral responses were related to all sources of stimuli (e.g. aircraft overflights, rock falls, other wildlife, the observer's location and activity, broadcast noise and petroleum exploration activities).

Habituation

Behavioral conditioning of goats to accept or tolerate noise and human presence was based on the conceptual model of the ruminants "Umwelt" described by Geist (1971) and Thompson and Spencer's (1966, in Leaton and Tighe 1976) characteristics of habituation. The following criteria were central to the habituation procedures:

1. Repeated application of stimuli;

2. A gradual increase in the magnitude and duration of stimuli;

3. Consistency in the location of the stimuli source;

4. Indirect stimulation to foster learning by goats that acoustic, olfactory and visual stimuli emanating from a distance are harmless;

5. The use of noise stimuli that could be controlled by the observers and withdrawn or reduced in intensity if adverse behavioral responses by goats were observed; and

6. The overt behavioral response of goats was monitored to determine whether the magnitude of stimuli was sufficient to facilitate habituation, avoid adverse responses (that would develop negative associations and thus dishabituation), and to document the process of behavioral change.

Table 2. Index of mountain goat behavioral response to environmental stimuli.

R1. NO OVERT RESPONSE

Overt behavior did not indicate awareness of a stimulus. Goats were resting, often with their heads down and eyelids closed, or foraging intently.

R2. UNCONCERNED RESPONSE

Goats raised their heads at irregular intervals (Chadwick, 1977), or appeared to be aware of a potential stimulus as shown by the position of ears and occasional directional glance but continued feeding, bedding or other activities.

R3. CURIOUS RESPONSE

Goats exhibited a directional alertness to a stimulus and periodically watched or listened intently for short periods but continued the normal maintenance activities.

R4. CONCERNED RESPONSE

Goats appeared very alert but did not exhibit directional movement. Goats stood if bedded or stopped feeding to watch and listen intently in the direction of a stimulus. Tail posture was partially erect. Some feeding movements occurred, possibly as displacement behaviour.

R5. ALARMED RESPONSE

Directional movement or flight by walking and/or trotting, usually to more secure escape terrain, where goats stood, watched and listened intently. The goats moved into adjacent forest cover and along trails leading to nearby escape terrain. Flight was immediate or followed a period of concerned response. The tail was held erect, indicating fear and alarm (Singer, 1978).

R6. VERY ALARMED RESPONSE

Rapid flight to escape terrain, movements on the cliff units to more inaccessible rock outcrops and huddling under ledges or against a rock face. Alternatively, goats abandoned the escape terrain and ran to adjacent forest cover and moved rapidly along ridges and trails to secure terrain of nearby cliff units.

Noise came from a 1750 watt gas-powered generator and pre-recorded noise of an operating drilling rig, amplified by 50 watt speakers. Additional noise stimuli during part of the programs were from the periodicuse of chain saw, all-terrain vehicles and the striking of a suspended steel pipe with an axe to resemble noise of the tripping operations (i.e. the replacement of pipe-string sections) on a drilling rig.

During the initial habituation program, temporal comparisons for the evaluation of goat responses were obtained from preceding baseline studies and by systematic observations several days prior to, and following stimulation procedures. The intensity and duration of stimuli were gradually increased in the months preceding the planned start-up of drilling operations.

The program to condition goats prior to the seismic program consisted of three 7 day sessions of gradually increased noise stimulation within a 30 day period. In addition, a 12 gauge shotgun was used to simulate the sudden explosions generated for seismic recordings. Gun shots were repeated in a series of 3 and spaced at intervals of 1 to 4 minutes. Gun shot stimuli were generated between the 15 minute observation intervals. Up to 5 series of gun shots were fired each day, depending on goat activity and visibility to the observer to allow for the assessment of behavioral response.

In the recent field program when the drilling site was located near the goat's traditional winter range, efforts were concentrated on documenting the distribution of goats during the rutting season, the time of movement to the winter range and observations of the goat's behavioral response to noise from the drilling activities.

RESULTS AND DISCUSSION

Program 1: Experimental Habituation

Mountain goats appeared to develop a tolerance of indirect and persistent noise stimuli in their environment, but continued to exhibit elevated behavioral response levels to initial, novel or sudden noise and visual stimuli. Goats recognized and investigated unfamiliar or initial stimulus, such as the daily introduction of noise stimuli and changes in the nature and intensity of sounds, but generally ignored the persistent and low intensity roar of broadcast sounds of a drilling rig. This is evidenced by the absence of significant overt responses (R3-or-greater) during about 98% of the observation-intervals (Table 3). The apparent habituation of the goats to noise was not demonstrated by a decline in the response frequencies recorded during the sequential stimulations. This was a result of the gradual increase in stimuli intensity, which maintained low levels of behavioral response to the noise stimuli throughout the twelve month program and allowed goats to become acclimatized to the noise disturbance.

The number of goat responses R3-and-greater per 100 goat-hours (GH) observation was significantly greater during days of stimulation than for days of non-stimulation (92.7 and 46.0/100 GH: $P>0.05$) (Table 3). This trend was less pronounced during the fall and spring when the general

Table 3. Percent frequency of goat behavioral response and number of responses R3-or-greater per 100 goat-hours observation during experimental habituation and seismic programs at Pinto Creek, Alberta.[a]

Behavioral index	Stimulation phase	Experimental habituation: Non-stimulation phase: Basel.	Pre-	Post-	Mean	Seismic program sessions: 1	2	3
Percent Frequency of Responses at observation intervals:								
R1	94	97	95	97	96	73	87	82
R2	4	2	3	2	2	17	11	9
R3	1	1	1	<1	1	10	2	8
R4	<1	<1	<1	<1	<1	0	<1	<1
R5	<1	<1	0	0	<1	0	0	0
R6	0	0	0	0	0	0	0	0
Number of observations	6408	2228	3920	2868	9016	808	942	1744
Number of Responses R3-or-greater per 100 GH:								
R3	74.9	24.2	36.4	32.0	30.9	130.1	70.4	92.7
R4	11.7	5.4	13.0	9.0	9.1	10.4	5.9	8.9
R5	6.1	7.4	3.4	7.3	2.4	2.0	0	2.1
R6	0	0	0	0	0	0	0	0
Total	92.7	37.0	52.8	48.3	46.0	142.5	76.3	103.7
Hours of observation	427	149	261	191	601	202	236	436

[a] Combined data from total observation times during the experimental habituation study: June, 1982 to July, 1983, and seismic program: November-December, 1984.

increased alertness of goats coincided with the rutting, kidding, and post-kidding periods. Noise stimuli was the documented source of 48% (spring) to 78% (winter) of elevated goat responses (R3-or-greater) (Table 4).

Daily introduction of acoustical stimulation, sound surges (due to changing wind patterns) and sudden noises resulted in more frequent responses by goats than from the more consistent, predictable drilling rig sounds. The periodic noise from pipe clanging and the use of a chain saw at the generator site was also effective in capturing the goat's attention, and evoked curious responses (R3).

Goats responded to human presence (observers) in a manner similar to their acceptance of introduced noise stimuli. Our cautious approach during the program allowed the goats to learn that our presence across the valley was predictable and harmless. Goats exhibited curious responses to the observer's arrival at an observation site but mostly ignored our presence thereafter. Goat's awareness of observer presence, changes in observer position, or sudden movements was evidenced by their unconcerned (R2) and curious (R3) responses. Goat response to observer presence was similar between stimulation and non-stimulation periods in fall, winter and summer (Table 4). Nannies, during the kidding and post-kidding season, exhibited a greater awareness of observers and alertness to other environmental stimuli than in other seasons (Table 4).

Daily activity patterns were characterized by alterations in feeding and resting periods. The proportion of time spent feeding on stimulation days was not consistently greater or less than control comparisons for various months or seasons. The average duration of feeding bouts during stimulation days (1.9 hours) was similar to the preceding days (2.0 hours) but less than post-stimulation days (2.4 hours) (Table 5). Increased frequency of feeding bouts were accompanied by a reduced duration of feeding bouts so that the total foraging time per day (annual mean of 4.8 hours) remained the same between stimulation and non-stimulation periods.

Goats exhibited their greatest sensitivity to unusual or sudden stimuli such as rock falls, aircraft overflights and predators (Table 4). Stimuli that could be seen or seen and heard by goats elicited a stronger response than most types of noise alone. The goat's response to fixed-wing aircraft overflights was usually unconcerned (R3) while the sounds of a helicopter frequently elicited concerned (R4) or alarm (R5) responses. Previous experience with helicopters may have been a sensitization factor influencing the goat's behavioral response.

In conclusion, goats accepted or tolerated indirect and persistent noise disturbance based on insignificant changes in behavior, activity and habitat use.

Program 2: Seismic Exploration

Nine goats were monitored between November and December, 1984 (Table 1). Location of goats on the southern cliff complexes during the rut was similar to seasonal distribution patterns observed in previous years. Movements of the herd (with the exception of an injured male) to the

Table 4. Number of behavioral responses per 100 goat-hours at levels R3-and-greater to different environmental and introduced stimuli during 4 seasons of the habituation program and the seismic program.

	Responses per 100 goat-hours: stimulation days						
	Habituation program				Seismic program		
Stimuli source	Winter	Spring	Summer	Fall	1	2	3
Introduced Stimuli							
general broadcast	20	37	19	24	11	28	20
initial start-up	21	27	21	34	4	14	12
sound surges	4	0	7	5	-	-	-
horn	2	10	2	11	-	-	-
pipe clanging	9	13	0	0	-	-	-
chain saw	3	10	-	-	9	1	0
snowmobile/ATV	3	-	-	-	0	8	3
subtotal	62	97	49	74	24	51	35
Other Stimuli							
observer	5	17	14	21	25	7	10
predators	1	-	-	-	-	-	-
birds	4	0	0	1	17	1	1
rock falls	1	-	3	-	-	-	-
aircraft	-	3	3	-	9	-	4
intraspecific	2	3	5	6	42	7	5
seismic program	-	-	-	-	-	-	24
other/unknown	4	80	6	2	20	11	24
subtotal	17	103	31	30	113	26	68
Total	79	200	80	104	137	77	103

	Responses per 100 goat-hours: non-stimulation days			
	Habituation program			
Stimuli source	Winter	Spring	Summer	Fall
observer	6	46	17	15
nowmobile/ATV	7	0	0	3
predators	10	-	-	-
birds	6	7	1	0
rock falls	2	-	3	-
aircraft	2	5	1	4
intraspecific	3	34	2	2
other/unknown	0	90	12	5
Total	46	182	36	29

Table 5. Number and duration of daily feeding bouts by adult female mountain goats during baseline and habituation studies.[a]

	Number (duration in hours) of daily feeding bouts				
	Winter	Spring	Summer	Fall	Mean
Study phase	No.(dur)	No.(dur)	No.(dur)	No.(dur)	No.(dur)
Baseline	2.2(2.3)	3.8(1.8)	4.0(1.1)	2.7(1.7)	2.9(1.7)
Experimental Habituation					
Pre-stimuli	1.7(2.7)	5.0(1.3)	2.5(0.8)	2.5(1.2)	2.6(2.0)
Stimulation	2.5(2.2)	3.0(1.7)	2.3(1.2)	2.6(2.0)	2.6(1.9)
Post-stimuli	1.8(3.0)	6.0(1.1)	-	1.7(1.6)	2.5(2.4)
Habituation and Seismic Program					
Stimuli	2.3(2.1)	-	-	-	-

[a] Data are means of the most complete days of goat observations.

traditional winter range was earlier than in previous years and may have been influenced by severe weather and 30 cm of snow. This program required rapid acclimatization of the goats to noise during 3 habituation sessions.

Goats exhibited an unconcerned behavior (R1 and R2) to noise and other stimuli in their environment during the majority of observation intervals (90%, 98% and 91% during sessions 1 to 3, respectively) (Table 3). Overt responses of R3-and-greater during and between observation intervals were greatest during the first habituation session (142.5/100 GH), least during the second session (76.3/100 GH) and intermediate in frequency during the last session (103.7/100 GH) (not including the gun shot stimuli) (Table 3).

The heightened level of goat alertness during the first session was attributed to intraspecific responses related to rutting behavior, observer presence, and the introduction of noise (Table 4). Rutting activities appeared to increase the alert behavior of adult goats, particularly the dominant billy. Goats were more responsive to the noise stimuli on the first day of each session (mean of 46/100 GH) than on subsequent days (mean of 16/100 GH). The goats were more responsive to infrequent and novel sounds created by the use of a chain saw, distant vehicles and aircraft overflights than the constant generated noise.

During the second session, goats were located mostly on cliff 11 (Figure 1) across from the sound generation site. Broadcast sounds were responsible for an average of 55% of the responses R3 or greater. Goats exhibited overt behavioral responses to the initial introduction of noise each day, sound surges or unusual sounds such as the horn blast on the tape, and appeared to ignore the more constant noise stimuli. The directional alertness associated with curious (R3) responses to acoustic stimuli were normally of short duration (i.e. less than 60 seconds) before the goats resumed maintenance activities.

The third habituation session overlapped a 5 day period when seismic lines were being cleared near the traditional winter range at cliff unit 1 (Figure 1). A drilling rig, about 5 km west of the winter range, was also audible periodically. The noises from the line-clearing activities were discontinuous and varied in nature, intensity and location over several days. Goat responses to these stimuli were mainly curious (R3), with directional alertness. On 3 days during the peak of seismic line clearing activities, the goat herd exhibited an increased nervousness and several prolonged periods (up to 2 hours) of concerned (R4) response to noise stimuli. Several goats exhibited alarm responses (R5). After the periods of elevated alertness, goats would begin foraging, often in the upland forest zone, 50 to 100 m from escape terrain. We interpreted the goat's behavior as nearing the threshold of tolerance before abandonment of the cliff unit for other secure locations. The dozer, drilling rig and broadcast noises appeared to have a cumulative effect with a resulting higher frequency, intensity and duration of behavioral responses by goats. Stopping the broadcast noise was later followed by a more relaxed behavior by the goats. On the following days the noise from the line clearing operation were infrequent and less intense and the goats exhibited a tolerance of noise disturbances.

The intensity of gun shot noise was increased during the habituation program by changing the direction of the shots and reducing the distance between the goats and the gun shots. The initial sequences of gun shots resulted in directional alertness and concern (R3 and R4 responses) by all goats which lasted several minutes. The frequency and intensity of behavioral responses declined with subsequent gun shots in each series and subsequent gun shot series during a particular day (Table 6). The average frequency of response (R3-or-greater) for a sequence of three shots for all observations combined was: 38, 26 and 19% of the goats, respectively. Alert responses to a sequence of 4 gun shot series in one day averaged 40, 23, 17 and 12%, respectively. The overall response frequencies (R3-or-greater) also declined during the three habituation sessions: an average of 40, 22 and 14%, respectively. During the last session, gun shots directed towards the goats from a distance of about 500 m resulted in very few alert responses by goats.

The behavioral responses of mountain goats to the gun shot stimuli are perhaps the best indication that goats can become conditioned to potentially disturbing noise stimuli. Goats did not appear to associate the gun shot noise with the observers and thus a negative association was not formed. Goats exhibited an increased tolerance of both the observers and gun shots during the habituation program. The higher frequencies of goat responses (R3-or-greater) at the initiation of gun shots during each day, each series and monitoring session shows their re-investigation of this stimulus (i.e. spontaneous recovery from conditioning).

Goats maintained typical patterns of daily activity and habitat use throughout the habituation and seismic program in comparison to baseline data. Results suggested that goats tolerated the potentially disturbing noise stimuli that would accompany seismic activities.

Program 3: Drilling of an Exploratory Natural Gas Well

The drilling rig was about 2100 m from (behind) the traditional winter range (cliff 1, Figure 1) and was not visible to the goats. Noise abatement from drilling activities included use of a diesel-electric generator and the piling of clearing slash along the southern perimeter of the well site. Noise levels of the operating rig at the well site averaged about 69 dBA. The highest noise levels (79 to 92 dBA) were from the warning horn and drum brake (i.e. a friction brake that controls the pipe-string and emits a high frequency noise). Drilling rig noises attenuated rapidly within the first 500 m of forest cover and then more slowly with increasing distances up to 2000 m. On goat winter range, noise levels were near ambient sound pressure levels in the A scale, but intermittently audible to the observer as distinct sounds. Under conditions of better sound transmission, drilling rig noise was perceptible to the observer at central and southern cliff complexes (6100 m and 8600 m, respectively). These noise levels were within the range of introduced noise disturbance that goats tolerated or became habituated to in previous investigations.

Eleven goats were monitored (Table 1). The nursery group of goats did not move to the traditional winter range, but remained in the central and southern part of their range and moved frequently between cliff units

Table 6. Frequency of behavioral responses R3-or-greater to sequential gun shots during habituation of mountain goats to seismic activities at Pinto Creek, Alberta.

		Habituation session			
Series (N)[a]	S[b]	1	2	3	Mean[c]
First (75)	1	71	50	48	56
	2	71	22	16	36
	3	67	10	16	30
Second (37)	1	45	23	0	30
	2	25	45	0	24
	3	15	25	0	14
Third (37)	1	32	11	50	22
	2	32	11	0	19
	3	25	0	0	11
Fourth (28)	1	13	33	0	18
	2	0	25	0	11
	3	0	17	0	7
All series (177)	1	47	34	28	38
	2	40	22	8	26
	3	34	10	8	19

[a] N: sample size of goats observed during gun shot sequences; responses from the days of each stimulation session are combined.

[b] S: sequence of gun shots in each series.

[c] Weighted means are total responses divided by all possible responses for the period represented.

during winter. Observations of the nursery herd provided few indications that these goats perceived the noise from the drilling program. Observations of the goat herd's behavior in December were interpreted as a possible attempt to move from the central cliffs to the winter range. The goats engaged in several excursions to the northern limits of the cliff complex but returned as a cohesive group to the security of the main cliff unit. The goats did not exhibit notable overt behavioral responses to indicate concern or alarm. Several nannies exhibited curious responses (R3), with directional alertness to the drilling noises. Although there was no behavioral evidence to indicate that noise disturbance was a factor, the failure of the nursery herd to move to the traditional winter range coincided with the occurrence of the drilling program.

In contrast to the nursery herd, both adult males utilized the winter range during the drilling program. One adult male, first located on the winter range in October, was alert (R3) to low intensity drilling noise, but did not exhibit concerned responses. This animal soon travelled to the southern cliff units where he tended 2 nannies for the duration of the rut. The other billy moved to the winter range following the rut and remained there for four months in the presence of noise from the drilling program. This billy appeared to be constantly aware of, and alert to, the variations in sound stimuli from the drilling rig (primarily R3 responses). The goat's responses were interpreted as investigative behavior to sudden or novel sounds and a tolerance of the persistent noise stimuli.

The winter drilling program did not appear to have an impact on the health and survival of the goat herd. The 11 goats were still present in March. The birth of 3 kids in May and the expectation of another kid from a pregnant nanny indicated that the unusual winter distribution did not have significant adverse effects on the nutritional status and health of the adult females, as evidenced by reproductive success. It may have been fortuitous that this winter was relatively mild and had low snow accumulations. These conditions facilitated goat movements between cliff units and made forage readily available during much of the winter.

Wildlife managers believe mountain goats are particularly vulnerable to disturbance (or harassment as defined by Geist 1978) and that this high sensitivity should be reflected in management strategies when goat populations are subjected to industrial activities (Pendergast and Bindernagel 1977, Smith 1982, Joslin 1986). Joslin (1986) reported that seismic activities for energy exploration did not result in abandonment of home ranges by mountain goats in Montana, but did coincide with a decline in adult female numbers, kid numbers and productivity in one population segment. Joslin (1986) suggested that stress induced by the seismic activities was cumulative over several years, resulting in reduced mountain goat productivity.

Geist (1978) noted that, in contrast to bighorn sheep (Ovis canadensis) which are easily habituated to humans provided there is no hunting, mountain goats tend to remain flighty and are far less readily approached. Singer (1975) examined the influence of a highway, passing traffic and visitors on mountain goat movements and use of a mineral lick. While he demonstrated a negative association of highway crossings by goats with vehicle passage and visitor presence he also showed goats at the lick became habituated to sounds of visitors on the exhibit and passing trains across the river, but continued to perceive the sounds and presence of passing vehicles as a hazard. Foster and Rahs (1980) found that goats in the Stikine Canyon, that were subject to drilling disturbances in full view of normally used cliffs, shifted their distribution one to three kilometers for the duration of the drilling program and returned to their normal distribution soon after rig removal. McFetridge (1977) suggested that the absolute amount of forage available to any herd of mountain goats is a function of the distance that they will travel from core area of high security and that the total area used by goats or the frequency of excursions might be reduced by disturbance.

Large mammals can habituate to potentially adverse stimuli (Kelsall 1968, Geist 1971, Erickson 1972, Bergerud 1974, MacArthur et al. 1982). Big game animals can become conditioned to, and tolerate or accept, noisy highways and airports, crowds of tourists, and the presence of loud, dusty and smelly industrial activities, all of which tend to be localized and therefore highly predictable (Geist 1978).

From the Pinto Creek investigations, we concluded that goats are adaptable and can habituate to potentially adverse stimuli if they are gradually acclimatized and negative associations are avoided. The conditioning of mountain goats to potentially disturbing stimuli prior to the initiation of development activities is a positive mitigation measure that can reduce potentially adverse impacts. This approach may also be applicable for other big game species in situations where industrial activity impinges on critical habitat.

LITERATURE CITED

Altmann, J. 1974. Observational study of behavior: Sampling methods. Behavior. 49:133-154.

Bibaud, A. 1977. Pinto Creek Reservation. Alberta Fish and Wildl. Div. files, Edmonton. 3 pp.

Bibaud, A. and W. K. Hall. 1976. Pinto Creek goat survey. Alberta Fish and Wildl. Div. Proj. No. W-4-76. Edmonton, Alberta.

Bergerud, A. T. 1974. The role of the environment in the aggregation, movement and disturbance of caribou. Pp 552-584 in: V. Geist and F. Walther (Eds), The behavior and management of ungulates and its relation to management. Vol. 2. IUCN New Ser. Publ. 24. Morges, Switzerland.

Chadwick, D. H. 1977. The influence of mountain goat social relationships on population size and distribution. Pp 74-91 in: W. M. Samuel and W. G. Macgregor (Eds), Proc. First Internat. Mountain Goat Symp. Kalispell, Montana. 243 pp.

Erickson, C. A. 1972. Some preliminary observations on the acoustic behavior of semi-domestic reindeer (Rangifer tarandus tarandus) with emphasis on intraspecific communication and the mother and calf relationships. M. Sc. Thesis. Univ. of Alaska. College, Alaska.

Foster, B. R. and E. Y. Rahs. 1980. Relations between mountain goat ecology and proposed hydroelectric development within the Upper Grand Canyon of the Stikine River, northwestern British Columbia. Rpt. prep. for B.C. Hydro and Power Authority By Mar-Terr Enviro-Research Ltd. 102 pp.

Geist, V. 1971. A behavioral approach to the management of wild ungulates. Pp 413-424 in: E. Duffy and A. S. Watt (Eds), The Scientific Management of Animal and Plant Communities for Conservation. 11th Symp. Brit. Ecol. Soc. Oxford, Blackwell.

________. 1978. Behavior. Pp 283-296 in: J. L. Schmidt and D. L. Gilbert (Eds), Big Game of North America - Ecology and Management. Stackpole Books, Harrisburg, Pennsylvania, and Wild. Manage. Inst., Washington, D.C. 494 pp.

Hicks, L. L. and J. M. Elder. 1979. Human disturbance of Sierra Nevada Bighorn Sheep. J. Wildl. Manage. 43:909-915.

Joslin, G. 1986. Mountain goat population changes in relation to energy exploration along Montana's Rocky Mountain Front. Fifth Bienn. Sump. North. Wild Sheep and Goat Counc. 5:253-268.

Kelsall, J. P. 1968. The migratory barren-ground caribou in Canada. Can. Wildl. Serv. Monogr. Ser. No. 3. Ottawa. 340 pp.

Kerr, G. R. 1965. The ecology of mountain goats in west-central Alberta. M. Sc. Thesis, Univ. of Alberta. Edmonton.

Leaton, R. N. and J. R. Tighe. 1976. Comparisons between habituation research at the developmental and animal-neurophysiological levels. Chapter 10, in: J. R. Tighe and R. N. Leaton (Eds), Habituation Perspectives from Child Development, Animal Behavior and Neurophysiology.

MacArthur, R. A., V. Geist and R. H. Johnston. 1982. Cardiac and behavioral responses of mountain sheep to human disturbance. J. Wildl. Manage. 46:351-358.

McFetridge, R. J. 1977. Strategy of resource use by mountain goat nursery groups. Pp 169-173 in: W. M. Samuel and W. G. Macgregor (Eds), Proc. First Internat. Mountain Goat Symp., Kalispell, Montana. 243 pp.

Pendergast, B. and J. Bindernagel. 1977. The impact of exploration for coal on mountain goats in northeastern British Columbia. Pages 64-68 in: W. M. Samuel and W. G. Macgregor (Eds), Proc. First Internat. Mountain Goat Symp. Kalispell, Montana. 243 pp.

Penner, D. F. and P. Jalkotzy. 1984. Ecological and behavioral studies on mountain goats at Pinto Creek, Alberta. Part I. Ecological Studies, 141 pp; Part II. Behavioral Disturbance Studies, 75 pp: Part III. Impact Assessment, 75 pp. Rpt. prep. for Gulf Canada Resources Inc., Calgary.

Penner, D. F. 1986. Habituation of mountain goats to auditory stimuli prior to a seismic program at Pinto Creek, Alberta. Rpt. prep. for Fish and Wildl. Div., Alberta Energy and Natural Resources, Edmonton. 48 pp.

Penner, D. F. 1988. Monitoring of mountain goats at Pinto Creek, Alberta in relation to an AMOCO drilling program: Winter 1986-87. Rpt. prep. for AMOCO Petroleum Company Ltd., Calgary. 55 pp.

Rowe, J. S. 1972. Forest regions of Canada. Dep. of the Environ. Can. For. Serv. Publ. No. 1300. 171 pp.

Shank, C. C. 1979. Human-related behavioral disturbance to northern large mammals: a bibliography and review. Rpt. prep. for Foothill Pipelines Ltd., Calgary, Alberta. 244 pp.

Singer, F. J. 1975. Behavior of mountain goats, elk and other wildlife to U.S. Highway 2, Glacier National Park, Montana. Compl. Rep. Nat. Park Serv., West Glacier, Montana. 96 pp.

Singer, F. J. 1987. Behavior of mountain goats in relation to U.S. Highway 2, Glacier National Park, Montana. J. Wildl. Manage. 42:591-597.

Smith, K. G. 1982. Winter studies of forest-dwelling mountain goats of Pinto Creek, Alberta. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:374-386.

Smith, K. G. 1984. Report on Pinto Creek mountain goat herd. Alberta Fish and Wildl. Div. Files, Edmonton.

Stelfox, J. G. and G. R. Kerr. 1962. The status of Rocky Mountain goat in the forested regions of the Wildhay River and Pinto Creek areas in Zone 14, east of the sixth meridian; and their prospects for future survival. Alberta Fish and Wildl. Div., Edmonton. 8 pp.

Taggart, J. 1985. Report on Pinto Creek mountain goat herd. Alberta Fish and Wildl. Div. Files, Edmonton.

Taggart, J., R. Quinlan and K. Smith. 1986. Report on Pinto Creek mountain goat herd. Alberta Fish and Wildl. Div. Files, Edmonton.

Bienn. Symp. North. Wild Sheep
and Goat Council 6: 159 - 164

BIGHORN SHEEP USE OF A GAS WELLSITE DURING SERVICING AND TESTING: A CASE STUDY OF IMPACT AND MITIGATION

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Abstract: Between May and August 1985, Canterra Energy serviced and tested a 69% sour gas well along the eastern slopes of the Rocky Mountains, 3 km from the boundary of Banff National Park, Alberta. The well had been drilled in 1961 and since then bighorn sheep had used the seepage through the old sump as a mineral lick. During the initial stages of well testing, in May 1985, a surprising number of animals made extensive use of the mineral lick, located 30 m from the well head. Apparently attracted by rig detergent, the animals abandoned the mineral lick and spread over the lease licking pipes and equipment. Immediate mitigation was successful in attracting sheep away from the lease onto surrounding higher elevation ranges. Concerns, field techniques and mitigation are discussed.

In 1985, Canterra Energy Limited serviced and tested a 69% sour gas well located at 2,000 m elevation along the east slopes of the Rocky Mountains in west-central Alberta, 3 km from the east boundary of Banff National Park. The well had been drilled in 1961, but due to its high sulphur content had not been developed. Drilling of the well resulted in an artificial mineral lick located 30 m from the well head. The lick was formed by water seeping through the drilling fluids sump. In December 1984, when Canterra Energy applied to regulatory Government Agencies for servicing and testing the gas well, the number and distribution of bighorn sheep in the region, and the time of the year and the extent of use of the mineral lick, were not known. In order to provide this information, a wildlife monitoring program was initiated. Its two main objectives were to assess the impact of Canterra operations on bighorn sheep and to assist the company in mitigating potential negative impacts. Throughout the period of well servicing and testing (May-September), experienced wildlife biologists monitored the presence and the movements of bighorn sheep in the area on a daily basis.

SEQUENCE OF EVENTS

Since early April 1985, bighorn sheep were observed grazing on the open slopes surrounding the wellsite and using the mineral lick. In May, when Canterra Energy moved equipment on site, the mineral lick was consistently used by herds of rams. The animals were seen within 100 m of the wellhead during road grading and wellsite preparation, during the initial pressure testing of the well and with a service rig on site. Attracted by the mineral lick, 10 m from the lease boundary, and 30 m from the derrick, rams did not appear afraid of rig operation and noises. Yet, they were continuously alert, frequently running for 5-10 m whenever a sudden loud equipment noise was made.

During the third week of May, the number of animals present around the wellsite increased rapidly. On May 20, a total of 40 rams were counted. Between May 22 and May 25, the number increased to 60 different animals, of which 23 were mature rams. To further compound the situation, the animals began using the wellsite itself. On May 22, several bighorn sheep were observed for the first time licking pipes that had just been cleaned with a rig detergent. On May 23, the animals were more attracted to the wellsite than to the mineral lick nearby. Several herds walked onto the wellsite and spread out over the area among the rig workers.

CONCERNS

The initial use by bighorn sheep of a mineral lick in the vicinity of a critical sour gas well during servicing operations raised a substantial amount of controversy. The presence of animals so close to industrial activities appeared to support the position of numerous individuals in the oil industry that their activities were not affecting wildlife. At the same time, environmental public opinion groups were questioning the wisdom of allowing an oil company to conduct operations in such an apparently sensitive area for bighorn sheep.

From a biological and management point of view, several concerns were identified. Specifically:

1. The animals, when using the mineral lick, appeared continuously tense and alert. This enhanced physiological status, if prolonged, could have a significant impact on the animals' welfare at a time when they had already been taxed by a severe winter.

2. The overriding attraction to the mineral lick and the continuous close presence of people and activities could have led to the habituation of rams to humans. In view of the potential for poaching and harassment, and considering the recreational value of the animals, habituation was not desirable.

3. The use of the area left the animals exposed to minor industrial accidents, which, as unlikely as they were, could not be discounted.

4. Later in spring and summer, more animals, ewes and lambs, could move to the mineral lick, and hence be exposed to the activities at the wellsite.

When the animals abandoned the mineral lick and spread over the wellsite, a major concern overrode all the others. The rams were quite bold and aggressive. They were exposed to industrial accidents and toxic chemicals on site. They were also a hazard and a source of distraction for rig workers, and they were affecting normal well-servicing operations.

OPTIONS

Prior to the animals' attraction to equipment and chemicals at the wellsite, discussions about whether bighorn sheep should be moved away from the area or should be left using the mineral lick were confined to Government and University wildlife biologists and private consultants.

The total absence of baseline data on the yearly use of the mineral lick restricted the number of options available to the following:

1. Stop or delay the well testing operation.

2. Fence the entire area, including the wellsite and mineral lick, with page-wire.

3. Remove the mineral lick through fencing or other means, and bait the animals away onto adjacent valleys with supplementary salt.

4. Remove the mineral lick without replacing it with supplementary salt in adjacent valleys.

5. Leave status quo.

Canterra Energy was prepared to stop or delay the operation if the animals safety could not be insured.

For safety reasons, the second option was unacceptable. In view of the high sulphur content of the gas, in the event of a leak rig workers had to have the option to escape up-wind wherever the conditions of the moment allowed.

The third and fourth options had positive and negative points.

There was no guarantee that replacing the mineral lick with salt boxes, and/or baiting the animals away, was going to be effective. If effective, it could have attracted other animals which, otherwise, would not have moved in the area. Removing access to the mineral lick without providing any artificial alternative appeared to be a long term solution. It was also feared that placing large rocks on the lick or fencing it would have resulted in animals searching for salt on the wellsite itself. This indeed happened despite the availability of the mineral lick.

Leaving the status quo was not favored by Canterra Energy Limited and by Government officials because of repercussions of an unlikely, but possible, accident.

Ultimately, a decision was made to bait the animals from the area without removing the mineral lick. Unfortunately, that decision was reached the day before the rams were attracted to the equipment on the wellsite. At that point, the only option available was to chase the animals away from the wellsite.

MITIGATION

Attempts to chase bighorn sheep off the wellsite proved unsuccessful. Flares, loud noises and people, on foot or horse-back, were effective only in forcing the animals to retreat for a few minutes or to circle around the source of disturbance.

In order to bait sheep away from the site, a large amount of loose mineral supplement was left in 2 weatherproof boxes set on the surrounding slopes, at a 100 m higher elevation, 500 m distant from the wellsite. At that time, the animals were slowly herded from the wellsite to the baited area.

During the following two days, mitigation attempts appeared to be successful. About 60 bighorn sheep were grazing on the surrounding open slopes. Some used the salt boxes, but only 5 rams came down to the wellsite.

When bighorn sheep were back on the wellsite, eating dirt and licking pipes, a single wire electric fence was strung at the edge of the wellsite on the mineral lick side. Initially, that proved effective in keeping the animals off the equipment area. However, the following day, 18 rams and ewes came onto the wellsite from another side not fenced, and, when chased off, ran across the lease and easily jumped the electric wire. Consequently, a second and third bait site, further away from the wellsite, were established. By May 30, 7 days since bighorn sheep began licking equipment on the wellsite, only ten animals still remained in its vicinity. All the others used extensively the salt boxes containing mineral supplement. The salt boxes were gradually moved further away in valleys adjacent to the wellsite basin.

Mineral supplementation boxes were used by bighorn sheep throughout the summer and were successful in keeping ewes and lambs away from the wellsite. In total, over the summer, the animals consumed some 700 kg of salt and supplement. All the boxes were removed in September, when Canterra ceased its operations at the wellsite.

Initially, it was decided to permanently cover the mineral lick by the wellsite. However, after discussions with Government biologists, the lick was left open on the basis of the following considerations:

1. It was a safe source of minerals.

2. Bighorn sheep were highly attracted to the wellsite. Keeping them away from it was the priority.

3. The electric fence on the edge of the wellsite was effective in keeping the animals away from it only as long as they did not want to get in. A similar fence around the mineral lick was not effective. Rams pushed the wire down. Hence, it was feared that removing access to the mineral lick could have led the animals to push their way onto the wellsite.

CONCLUSIONS

The series of events that happened on Canterra Energy wellsite are indicative of the risks associated with oil and gas development on bighorn sheep ranges.

There is a general agreement that the disturbance associated with drilling new gas wells on bighorn sheep ranges can affect animal distribution and habitat use. Unfortunately, the impact of existing wellsites on animal distribution, and the impact of bighorn sheep overriding attraction to minerals used during drilling and servicing, are less appreciated (Morgantini and Bruns 1988). The attraction to salt impregnated soil on wellsite not only can alter distribution and movement patterns, but it can also expose animals to a large array of potentially toxic chemicals. This risk is very high during drilling and servicing operations, when high concentrations of potentially attractive chemicals are present.

On Canterra wellsite, bighorn sheep were so strongly attracted to the rig detergent (Na = 12%, pH = 13.4), that no level of active harassment appeared effective in keeping the animals away from it. A single wire electric livestock fence was also of limited use. Erecting a game-proof fence should have succeeded in making the site unaccessible, but it was not advisable for the safety of the workers servicing the well. In this regard, it would be noted that, at another wellsite, bighorn sheep rams tried to access an open sump pit by striking head-on a just erected 2 m high pagewire fence (Morgantini and Bruns 1988).

The evidence indicates that we were successful in resolving the bighorn sheep-wellsite conflict by extensive baiting and actively herding the animals away. Based on a two years intensive study, initiated when wellsite operations were completed, the animals appears to have re-established their previous distribution patterns. No indication of long term impacts was found. However, we believe that the success of the mitigation is attributable, at least in part, to several factors, such as the physiography of the area, the location of the site, the short term duration of industrial activities, the complete removal of vehicular access afterwards, and the fulltime involvement of wildlife biologists. Therefore, our approach should not be seen as "the answer" to any other bighorn sheep-industrial development conflict. Baiting bighorn sheep away from a site is not a solution because of the potential long term risks involved: altered animal distributions, range depletion, crowding and spreading of diseases, and increased legal and illegal hunting (Morgantini and Bruns 1988). If development of suspended wellsites or drilling on bighorn sheep range is allowed, strict measures should be taken to minimize wildlife-wellsite interactions. Mitigative measures should include the selection of an appropriate construction window (e.g. fall-winter), vehicular access control, avoiding use of rig detergents, effective control of spillage, and pro-active wildlife management. Baseline data on local animal populations and the presence of experienced wildlife biologists are also needed to detect potential problems or to minimize unexpected wildlife-gaswell drilling conflicts.

LITERATURE CITED

Morgantini, L. E. and E. Bruns. 1988. Attraction of bighorn sheep to wellsites and other man-made mineral licks along the eastern slopes of Alberta: a management concern. Proc. Bienn. Symp. North. Wild Sheep and Goat Symp. 6(in press).

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and Goat Council 6: 165 - 167

DRILLING IN SHEEP COUNTRY: GAS DEVELOPMENT AT PRAIRIE BLUFF, ALBERTA

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Abstract: In 1987, Shell Canada Limited was in the process of drilling and developing 2 gas wells on a mountain ridge in southwestern Alberta. The area is a well known bighorn sheep winter range. In order to address a widespread concern about negative impacts from industrial activities on bighorn sheep, Shell adopted a series of measures designed to mitigate potential impacts. In addition, because of a limited availability of baseline data on bighorn sheep movements and distribution in the region, Shell initiated a bighorn sheep study whose objectives were to identify seasonal ranges, locate alternate winter ranges, and determine whether the industrial activity resulted in negative impacts on the sheep.

The Waterton Gas field in southwest Alberta was discovered by Shell Canada Ltd. in 1950's. Production from the field and processing of the gas through the Waterton Gas Plant started in the early 1960's. By the end of 1986, a total of 46 wells had been drilled.

DRILLING AT PRAIRIE BLUFF: CONCERNS AND MITIGATION

In early 1986, as part of the on-going development of the Waterton Field, Shell geologists proposed the drilling of two or three wells into the portion of the gas reservoir that was known to exist beneath Prairie Bluff. After reviewing the need to maintain proper well spacing and the geographical constraints of the area, it was determined that 2 wells were required on top of the secondary ridges connecting Prairie Bluff to Victoria Peak, a major mountain approximately 6 km southwest. This area had been long recognized as important winter-spring range for bighorn sheep. A major concern for Shell, the Alberta Government and numerous public interest groups and individuals was whether the drilling and/or the presence of gas wells would seriously impact the bighorn sheep in the area. The following issues were identified: improved access and increased legal and illegal hunting; habitat destruction; habitat loss resulting from range abandonment; and increased stress.

Several mitigative actions were proposed by Shell and approved by the Government. They were: construction/drilling would not occur between December 1 and April 30 to avoid any potential impact during a critical period; the new access road would be gated to prevent public use throughout the life of the wells; buried concrete tanks would be used for the collection of drilling wastes prior to offsite disposal; and all disturbed areas would be promptly reclaimed.

Road and wellsite construction was initiated during the month of November 1987. It will be completed in May 1988, followed by the drilling of 2 wells simultaneously.

THE BIGHORN SHEEP MONITORING PROGRAM

When Shell Canada first proposed to drill the gas wells at Prairie Bluff, little was known on the spatial and temporal use of the area by bighorn sheep. Furthermore, very little data existed to verify what impacts result from industrial activity in critical winter/spring range.

In October, 1986, after consulting with Alberta Fish and Wildlife staff, representatives of the Alberta Fish and Game Association, the Alberta Wilderness Association, and experienced wildlife professionals, Shell initiated a bighorn sheep monitoring study. The objectives were to: 1) determine the timing and amount of sheep use of the area; 2) identify important feeding areas, trails, etc.; 3) monitor and assess reactions to construction, drilling and production activities; and 4) record any other wildlife and recreational use of the area.

A review of the results obtained from October, 1986 to June, 1987, led to an expansion of the study with 2 more objectives: 5) obtain more information on the annual movements and distribution of the Prairie Bluff herd, by the use of radio-collars; and 6) conduct a vegetation assessment of the feeding areas on Prairie Bluff and identify other similar areas in the vicinity. The purpose was to have baseline data in the event that a habitat improvement project was required.

PRELIMINARY RESULTS

1. Bighorn sheep used Prairie Bluff throughout 1987, although summer and early fall use was relatively light. Some lambing occurred.

2. The Prairie Bluff herd appeared to be expanding after a major die-off in southwestern Alberta in the early 1980's. During the winter of 1986-1987, Prairie Bluff supported up to 43 animals (15 rams, 17 ewe-yearlings, 11 lambs). During the following winter (1987-88), 51 animals were counted (12 rams, 27 ewe-yearlings, 12 lambs).

3. The portion of the sheep range that will be destroyed by road and wellsite construction is a small portion of the total range available in the area.

4. Road and wellsite construction activities in November, 1987, resulted in temporary displacement of the animals (Figure 1), but they quickly re-established themselves in the area when construction ceased.

5. Helicopter activity caused much stronger reactions than blasting, use of heavy machinery, or the presence of people.

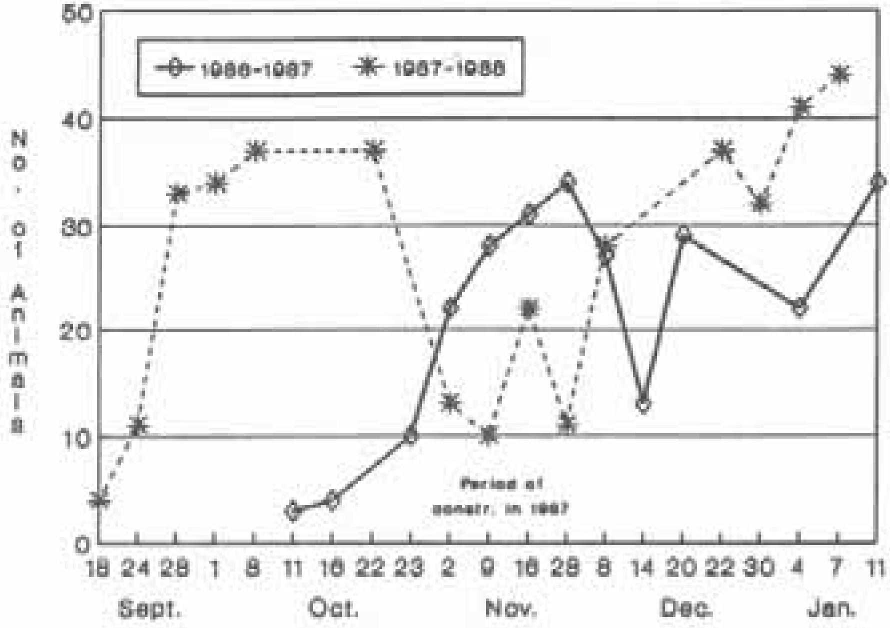

Figure 1. Number of bighorn sheep in the Prairie Bluff area of southwestern Alberta.

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MOUNTAIN GOAT STATUS, BLACK HILLS, SOUTH DAKOTA

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Abstract: An apparent decline in population of Rocky Mountain Goats (Oreamnos americanus) within the Black Hills, South Dakota dictated a baseline study to determine population numbers, dynamics and habitat use. From 1983 through 1987, 48 marked and/or radio-collared mountain goats were monitored. Home range for adult males averaged 29 km^2. Adult female home range averaged 5 km^2. Use of granite outcroppings demonstrated seasonal preference ranging from 99% use during winter to 74% during fall. Time spent off granite outcroppings was primarily feeding in open slopes, meadows, clear-cuts, and riparian areas. Age specific natality representing 41 female goat-years productivity varied from 0% for 2-year-olds to 68% for 5-or-more-year-olds. Documented kid production remained stable during 1983, 1984, 1985, but increased 30% during 1986. During study duration, yearly mortality estimates were 14% for 1+ year-old adults. Known kid mortality ranged from 40% to 20% for the same time period. Population estimates indicated a stable to slightly increasing population. Findings suggest highly fluctuating reproductive rates and annual kid mortality, mandating conservative harvest strategies.

A small population of Rocky Mountain Goats (Oreamnos americanus) exists within the Black Hills of South Dakota. However, they are not indigenous to the state. In 1924, Custer State Park obtained 6 animals from Alberta, Canada. The first night, 2 escaped a holding enclosure, and by 1929, all remaining goats had escaped (Richardson 1971). By the late 1940's an estimated population of 300-400 goats inhabited granite outcroppings around Harney Peak (Hanson 1949), an area approximately 12 km (10 mi) northwest of Custer State Park.

Population numbers remained stable from the 1940's through early 1970's (Cruse 1959, Richardson 1971). Occupied range was 13,000 ha (32,000 ac) with a primary range of 800 ha (2,000 ac). Richardson (1971) reported kid/adult ratios ranging from 23/100 in 1950 to 39/100 in 1967. He felt annual mortality was low for all age classes.

Richardson and Blankenship (1967) reported overutilization of available forage on primary goat range within the Black Hills by late 1960's. Overutilization of available forage by mountain goats is difficult to assess since no preference is shown for a particular plant species; one must consider all plants within their habitat (Chadwick 1983). However, lack of logging or thinning since 1956 (Theron Schenck, Forest Biologist, United States Forest Service, Custer, pers. comm.)

and/or natural fire have allowed pine encroachment into areas that would normally provide mountain goats with needed forage. At present canopy closure within the area averages 70% (Edward Johnson, Silviculturist, United States Forest Service, Custer, pers. comm.) and is expected to increase in future years, therefore, decreasing present available forage.

Human-mountain goat interactions have increased substantially since periods of stable population numbers. In December, 1980, the area surrounding Harney Peak was designated the Black Elk Wilderness Area which included most of the primary range of mountain goats. Currently, there are approximately 18 km (11 mi) of trails within the wilderness area, and an additional 41 km (25 mi) of trails in surrounding Norbeck Wildlife Preserve.

Hunting seasons with limited permits were initiated in 1967. No licenses were issued in 1972, 1974, 1975, 1982, 1983 and 1984. Hunter success averaged over 90% with a harvest of 134 billies and 102 nannies. Most of the harvest occurred on historic primary range. However, harvest from 1976 through 1981 indicated more pressure on secondary range (Fig. 1). This may have been due to population declines on primary range. In addition, from 1960 through 1968, 43 animals were removed from the population for transplanting to other states.

Prior to 1980, management surveys were limited to yearly population count from horseback. During 1980 and 1981, hunter input indicated a substantial decline in goat numbers may have occurred. Organized surveys in 1981 and 1982 using simultaneous ground and air observations confirmed the decline.

Severity and time of decline are unknown due to the absence of baseline data. The last comprehensive population study was conducted by Richardson (1971). Speculation on causes of the decline were numerous: increased natural mortality, overutilization of available habitat, human-mountain goat interactions, and/or overharvest of population.

Richardson (1971) reported low annual mortality during periods of a stable mountain goat population. However, several authors have indicated that winter mortality may affect overall population levels. Majority of annual mortality for all age groups occurs during winter months (Casebier et al. 1950). Nichols (1980) reported 42% kid mortality and 27% yearling mortality during winter in Alaska. Anderson (1940) reported a 20-80% kid mortality depending on winter conditions in Washington state. In Colordao, Adam and Bailey (1982) felt that reproductive success of mountain goats was negatively correlated with depths of spring snow. Highly fluctuating reproductive and mortality rates have been reported for mountain goats in coastal "ecotypes" in both Alaska and Canada (Smith 1984, Hebert and Smith 1986).

Joslin (1980, 1982) felt that uncontrolled and intensive activities in mountain goat range had detrimental affects in Montana. She recommended elimination of human interference in mountain goat winter, nursery and breeding areas. However, Bergman (1984) indicated human and mountain goat interactions had no observable effects on mountain goat

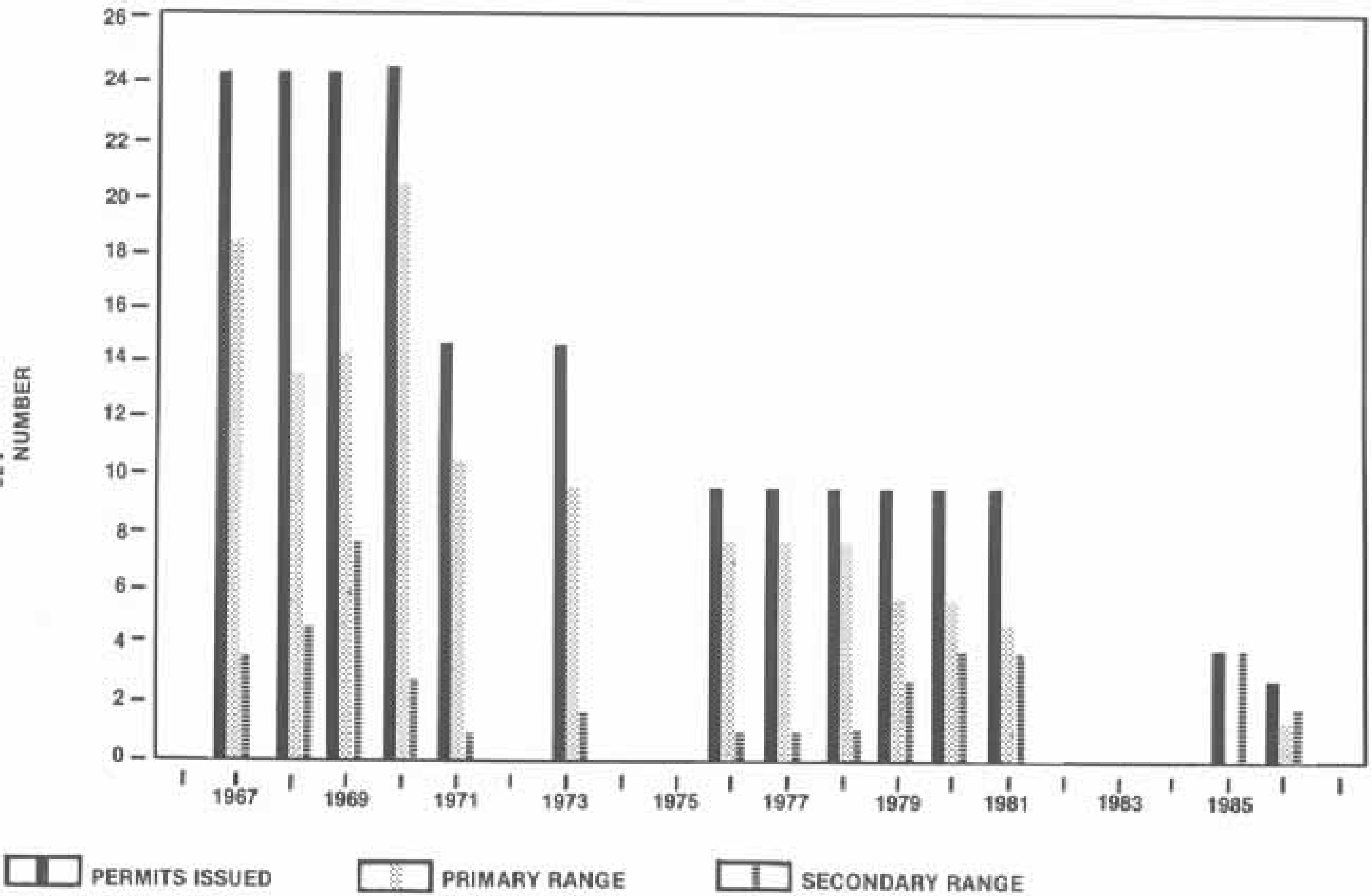


Figure 1. Mountain goat harvest, 1967-1986

populations. Yet, apparent decline in Black Hills mountain goats coincided with increased human activity in the primary range.

Coinciding with increased human activity, removal for transplant programs coupled with hunter harvest in primary range from 1967 through 1978 may indicate that overharvest occurred. This in turn could have caused subsequent overharvest during the 1980's even though license numbers were reduced. Kuck (1977) reported overharvesting may have caused declines in mountain goat populations of Idaho and hunting should be considered an added mortality factor with no compensating increases in reproduction or in forage utilization. Both Kuck (1977) and Chadwick (1983) felt mountain goats were self-regulating and that standard reasoning for harvesting animals did not hold true. Adams and Bailey (1982) determined that a population could be harvested if harvest level was below 7.5% of the population. Mountain goat females learn home range from their mother (Chadwick 1983). If a nannie is harvested in a particular area, then the process of passing that home range on to future female offspring is eliminated. Furthermore, Nichols (Lyman Nichols, Wildlife Biologist, Alaska Dept. Fish and Game pers. comm.) believed that if a nannie was harvested in fall, her kid may not survive the winter. However, Swenson (1986) felt that reproduction of a Montana population was density dependant and that an increase in harvest may increase kid production.

Whatever the cause(s) of decline in mountain goat numbers in the Black Hills, proper management dictated that baseline data be collected. Population dynamics were virtual unknowns. Mortality estimates, reproductive rates, and habitat use needed to be determined before proper management of the species could be accomplished. The objectives of this study were to determine population numbers, dynamics and habitat use of Rocky Mountain goats in the Black Hills, South Dakota.

STUDY AREA

The study area encompassed the Black Elk Wilderness and immediate surrounding areas consisting of approximately 13,000 ha (32,000 ac) within the Black Hills National Forest (Fig. 2). Elevations within the area range from 1,515 m (5,000 ft) to 2,195 m (7,242 ft).

The Black Elk Wilderness is characterized by numerous granite outcroppings rising from Ponderosa pine (<u>Pinus ponderosa</u>) forests with occasional open ridges and meadows. Geomorphic features of the granite outcroppings are comprised of a variety of caves, crevasses, and horizontal shelves. Vegetation types found on the granite outcroppings are primarily Ponderosa pine associations: 1) Ponderosa-bearberry (<u>A. uva-ursi</u>), 2) Ponderosa-grass, forbs, and 3) Ponderosa-browse, grass.

METHODS

Forty-eight mountain goats were captured and released during 1983 and 1984. Nineteen adult females, 9 adult males, 4 yearling females, 7 yearling males, 2 female kids, and 7 male kids were marked with livestock ear tags and/or fitted with radio-collars. Capture was accomplished with clover traps baited with salt or with the use of a hand held net gun from

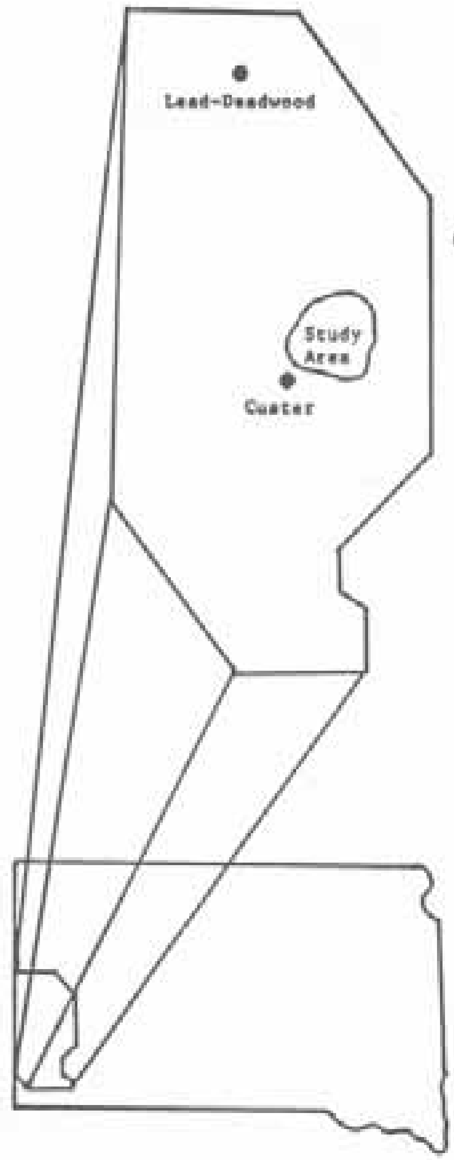


Figure 2. Mountain goat study area, Black Hills, South Dakota.

the ground. Animals were captured at five different locations covering the entire mountain goat habitat.

Daily/seasonal movement and home range were determined from 1,052 radio locations and 658 observation of marked animals. Preferred habitat was determined using 1,128 observations of marked and unmarked animals. Population dynamics were calculated using 658 observation of marked mountain goats. Population estimates employing mark-recapture methodology (Standard Lincoln index) were calculated using 1,598 observations. Study was conducted from January 1983, through November, 1986. Data collection was conducted on the ground and occurred year-round averaging three days per week.

RESULTS

Home Range

Marked differences in home range size between adult billes and nannie groups or single nannies was documented. The largest adult billie home range was approximately 29 km^2 (11 mi^2) whereas single nannies or nannie/kid groups averaged 5 km^2 (2 mi^2). Adult billie home range expanded during successive years. In contrast, nannies and nannie/kid groups did not increase home range during study duration and demonstrated a fidelity to their home range. Seven nannie group areas were identified and mapped within the mountain goat range. Each area was used by a combination of all nannie/nannie groups established within that area, and was usually separated from another by an expanse of ponderosa forest with a lack of major granite outcroppings. Entire home range was utilized by both sexes throughout the year with no discernible seasonal movement expect for brief periods during weather extremes.

During kidding season (May-June), movement for parturient nannies ceased. Activity was closely associated with kidding areas which were large granite outcroppings. Sufficient soil formation had occurred on the outcroppings for some forage production on flat areas and crevasses. Forage present included trees, shrubs, grasses, forbs, and lichens. There were also shallow depressions on granite surfaces near or on the summit that captured and held water. Most outcroppings provided south-facing aspects for loafing in early morning hours and shade on north faces or crevices during heat of day. These outcroppings provided kidding nannies with all life requirements (Rice and Benzon 1985).

Kidding sites were mapped for radio-collared nannies in 1985 and 1986. During 1985, 6 radio-collared nannies gave birth. Three of these gave birth the following year in 1986. Of these, only one returned to the same granite outcropping used in 1985. Sample size was small, however, this may indicate that mountain goats do not have traditional kidding sites that are used in consecutive years.

Habitat Use

Habitat use by mountain goats was primarily associated with the many granite outcroppings within home range. Seasonal preference for outcropping use vary with 99% use during winter, 90% during spring, 78% during summer and 74% during fall (Fig. 3).

Use of granite outcroppings during winter (99%) and spring (90%), clearly demonstrated the dependance of mountain goats on the various ecotypes within the outcroppings. Ponderosa-bearberry ecotype was the most utilized for forage during winter (43%). However, during other seasons Ponderosa-grass and forbs was the most consistently preferred ecotype for foraging: 24% in spring; 23% in summer; and 34% in fall. Due to limited amount of forage on the outcroppings, and probably overutilization during winter and spring, mountain goats increased use of other habitat types for foraging in summer and fall. During fall mountain goats spent the largest percent of time foraging in habitats other than outcroppings (26%). It was assumed that it is during the fall season that

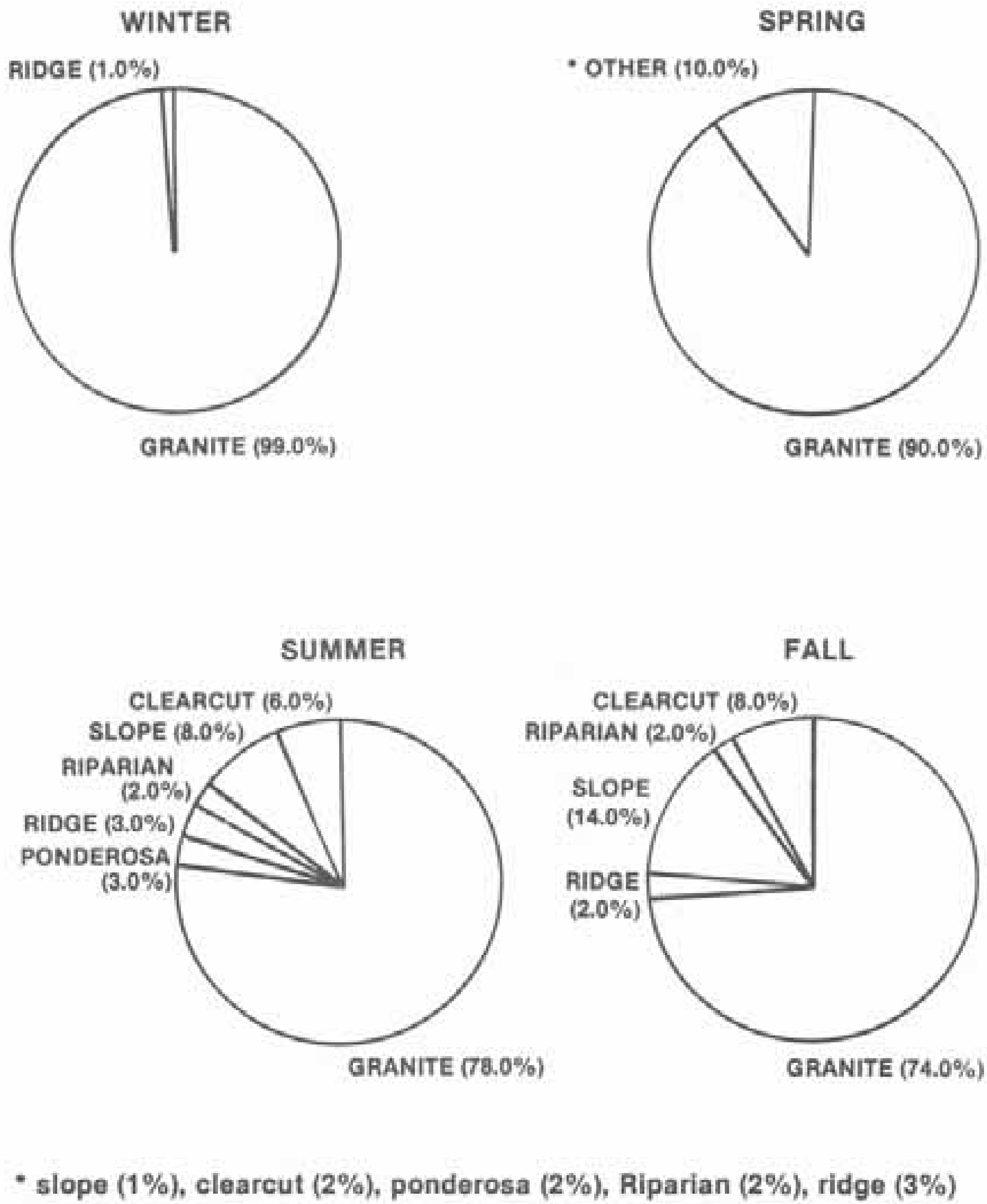


Figure 3. Mountain goat habitat, use by season, 1983-1986

mountain goats must store enough body fat to survive the rigors of winter months on the granite outcroppings.

Off-granite feeding patterns were still associated with outcroppings but distance traveled varied with season. During spring, goats foraged within 50 meters of a granite outcropping 69% of the time and within 50-100 meters the remaining 31%. Summer feeding observations varied from 65% within 50 meters; 28% from 50-100 meters; and 7% greater than 100 meters. Fall feeding patterns had the largest disassociation with granite outcroppings during intense feeding periods with 49% within 50 meters; 32% from 50-100 meters; and 19% greater than 100 meters. Summer and fall habitat use observations clearly showed the need for forage within close proximity of granite outcroppings. Foraging was primarily spent in open slopes, meadows, or clearcuts (Fig. 3).

Slope preference.--Habitat use on granite outcroppings also showed seasonal slope exposure preference (Fig. 4). North facing slopes were used during spring (6%), summer (9%), and fall (3%) for thermal cover and foraging; no use was observed during winter, probably due to temperature and snow depth. Combined summit and south facing slope use during winter (67%), spring (60%), and fall (68%) was for snow-free foraging areas and loafing. Lower summer use (39%) was probably due to avoidance of intense mid day heat. Largest percent of time spent on granite during summer was west aspect (34%). Percent of time goats spent on top of exposed granite averaged 32% throughout the year.

Population Dynamics

Reproduction.--Reproductive history was documented for 23 marked female mountain goats in 1985 and 1986 (Table 1). It must be noted that observations were conducted during entire summer season and a nannie could have produced a kid that died prior to observation. Therefore, reported reproductive rates are minimal and based on a small sample size.

Age specific natality for 1985 and 1986 resulted in a sharp difference between age of first parturition for Black Hills nannies. The initial year's data indicated that first parturition was 4 years of age (Rice and Benzon 1985, Benzon and Rice 1986). During 1986, 2 of 3 marked 3-year-old nannies were documented to give birth (Table 1). Richardson (1971) documented frequent reproduction by 2-year-old nannies of the same population in the late 1960's. Chadwick (1983) reported that goats introduced into areas of unutilized forage had first parturition at 2 years but stabilization of populations resulted in reproduction at 3 years. Smith (1984) found 38% reproduction for 2-year-old nannies, 64% for 3-year-olds, 60% for 4-year-olds, and 100% for 5-or-more-year-old nannies in a mountain goat population in "coastal ecotype". Joslin (1980) felt stable populations exhibited first parturition at 3 years of age. Nichols (1982) reported first parturition at 4 years of age for a population without minor fluctuations. Combined age specific natality for marked Black Hills nannies during 1985 and 1986 representing 41 female goat-years' productivity, resulted in 0% reproduction for 2-year-olds, 25% for 3-year-olds, 78% for 4-year-olds, and 68% for 5-or-more-year old nannies (Table 2).

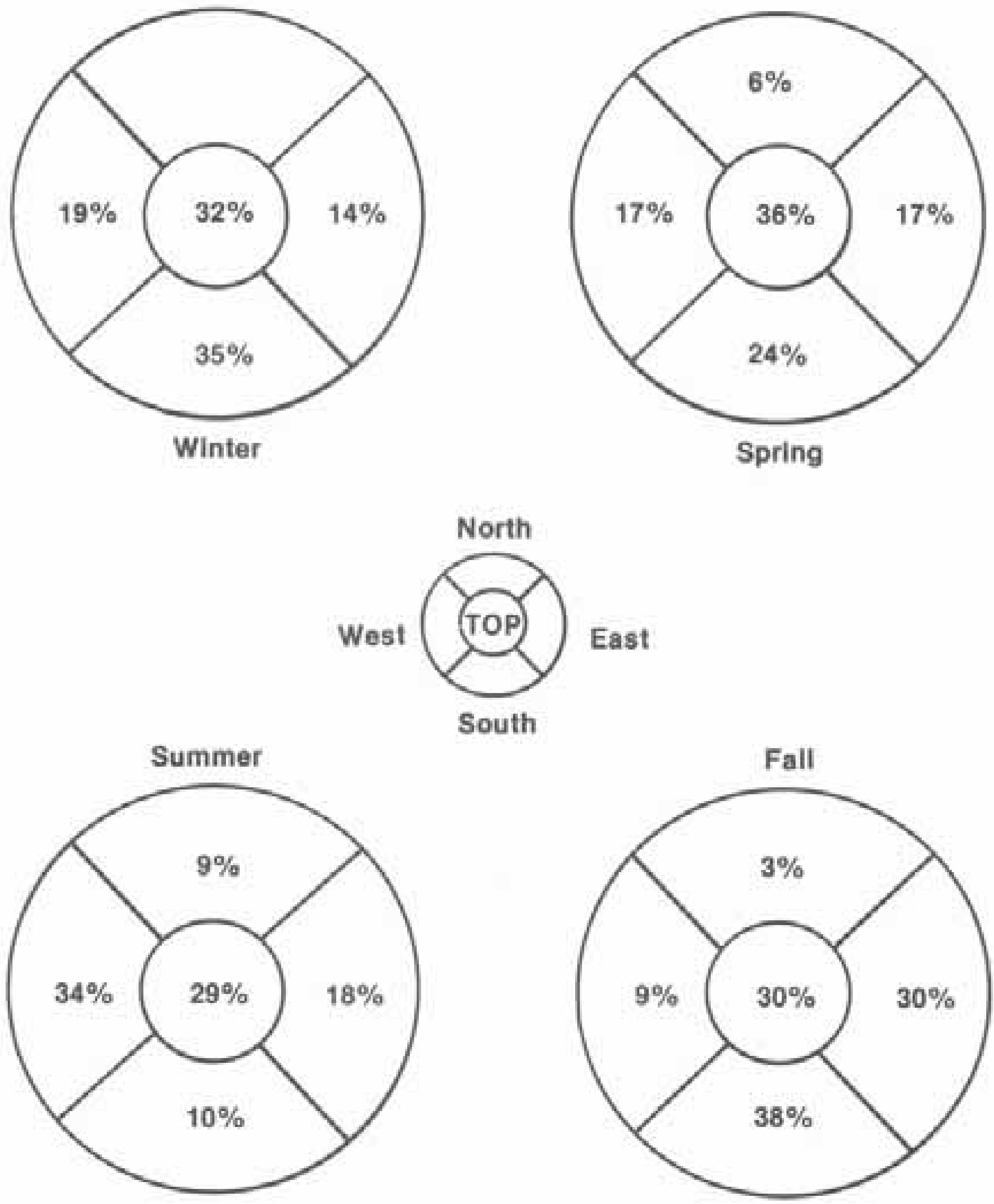


Figure 4. Mountain goat slope preference on granite outcropping by season, 1983-1986

Table 1. Reproductive history of mountain goats in the Black Hills.

			1985		1986
Area	Number	Age	Kid Observed	Age	Kid Observed
Rushmore	BK#1	6	yes	7	yes
	BK#4	4	yes	5	yes
	BK#6	3	no	4	yes
	BK#7	6	yes	7	yes
	BK#8	6	yes	7	no
	BK#9	3	no	4	no
Bear Bulch	R#1	9	yes	10	yes
	R#2	2	no	3	no
	R#4	2	no	3	yes
	R#5	6	yes	7	yes
	R#6	4	yes	5	no
Cathedral Spires	B#1	4	no	5	no
	B#2	2	no	3	yes
	B#6	6	no	7	yes
Needles	G#4	6	unknown	7	no
	G#6	4	yes	5	yes
	G#8	3	no	4	yes
	G#9	9	yes	Dead	
	G#13	3	no	4	yes
	G#15	1	unknown	2	no
	G#18	4	yes	5	unknown
	G#20	3	no	4	unknown
	G#21	8	unknown	9	no

Table 2. Age specific natality for marked female mountain goats, 1985-1986.

Age Size	% Natality[a]	Sample
	1985	
1	Unknown	1
2	0	3
3	0	5
4	80	5
5+	86	7
	1986	
1	0	0
2	0	1
3	67	3
4	75	4
5+[b]	58	12
	Combined 1985 and 1986	
1	Unknown	1
2	0	4
3	25	8
3	78	9
5+[b]	68	19

[a] Based on observations during summer months
[b] Oldest female giving birth was 10 years of age

Documented kid production for both marked and unmarked goats the over entire range remained stable during 1983, 1984 and 1985, however, an increase of approximately 30% was recorded for 1986 (Fig. 5). This increase may be due to an increased number of nannies maturing to reproductive age, plus documented parturition of 3-year-olds.

Samples from trapped goats during 1983 showed 22% of population was kids. Winter census counts indicated 20% of the population was kids. In 1984, 14% of all animals trapped were kids while census counts determined 20% was kids. Census counts for 1985 recorded 28% kids, and 24% in 1986. Disparity between documented kid production and results of census counts was attributed to low observability of mountain goats due to high canopy closure within mountain goat range.

Mortality rates.--Mortality rates were estimated using 3 different samples: 1) age at capture, 2) observations of marked animals, and 3) census counts. Time specific life tables calculated for combined sex, yearling + age classes for 1983 was 24% annual Qx; 1984 captures resulted in a 33% yearling + annual mortality. Combined age structures for both years resulted in a 28% annual yearling + mortality. This was based on capture results, which may not reflect true population age structures

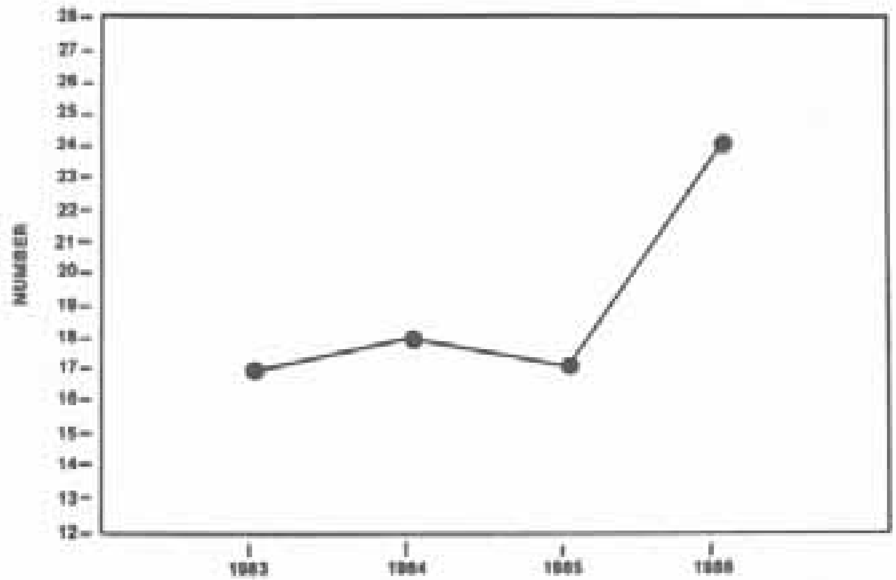


Figure 5. Documented mountain goat kid production, 1983-1986

(Rice and Benzon 1985). It must be emphasized that time specific life table methodology assumes an age stable, stationary population. It was suspected that mountain goat numbers were slightly increasing, therefore, mortality rates would be overestimated using this methodology.

Observations of the 26 mountain goats marked in 1983 indicated a 23% mortality rate over a 3 year period (average of 8% per year). Mountain goats marked in 1984 had a 40% mortality rate over a 2 year period for 20% average annual mortality. The 2 groups combined had 14% annual mortality. These estimates are based on several assumption: 1) an animal not observed during the period of January to October, 1986, was dead, 2) all age classes and sexes of mountain goats are equally observable, and 3) mortality rates were equal between years; therefore, estimates would be maximum mortality. During the study period, January, 1983 through November, 1986, one marked nannie was found dead. An additional 2 marked nannies were found dead after study was concluded.

Kid mortality was estimated using 2 methods: 1) ground census counts, and 2) radio telemetry of kid-bearing nannies. Census counts of kid/adult ratios during November through May were compared to yearling/adult ratios from June through October for 1984 and 1985 kid populations. Data indicated a 66% annual kid mortality for 1984 and 10% for 1985. Radio-telemetry results showed 40% kid mortality during 1984, 33% during 1985, and 20% during 1986 (Fig. 6). Kid mortality for kid-bearing radio-collared nannies occurred during mid-summer and early fall and kid/adult census counts were conducted during winter and spring. Again the high degree of variability between census and telemetry methodology may be due to limited observability due to canopy cover.

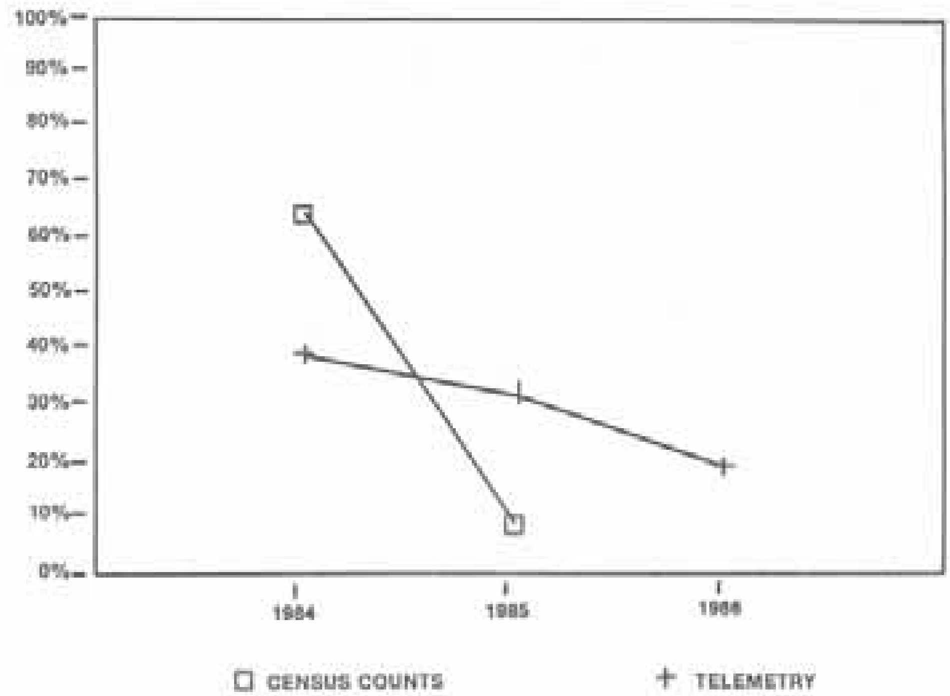


Figure 6. Mountain goat kid mortality, 1984-1986

[1] 1987 estimate is based on annual mortality for 1986 population.

Figure 7. Mountain goat pre-kidding population estimates, 1983-1987

Population Estimates

Estimates placed the mountain goat pre-kidding population at 80 animals in 1983 and 110 in 1984. These estimates were calculated from observations of separate groups of unmarked animals and were subject to a high degree of variability.

Subsequent population estimates were determined by using mark-recapture methodology (i.e., observation of a marked and/or unmarked animal).

Calculations resulted in an estimated pre-kidding population of 115 (SE=±20) in both 1985 and 1986. After the 1986 kidding season, population estimates were 150 (SE=±22) animals. Estimated kid mortality of 20%, and yearling + mortality of 14%, placed pre-kidding 1987 population estimates at 125 (Fig. 7).

CONCLUSION AND MANAGEMENT RECOMMENDATIONS

Movement and Preferred Habitat Use

Marked differences in home range size between adult billies and nannie/nannie groups were documented. While billies increased their home range during successive years, nannie/nannie groups demonstrated fidelity to a specific area. Management of the herd should focus on the 7 nannie/nannie group areas identified. Habitat improvement in any 1 of the 7 areas would definitely increase forage production for that specific group of nannies, however, this would not impact the entire herd as a whole. Habitat use results clearly demonstrated a need for habitat improvement either by clear-cutting or fire, however, improvements should be made within each nannie group area to benefit the entire herd.

Observation of marked animals showed nannie kids establish home ranges within the same nannie group area as their parents. Therefore, density of mountain goats for each nannie group area was different and could fluctuate according to habitat improvement, reproductive success, and natural or hunting mortality. Nannie harvest should be evaluated for specific areas of kill, and harvest recommendations should reflect the loss of reproductive nannies either by lowering permits issued, or recommending that hunters avoid that specific area.

Human activity within a specific nannie group area could also impact that specific group. During kidding season (May - June), nannies select large granite outcropping and generally remain there for 2-to-3 weeks after giving birth. This is a critical period for newborn kids, and human activity could cause nannies to leave the outcropping increasing the likelihood of kid mortality. Since nannies did not demonstrate traditional kidding site behavior, then any granite outcropping should be considered a possible kidding site and recreational use plans should avoid major outcroppings.

Population Dynamics

Increase in estimated population numbers of 80 in 1983 to 125 by

1987 may reflect both documented decrease in kid mortality and increase in kid production during 1986. Adult mortality appeared to be stable (14%) over the study duration suggesting kid production and survivorship as the crucial factor determining population trend. Determining annual kid mortality would prove too costly for management purposes, leaving kid production as the most reliable method of determining herd status.

Stable kid production during 1983, 1984, and 1985 with an increase of 30% during 1986, combined with a lower age at first parturition during 1986 suggests a possible fluctuating reproductive rate for Black Hills mountain goats, at least for certain years. As with mountain goats in "coastal ecotypes", reproductive rates could decrease and/or kid mortality could increase causing a decline in population numbers in a specific group or as a whole. Management practices should consider that kid production may fluctuate effecting overall population numbers.

Future Management

Data for the period of decline in Black Hills mountain goat numbers was too limited to accurately assess the factor or factors that caused the decline. The three factors of possible overharvest, increased recreational activities, and loss of habitat could have all singularly caused mountain goat numbers to decline. However, a combination of all three would assuredly have a negative impact on mountain goats and are the suspected cause of the decline in mountain goat numbers. Future management should emphasize habitat improvement, input into recreational use plans, and conservative harvest strategy. Additional research should be directed toward mountain goat/human interactions and possible effects.

LITERATURE CITED

Adams, L. G. and J. A. Bailey. 1982. Population dynamics of mountain goats in the Sawatch Range, Colorado. J. Wildl. Manage. 46:1003-1009.

Anderson, N. W. 1940. Mountain goat study. Washington Dept. of Game, Seattle. Biol. Bull. No. 2. 21 pp.

Benzon, T. A. and L. A. Rice. 1986. Rocky Mountain Goat population in the Black Hills, South Dakota. S. D. Dept. Game, Fish and Parks, Pierre. Pittman-Robertson Progr. Rpt. 25 pp.

Bergman, C. 1984. The mt. goat forments trouble in a fragile paradise. Smithsonian, August, 103-109.

Casebier, R. L., M. J. Rognurd and S. Bradborg. 1950. Rocky Mountain Goat in Montana. Montana Fish and Game Commission, Wildlife Restoration Division, Helena. Pittman-Robertson Fed. Aid Proj. Bull. No. 5, 107 pp.

Chadwick, D. H. 1983. A Beast the color of winter, Sierra Club Book, 208 pp.

Cruse, J. 1959. The mountain goat in the Black Hills National Forest.

Black Hills National Forest Supervisor's Office, Custer, South Dakota. 5 pp.

Hanson, W. O. 1949. Survey and management of the mountain goat in South Dakota. Unpubl. Pittman-Robertson Rept., S. D. Game, Fish and Parks, Pierre. 5 pp.

Hebert, D. and T. Smith. 1986. Mountain goat management in British Columbia. Bienn. Symp. North. Wild Sheep and Goat Counc., 5:48-59.

Joslin, G. 1980. Mountain goat habitat management plan for the Cabinet Mountains, Montana. Ecological Services Division, Montana Dept. Fish, Wildlife and Parks, Helena. 122 pp.

________. 1982. Montana mountain goat investigations along the east front of the Rocky Mountains Lewis and Clark National Forest. Montana Dept. Fish, Wildlife and Parks, Helena. Progr. Rpt., 69 pp.

Kuck, L. 1977. The impacts of hunting on Idaho's Pahsimeroi mountain goat herd. Pp. 114-125 in W. M. Samuel and W. G. MacGregor (Eds.), Proc. First International Mountain Goat Symp., Kalispell, Mt. 243 pp.

Nichols, L. 1980. Mountain goat management technique studies. Alaska Dept. of Fish and Game, Juneau. Final Rpt. 51 pp.

________. 1982. Mountain goat movements study, Vol. II. Alaska Dept. of Fish and Game, Juneau. Prog. Rpt. 22 pp.

Rice, L. A. and T. A. Benzon. 1985. Rocky Mountain Goat population status in the Black Hills, South Dakota. S.D. Dept. Game, Fish and Parks, Pierre. Pittman-Robertson Progr. Rpt. 46 pp.

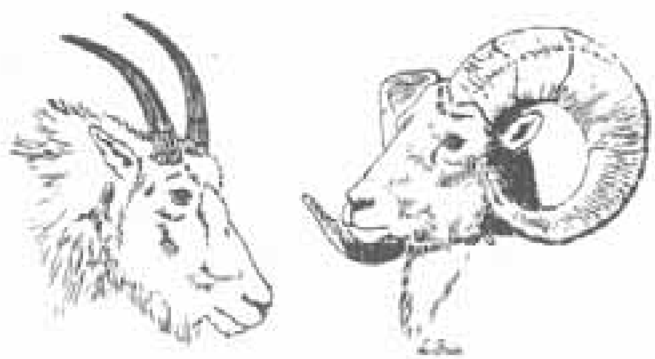
Richardson, A. H. 1971. The Rocky Mountain Goat in the Black Hills, South Dakota, S.D. Dept. of Game, Fish and Parks, Pierre. Bull. No. 2. 24 pp.

Richardson, A. J. and J. Blankenship. 1967. The Rocky Mountain Goat in the Black Hills. Unpubl. Black Hills National Forest Supervisor's Office, Custer. 4 pp.

Smith, C. A. 1984. Evaluation and management implications of long-term trends in coastal mountain goat populations in southeast Alaska. Bienn. Symp. North. Wild Sheep and Goat Counc., 4:395-424.

Swenson, J. E. 1986. Reproductive response of the Absaroka mountain goat population to an experimental reduction. Bienn. Symp. North. Wild Sheep and Goat Counc., 5:71-75.

Population and Nutrition



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THE BEAR MOUNTAIN BIGHORN SHEEP TRANSPLANT RESEARCH PROJECT: A PROGRESS REPORT

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Abstract: The precipitous decline of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) in North America, beginning in the late 1800's and continuing on into the mid-1900's, included the devastation of populations in Utah, leaving fewer than 100 at the lowest point. The Utah Division of Wildlife Resources began to reintroduce bighorn to former ranges in 1966. After 2 reintroduction attempts had failed, intensive research was initiated to help biologists more effectively manage future transplants. This report describes all phases of research related to the transplant of bighorn sheep on Bear Mountain.

Beginning in the late 1800's and continuing until the first decades of the century, numbers of Rocky Mountain bighorn sheep declined rapidly in the United States (Thorne et al. 1984). In the state of Utah, all but 1 native herd, numbering fewer than 100, had been extirpated by the 1950's (John 1975). John (1975) speculated that the 2 major causes for the decline were intensive grazing by domestic livestock with associated habitat deterioration, and over-hunting. Recent reports (Goodson 1982) suggest that diseases contracted from domestic sheep may have played a major role in precipitating bighorn die-offs as well.

In response to the near extirpation of all Rocky Mountain bighorn sheep populations in the state, the Utah Division of Wildlife Resources (UDWR) initiated its first bighorn sheep transplant in 1966 near Brigham City. (For a history, status and distribution of bighorn in Utah see Smith et al. 1988). These bighorn sheep, as well as those involved in the second transplant attempt were confined in an enclosed paddock before release into the surrounding area. Within 9 years the first transplant attempt had completely failed (J. Pederson, biologist, UDWR, pers. comm.). Within 4 years a second release, known as the Mount Nebo transplant, had failed as well (P. Tervort, biologist, UDWR, pers. comm.).

The UDWR laid plans in the late 1970's and early 1980's for a third attempt at reintroduction. Subsequent investigations indicated that the rugged Green River Corridor of northeastern Utah not only historically supported Rocky Mountain bighorn sheep but should again, if a release was made. Bear Mountain of the Flaming Gorge National Recreation Area was selected as the release site, because the area was remote, rugged, and isolated from domestic sheep allotments.

In January 1983, 19 sheep from Whiskey Mountain, Wyoming were released onto Bear Mountain. A second release of 17 sheep, also obtained from Whiskey Mountain, occurred in January 1984. Differing from the state's first 2 transplant efforts, the Bear Mountain sheep were released directly onto the mountain with no attempts to hold them for a time in an enclosure.

By the spring of 1985, when it became evident that the Mount Nebo transplant was failing, UDWR personnel concluded that intensive bighorn research would be invaluable in helping secure the success of future transplants. With a new and promising herd recently established on Bear Mountain, UDWR initiated the Bear Mountain research project.

THE BEAR MOUNTAIN BIGHORN STUDY

In the spring of 1986, a cooperative study involving the Utah Division of Wildlife Resources, Brigham Young University (BYU), the U. S. Forest Service (USFS), and the U. S. Bureau of Land Management (BLM) began and continues to date. Major emphasis was placed on population dynamics, disease-parasitism, inter-specific competition, and habitat selection. The primary research objectives include the following:

1. Estimation of population dynamics (natality, mortality, survivorship, and recruitment of the introduced herd of bighorns.

2. Determining and monitoring levels of internal parasites, as well as other disease factors.

3. Obtaining measurements of forage preferences, level of use, and seasonal diets.

4. Estimation and quantification of critical habitat parameters.

5. Monitoring bighorn movements, thereby determining home ranges and dispersion.

6. Identifying potential competitors such as mule deer (*Odocoelius hemionus*), elk (*Cervus elaphus*) and pronghorn antelope (*Antelocapra americana*) as well as monitoring predator populations and impacts.

7. Determining the nutritional quality of the occupied rangelands, as inferred by suckling and play behavior of lambs.

8. Evaluation of past prescriptive habitat improvements as well as identifying, implementing, and evaluating additional improvements.

STUDY AREA

Bear Mountain, within the Flaming Gorge National Recreation Area, is a high plateau (2200 m) bounded by precipitous cliffs, plunging 420 m to the Flaming Gorge reservoir below. The rim of the plateau is characterized by a ponderosa pine-mountain brush complex, while the interior is an open sage-grass community. The steeper slopes and cliffs support varying densities of pinyon-juniper cover. Several wild and prescribed burns have reverted dense pinyon-juiper areas to highly productive forb-grass meadows. Water is limited on top to ponding of snow melt in spring and several man- made guzzlers. A few small seeps and springs in the cliffs provide water in critical lambing areas.

Observations of bighorn sheep, petroglyphs and skeletal remains indicated that the area historically supported bighorn sheep which disappeared around the turn of the century. Pronghorn antelope, mule deer, elk, mountain lion (Felis concolor), bobcat (Felis rufus), and numerous smaller mammals also inhabit the mountain.

METHODS

In order to achieve the research objectives the following methods were utilized.

1. Population dynamics are monitored through frequent observations of the herd. Twenty-three radio-collared individuals, or 33% of all animals (70), allows accurate location of the herd. All radios have a mortality mode, facilitating the swift recover of dead sheep. Also, 10 of the 1987 lamb crop were radio-collared to allow close observation of this high-risk age class.

2. Internal parasites and diseases are observed by 3 approaches. First, levels of parasitic lungworm (Protostrongylus spp.) present in the herd are monitored using the standard Baermann technique. Samples are collected only from known, marked animals (24). Fecal analysis is performed by the Veterinary Research Laboratory at Montana State University. Concurrently, 3 anthelminthic drug applications (Panacur, Ivomec, and Zimecterin) have been given to 9 test animals (3 of each trail). Fecal analyses reflect the relative efficacy and longevity of these drugs in repressing lungworm levels.

   Second, blood physiologic values are commonly used as diagnostic tools for identifying diseases and measuring stress (Bunch et al. 1980). The UDWR, in conjunction with the Bighorn Research Institute of Palm Desert, California, and with assistance from BYU students and personnel, captured, via drop-net, a total of 15 sheep of the Bear Mountain herd in January 1988. Blood was drawn, nasal and throat swabs taken, and fecal samples collected. Procedures are described by Bagley and Buch (1980).

   Third, mortality sensor transmitters on 23 animals allow quick detection of deaths, thus aiding cause-of-death determination. Recovered mortalities are either field-examined or taken to a veterinarian for necropsy.

3. Forag preferences are being identified by direct observation, feeding site analysis, and by fecal analysis. Direct observation of foraging bighorn and a subsequent, detailed on-site analysis allows determination of plant species utilized and their degree of use.

Percent cover of each species present is estimated. Meter square plots are positioned on a grid, and all species clipped and weighed for a measure of above ground biomass. Fecal pellets are collected from known individuals representing all age/sex classes. These will be subjected to a microhistological technique for determination of percent composition of the various species present in the diet.

4. Transmitter-equipped bighorn locations are quantified as to critical habitat parameters. At each site: distances to cliffs, to cover, to habitat edge, to water and mineral licks are recorded. Additionally, horizontal visual obstruction is measured using a meter square, gridded target. Preferred habitat is, thus, described quantitatively.

5. Bighorn movements and home ranges are determined by radio-telemetry. Several times weekly, sheep are found and locations recorded on reduced 7.5 minute topographic maps. The computer program TELEM (Coleman and Jones 1986) is employed to generate information on home range size, distance moved per unit time, and activity centers for specific animals.

6. Assessment of potential habitat competitors is ongoing. During the year, numbers and distribution of deer, elk, and pronghorn antelope are recorded. Predator populations have been censused during winter via track counts and visual observations. All predator feces are collected and analyzed for bighorn remains.

7. Shackleton (1973) reported that nursing and play behavior in bighorn lambs quantitatively reflected the nutritional quality of the occupied rangelands. From May 25th through the end of July, observation of nursing behavior is conducted. Using a spotting scope and stopwatch, lambs and mothers are observed with particular attention paid to: initiator and terminator of nursing bouts, length of bout, number of bunts, and lamb play behavior.

8. The UDWR and USFS have implemented several habitat improvements including, guzzler construction, spring and seep developments, and prescribed burns to expand bighorn ranges. Documentation of water developments has been done opportunistically and by motion-sensitive cameras. Bighorn range expansion into burns is documented by means of telemetry-tracking and subsequent observation.

RESULTS

To date, comprehensive data analyses have not been conducted. They are to commence in fall of 1988. A brief summary follows of some preliminary results of research conducted to date.

1. Constant monitoring of the population over the past 2 years has indicated the following: reproduction is high (83% of all mature ewes bore young in 1986, 77% in 1987), survival of lambs to yearling age is moderate (50% in both years), and mortality for adults is low (less than 5% both years) due to the population being relatively young. The dense pinyon-juniper forests surrounding Bear Mountain not only block

emigration from the next nearest herd (48 km), but immigration as well.

2. A year of monitoring lungworms indicated that all animals (excepting newborns) have tested positive for lungworm, even though the entire herd was treated with anthelminthic drugs (ivermectin) before being released. Lungworm levels range from a high of 656 to a low of 0.4 larvae per gram of dry feces. Of the 3 anthelminthic drugs tested, none had long lasting effects, with most sheep showing reinfection within 2 months of treatment. Research has also revealed that lungworm larval output appears cyclic (high-low-high), with the cycle repeating approximately every 2.5 months. All pregnant ewes exhibited a peak in output just prior to parturition. Blood profiles are pending.

3. Dietary data are forthcoming and unavailable for comment. However, lambing habitat appears to be an area of concern. In the steep lambing areas, highly preferred forages show signs of over-utilization. If trends continue, preferred vegetation will be eliminated from these ranges. Permanent transects are being installed to detect trends in range quality.

4. Bear Mountain bighorn rarely range more than 250 meters from escape cover, nor do they enter areas where visibility is limited. During lambing, ewes choose areas with slopes exceeding 70%, whereas rams choose relatively level areas year-round.

5. Thousands of observations of bighorn sheep locations will provide accurate home range, herd expansion, and individual movement information. However, these data are yet to be analyzed and unavailable for comment.

6. Deer, elk and pronghorn antelope are seasonal occupants of Bear Mountain and do not compete with bighorns for forage and functional cover. Coyotes are occasionally found in the area but are not considered to have negative effects on this herd. Mountain lions may be a problem, but more research is needed to clarify their relationship with this herd.

7. Nursing and play behavior were closely monitored in summer of 1987. Over 300 nursing bouts in 200 hr of observation were recorded. Although precise data analysis is forthcoming, it was apparent that the age of a lamb has a great influence on nursing frequency. For example, on June 11th a 2-day old lamb was observed continuously for 11 hours. It nursed 38 times. Five days later (June 17th), this lamb nursed only 14 times, or 63% less, during a comparable time period. A sharp reduction in nursing frequency was also noted in other lambs, particularly newborns. Therefore it appears that in very young lambs suckling frequency is affected by age to a high degree. Other studies (Shackleton 1973) have shown differences in suckling lamb behavior patterns between "high" and "low" quality ranges. Lamb ages were either unknown or at least unreported. Therefore, inferences between "high" and "low" quality range comparisons based on lamb suckling

behavior may be biased or influenced by lamb age differences between sites or observations.

8. Evaluation of bighorn response to guzzlers suggests that bighorn avoid watering from them. This has also been reported by R. L. Schmidt (biologist, Colorado Division of Wildlife, pers. comm.). Development of catchments at springs have received immediate use by bighorns. In autumn 1985, 200 ha of dense pinyon-juniper, adjacent to bighorn ranges, were burned by the USFS heli-torch and reseeded for bighorn. The following year sheep moved into the area and fed heavily on the lush growth of grasses and forbs. In 1986, reseeded vegetation covered 23% of the bare soil. In 1987, reseeded vegetation provided nearly 50% ground cover. A problem was encountered, however, as the fire activated mustard seeds (Descurainia pinnata and Sisymbrium altissimum) dormant in the soil. These mustards grew into dense, 2 m high thickets which blanketed the entire burn, thereby reducing horizontal vision considerably (100% obstruction of vision at 7 m in all directions). Consequently, no bighorn sheep use was documented of this area in 1987. It is anticipated that this mustard will not persist and bighorns will move back into the area. Research data will be analyzed using the PATREC (Williams et al. 1977) habitat evaluation procedure. The PATREC model utilizes statistical inference for defining habitat evaluations, organizing existing knowledge about wildlife habitats and species' requirements in a quantifiable manner, and are flexible enough to use with a wide range of species. PATREC models are already developed for many species, including bighorn sheep (Holl 1982). The goal of PATREC model is to evaluate transplant sites for future releases within the state. It will also provide managers with another tool for improving habitat within existing bighorn population ranges.

DISCUSSION

Geist (1978) theorized that to maximize efficiency in bighorn management, knowledge of local populations is needed. Olsen (1986) reiterated the need for better monitoring of releases to determine movements and permanent herd establishment. Though in a broad sense, bighorn behavior and habitat requirements are becoming more clearly understood, regional environmental differences may present unique situations which demand varying responses from bighorn and game managers alike. The Bear Mountain research project is providing specific information for UDWR and USFS biologists that they may more effectively manage this, and other, bighorn herds in Utah.

LITERATURE CITED

Bagley, C. V. and T. D. Bunch. 1980. Procedures for collected and processing blood in wild sheep. Desert Bighorn Council Trans. pp 33-35.

Bunch, T. D., J. W. Bates, P. M. Webb, and E. L. Smith. 1980. Baseline physiologic values in desert bighorn. Desert Bighorn Council Trans. pp 46-49.

Coleman, J. S. and A. B. Jones. 1986. User's guide to TELEM: computer analysis system for radio-telemetry data. Dept. of Fisheries and Wildlife, Virginia Polytechnical Institute and State Univ., Blacksburg, VA. 46 pp.

Geist, V. 1978. Behavior. Pp. 283-296 in J. L. Schmidt and D. L. Gilbert, (Eds.), Big game of North America. Stackpole Books. Harrisburg, PA. 494 pp.

Goodson, N. J. 1982. Effects of domestic sheep grazing on bighorn sheep populations: a review. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:287-313.

Holl, S. A. 1982. Evaluation of bighorn sheep habitat. Desert Bighorn Council Trans. pp. 47-49.

John, R. T. 1975. Report from Utah. Pp. 46-48 in J. B. Trefethen, (Ed), The wild sheep in North America. The Boone and Crockett Club and Winchester Press, New York. 302 pp.

Shackelton, D. M. 1973. Population quality and bighorn sheep (Ovis canadensis Shaw). Ph.D. Thesis, Univ. of Calgary, Calgary. 227 pp.

Smith, T. S., D. W. Olsen and J. T. Flinders. 1988. Status and distribution of Rocky Mountain bighorn sheep in Utah. Bienn. Symp. North. Wild Sheep and Goat Counc. 6:(in press).

Thorne, E. T., W. O. Hickey and S. T. Stewart. 1984. Status of California and Rocky Mountain bighorn sheep in the United States. Pp 56-81 in M. Hoefs, (Ed.), Wild sheep, distribution, abundance, management, and conservation of the sheep of the world and closely related mountain ungulates. Spec. Rpt., North. Wild Sheep and Goat Counc., Yukon Wildl. Br., Whitehorse. 218 pp.

Williams, G. L., K. R. Russell and W. K. Seitz. 1977. Pattern recognition as a tool in the ecological analysis of habitat. Pp. 521-531 in Classification, inventory, and analysis of fish and wildlife habitat, the proceedings of a national symposium. Fish and Wildl. Serv., USDI.FWS/OBS-78/76.

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and Goat Counc. 6: 191 - 203

HOW MUCH DIFFERENCE DO DIFFERENT TECHNIQUES MAKE IN ASSESSING BIGHORN POPULATION TRENDS?

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Abstract: Using data collected during 1981-87 on the Cinnabar bighorn sheep winter range in southcentral Montana, we compared 5 estimators of numerical trend and 4 age/sex ratio estimators to determine: 1) the relative consistency of values derived using each estimator, 2) sampling intensity necessary to achieve consistency, and 3) the degree to which use of different techniques would have influenced our interpretation of population trend. None of the 5 numerical trend estimators would have produced satisfactory results from 1 survey. Two of the 4 ratio estimators would have performed well with a single survey if a high proportion of the herd were classified. All numerical and ratio estimators performed reasonably well (90% chance of being within 20% of yearly values obtained using all the available data) when derived from 6 surveys. Correlation coefficients, used as an index of agreement in rate/direction of change over time, were generally high ($\underline{r}$ = 0.69-0.99) for numerical trend estimators, lamb:ewe ratio estimators ($\bar{r}$ = 0.89-0.99), and ram:ewe ratio estimators ($\underline{r}$ = 0.87-0.97). Changes in the ratios of legally harvestable (3/4-curl or greater horns) rams to ewes varied ($\underline{r}$ = 0.55-0.93) among techniques. Most of the techniques would have led us to the same conclusions regarding the status of the Cinnabar herd. The analysis process we followed could be beneficial for biologists working with other herds, but no one should blindly adopt "off the shelf" sampling schemes without assessing the suitability of the techniques for the herds with which they are working.

Mountain sheep (*Ovis canadensis*) management relies heavily on winter surveys to assess population status and trends (Trefethen 1975). Sheep use open terrain, tend to concentrate on traditional winter/rutting grounds, and may be classified by horn characteristics to obtain population age structure (Geist 1966, 1971). Consequently, more detailed assessments of sheep populations are possible than for most other ungulates.

In conversations among ourselves and with other biologists, we

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discovered differences in the way "standard" population parameters were collected, analyzed, and reported that frequently are not obvious in methods sections of agency reports or published papers. While many of the differences are subtle, they could bias comparisons among herds studied by different biologists.

To determine the magnitudes of these differences, we examined results obtained from 5 techniques for assessing numerical trends and 4 for assessing ratios of lambs, rams, and legally huntable rams to ewes in a habituated herd in southcentral Montana. In our evaluation, we looked at similarity (Would different techniques produce similar values?), trend comparability (Were direction and relative magnitude of changes over time similar among techniques?), and efficiency (Did techniques differ in precision or in the sampling effort required to obtain a given level of precision?).

Data were collected from Rocky Mountain bighorn sheep (_O. c. canadensis_) wintering on the Cinnabar winter range (CWR) in the upper Yellowstone River valley 10 km northwest of Gardiner, Montana. The core winter range, approximately 5 km^2, was easily accessible via a county road, and sheep were habituated to humans. Vehicles could often approach within 5 m without causing sheep to move away from the road. The herd was hunted (Irby et al. 1986), and the Montana Department of Fish, Wildlife, and Parks (MDFWP) has monitored the population for >10 years.

Funding for this study was provided by the Welder Wildlife Foundation, the Foundation for North American Wild Sheep, the Boone and Crockett Club, the National Rifle Association, and Montana Department of Fish, Wildlife, and Parks. Field assistance provided by G. Erickson, K. Keating, and E. Arnett was greatly appreciated.

METHODS

During 1981-87, 118 ground surveys of the CWR were completed. Surveys were conducted 1-4 times per month during October - April along a county road through the winter range. About 50% of the core winter range, including most sheep concentration areas, was visible from the road. Because a plot of the number of sheep seen on individual surveys against time indicated that sheep numbers were highest on the survey route during November - January, we used only surveys from this period in our evaluations. Surveys in which <20 sheep were counted were deleted from most analyses as inadequate samples.

Numbers of individuals in recognizable age/sex classes were recorded during each survey. Rams were classified by horn shape (<1/2-curl, 1/2 - 3/4-curl, >3/4-curl) and, whenever possible, aged by horn annuli counts (Geist 1966). Ages were not assigned to ewes. Individually recognizable animals (collars or distinctively broken horns) seen during each survey were noted. Throughout the paper, we refer to annual periods by the year in which survey sets were initiated (i.e. 1981 = November 1981 - January 1982).

Descriptions and acronyms used to identify the techniques we evaluated are given in Table 1. Of the 5 numerical trend techniques, MEAN

Table 1. Approaches used for estimating numerical trends and age/sex ratios (lambs: rams: and legally harvestable rams:100).

Technique	Definition
POPULATION INDICES	
MEANC (Mean Count)	- Mean of all counts during Nov.-Jan.
MAX (Maximum count)	- Maximum total count for all surveys during Nov.-Jan.
MAX/C1 (Maximum count/class 1)	- Maximum count for all recognizable age/sex classes including male year classes (horn annuli counts). Individually recognizable animals not seen on days of maximum counts for their class were added to class total. Animals known to have died during Nov.-Jan. were subtracted from total. Includes all surveys during Nov.-Jan.
MAX/C2 (Maximum count/class 2)	- Similar to MAX/C1 except males were classified only by horn shape (<1/2 curl, 1/2-3/4 curl, 3/4+ curl), recognizable animals were not added to class totals, and known mortalities were not subtracted from totals.
LINC (Chapman - corrected Lincoln estimator)	- Estimates for individual surveys based on proportion of total individually recognizable animals (physical anomalies or collars) seen in counts >19 during Nov - Jan. a) Estimated number for individual surveys = $\frac{(\text{N marked} + 1)\ (\text{N observed} + 1)}{(\text{Marked animals observed} + 1)} - 1$ b) Estimated number for multiple surveys = mean of estimates for individual surveys.
CUMR (Cumulative ratio)	- Ratios based on cumulative counts of all animals sighted (including duplicated sightings) during Nov - Jan.
MEANR (Mean ratio)	- Mean ratio derived from ratios calculated for individual surveys with counts >19 during Nov - Jan.

(Table 1. cont'd.)

Technique	Definition
<u>RATIO ESTIMATORS</u>	
MAX R1 (Maximum/class ratio 1)	- Ratios calculated from maximum counts per distinguishable age/sex class recorded during all surveys from Nov - Jan. Males were classified by year classes, recognizable animals were added to totals when not seen in maximum counts, and known mortalities were subtracted from class totals.
MAXR2 (Maximum/class ratio 2)	- Similar to MAXR1 except males were classified by horn shape, marked animals were not added to totals, and known mortalities were not subtracted.

and MAX involved the smallest investment of time and money. These techniques required counts of sheep on winter range 1 or more times during winter but no marking or age/sex classification of animals.

MAX/C1 and MAX/C2 required more than 1 survey per winter and sufficient effort to classify animals by age and sex, but the presence of individually recognizable animals was not essential. MAX/C1 approximated conditions for an accessible, intensively studied population in which some individually recognizable animals are available and biologists could approach sheep closely enough to obtain horn annuli counts for rams. MAX/C2 approximated conditions in an inaccessible or unhabituated herd in which classification of rams by horn annuli counts is unfeasible and individually recognizable animals are not present.

The fifth technique, LINC, required marked animals. Population estimates were based on the lease complex mark-resight model (no heterogeneity in resighting probability, no avoidance of resighting by marked animals, and no variation in resighting probabilities over time) presented by Otis et al. (1978:21-24). Estimates from multiple surveys utilized the bias-corrected hypogeometric estimator (Chapman 1951) and methodology outlined by Rice and Harder (1977) and Bartmann et al. (1987).

During 1980-84, 11 females (1/2 - 4+ yrs) and 7 males (1 1/2 - 4 1/2 yrs) were captured (Keating 1982, Andryk et al. 1983) and fitted with individually marked radio collars (n = 16) or neckbands (n = 2). Seven additional individuals (5 females and 2 males) with distinctive broken horns were identified during 1981-86. Numbers of individually recognizable animals available as marked samples for individual surveys were determined based on total recognizable animals observed through April of each year. Radiocollared animals were not located using radio receivers during surveys.

Population estimates made using LINC were based on 5-15 recognizable sheep per survey. Estimates were calculated only for surveys during 1982-86 in which >19 animals, about 10-20% of the presumed population size, were counted and at least one marked animal was seen. Because we used an unrealistically simple model and a biased estimate of marked animals (Except for radiocollared animals with functioning radios, we could never be certain that an animal marked in an earlier year but not seen in the current year was not in the population), we refer to LINC as a population index in this paper.

Four techniques were evaluated for estimating age/sex ratios in the CWR population (Table 1). Lamb:ewe, ram:ewe, and legal ram (males with 3/4 or greater horn curl, regardless of age, that could legally be killed by hunters): ewe ratios were calculated using each technique. CUMR ratios were based on a simple summation of all animals classified during November - January. MEANR values represented the means of ratios derived from individual surveys. MAXR1 and MAXR2 values were calculated from maximum counts in each age/sex class from several winter range surveys. Ratios obtained using MAXR1 approximated conditions expected in a habituated herd in which rams could be aged by horn annuli counts. Ratios obtained using MAXR2 approximated conditions in an unhabituated herd.

> Similarities of values produced by numerical and age/sex ratio techniques were tested using blocked analyses of variance and Newman-Keuls means tests (Steel and Torrie:110-111, 132-146). An unbiased estimate of the missing 1981 value for the LINC method was calculated as suggested in Steel and Torrie (1960:139). Similarities in trends among the 5 population and 4 age/sex structure techniques were determined using Pearson correlations (Steel and Torrie 1960:183-187). Statistical analyses were conducted using the MSUSTAT statistical package (Lund 1983).

Because the estimates obtained using each technique were based on the same transect data and were sometimes derived from subtle variations of the same approach, the requirement for sample independence in analysis of variance and correlation analysis was violated. We elected to use these tests despite this violation of assumptions because the tests provided a conventionally recognizable manner of displaying differences.

We evaluated efficiency in terms of precision and, for techniques used to estimate trends in population size, the time costs of aging and sexing sheep versus merely counting them. Standard deviations, conventional measures of precision (Otis et al. 1978), were calculated for the MEANC, LINC, and MEANR techniques, but we were unable to locate suitable methods for calculating standard deviations for techniques relying on maximum or cumulative values from a series of counts. As an alternative, precision was assessed empirically by determining the number of surveys necessary to achieve results within a specific range using a variant of the "species-area curve" method (Oosting 1956). We calculated the percentage of individual surveys and of subsets of 3 and 6 randomly selected surveys that fell within 20% of values derived from all surveys within a single year. Surveys in which <20 sheep were counted were excluded from calculations to avoid variation due to obviously inadequate sample sizes. Six sets of 3 and 3 sets of six surveys were selected for each year for 1982-86. Twenty percent was selected as the acceptable level of deviation to avoid excluding values that differed from annual values by only 1-2 animals (i.e. with a 10% acceptance range, a lamb:100 ewe ratio of 12 would have been outside the "acceptable" range in a year in which the mean ratio was 10).

The additional field time required for classifying, rather than simply counting, animals was estimated from 2 segments of the survey route. One segment crossed the most heavily used portion of the winter range and included three 5-min scanning stops and 11 km of driving. The second segment crossed a portion of the winter range used by fewer sheep and included four 2-min scanning stops and 4 km of driving. At each stop, 7x35 binoculars and a 20-60x telescope were used to locate sheep. Counts (without age/sex classification) could be made in <2 min at stops on both segments.

RESULTS

Numerical Trend Indices

The numerical trend techniques produced 3 statistically different ($\underline{P}$ < 0.05) sets of estimates (Table 2). In order of increasing estimated numbers, the sets were: 1) MEANC, 2) estimates based on maximum counts (MAX, MAX/C1, and MAX/C2), and 3) LINC (AOV F = 66.25).

Table 2. Summary of the results of 5 techniques for estimating population trend on the CWR ($\underline{N}$ = number of surveys). Standard deviations are given in parentheses.

Technique	1981		1982		1983		1984		1985		1986	
	$\underline{N}$	Est.	$\underline{N}$	Est.	$\underline{N}$	Est.	$\underline{N}$	Est.	$\underline{N}$	Est.	$\underline{N}$	Est.
MEANC[a]	7	46(25)	16	62(28)	15	64(23)	11	46(17)	12	52(19)	12	54(22)
MAX	7	90	16	117	15	93	11	64	12	73	12	82
MAX/C1	7[b]	91	15	127	15	101	11	71	11	83	12	93
MAX/C2	7	91	16	117	15	95	11	68	12	77	12	88
LINC[c]			13	150(66)	12	135(35)	9	113(44)	10	96(29)	8	117(41)

[a] Definitions of acronyms are given in Table 1.
[b] Only yearling males were aged in 5 counts.
[c] Median numbers of recognizable individuals available were: 1982 = 8, 1983 = 10, 1984 = 9, 1985 = 8, 1986 = 8.

Positive Pearson correlations (r = 0.69-0.99) indicated that changes in values during 1981-86 were generally similar in direction among the 5 techniques. Significant correlations (r > 0.86: P < 0.05), indicating similarities in relative magnitude as well as direction of change, were identified among MAX, MAX/C1, and MAX/C2 (r = 0.98-0.99) and between LINC and MAX and MAX/C2 (r = 0.88-0.89). All techniques indicated a population decline between 1982 and 1984 and an increase between 1984 and 1986 (Table 2). Estimates of the magnitude of the 1982-84 decline varied from 25-45% with 2 distinct groupings: 1) MAX, MAX/C1, and MAXC/2 (42-45%), and 2) MEANC and LINC (25-26%). The 1984-86 increase followed a similar pattern with highest percentage increases obtained with MAX, MAX/C1, and MAX/C2 (28-31%) and smaller increases with MEANC (17%) and LINC (4%).

The proportion of individual surveys falling within 20% of average annual values for the 5 techniques varied from 0.20 to 0.54 (Table 3). Three surveys were judged inadequate (<90% chance of obtaining a value within 20% of the value calculated from complete sets of 11-16 surveys) for all techniques. Six surveys were apparently adequate for all techniques.

Table 3. Percentages of winter range surveys, sets of 3 surveys, and sets of 6 surveys that were within 20% of annual values for numerical estimators. Percentages were calculated from sets drawn from 61 surveys in which >19 sheep were counted during November-January, 1982-86.

Numerical estimator	1 survey (N = 61)[a]	3 surveys (N = 30)	6 surveys (N = 15)
MEANC[b]	54	83	93
MAX	34	73	93
MAX/C1	20	67	93
MAX/C2	33	83	93
LINC	48[c]	53	100

[a] N = number of values used to compute percentages.
[b] Acronyms are defined in Table 1.
[c] Based on 52 of the 61 surveys in which 1 or more marked animals were seen.

Age/Sex Ratios

The 4 methods used to determine lamb:ewe ratios (Table 4) gave comparable results (AOV F = 0.49, P = 0.70). Over a 6-year period, all techniques produced values within 20% of annual estimates in >50% of individual surveys and in >90% of sets of 6 surveys (Table 5).

Table 4. Lamb:ewe, ram:ewe, and legal ram:ewe ratios in the CWR population during 1981-86 calculated using 4 techniques.

	1981	1982	1983	1984	1985	1986
Total surveys	7	16	15	11	12	12
(Counts >19)	(6)	(15)	(14)	(10)	(11)	(11)
Total animals classified	322	972	950	516	666	633
TECHNIQUES						
Lambs:100 ewes						
CUMR[a]	35	34	11	16	40	24
MEANR (SD)	37(7)	36(16)	11(3)	17(5)	39(10)	23(6)
MAXR1	34	31	10	20	41	33
MAXR2	34	32	10	20	41	33
Rams:100 ewes						
CUMR	49	47	47	46	31	50
MEANR (SD)	45(16)	47(12)	47(10)	48(15)	33(14)	50(8)
MAXR1	60	64	59	58	48	70
MAXR2	60	56	53	50	34	63
Legal rams:100 ewes						
CUMR	25	17	13	21	17	18
MEANR(SD)	22(18)	16(7)	13(5)	22(12)	18(5)	18(6)
MAXR1	38	33	24	32	27	30
MAXR2	36	24	19	22	16	22

[a] Definitions for acronyms are given in Table 1.

Table 5. Percentages of individual winter range surveys (N = 61), sets of 3 surveys (N = 30), and sets of 6 surveys (N = 15) in which lamb:ewe, ram:ewe, and legal ram:ewe ratios fell within 20% of annual values using 4 techniques. Percentages were calculated from 61 surveys conducted during November-January 1982-86 and include only surveys in which >19 sheep were counted.

Technique	Lamb:ewe			Ram:ewe			Legal ram:ewe		
	Number of surveys in set								
	1	3	6	1	3	6	1	3	6
CUMR[a]	59	83	100	67	90	100	39	87	9
MEANR	67	80	100	67	90	100	39	77	93
MAXR1	52	83	93	36	67	100	21	67	100
MAXR2	51	80	93	56	83	100	43	97	100

[a] Definitions for acronyms are given in Table 1.

Ram:ewe ratios (Table 4) varied significantly among techniques (AOV F = 36.75). CUMR and MEANR produced the lowest ratios, MAXR2 significantly higher ratios, and MAXR1 the highest ratios. More than 50% of individual surveys fell within 20% of annual values in all techniques except MAXR1 (Table 5). All randomly selected sets of 6 surveys produced values within 20% of annual values.

Ratios of legal rams to ewes (Table 4) also varied among techniques (AOV F = 30.22). MAXR1 produced estimates 32% higher than those of the next highest technique, MAXR2. There was no significant difference between MEANR and CUMR. The probability of deriving a ratio within 20% of annual values on a single survey was low, but >90% of randomly selected sets of 6 surveys produced values within 20% of annual values for all techniques (Table 5).

Correlations here high (r > 0.87) among techniques used to derive lamb:ewe and ram:ewe ratios. Correlations of legal ram:ewe ratios among techniques were high (r > 0.80) except for MEANR with MAXR1 (r = 0.74) and MAXR2 (r = 0.55).

Time Costs of Classifying Sheep

The survey segment that passed through areas of high sheep density required 30 min to complete if no sheep were counted. In 10 replicates of this segment in which scanning stops were completed in the same order and times were noted, 4 to 56 sheep were classified (including aging rams by horn annuli counts). Mean time for completion of this segment was 66 min (range = 30-150 min, SD = 39), a 122% mean increase over the minimum time requirement.

The survey segment that passed through areas with low sheep density required a minimum of 15 minutes to complete. In 10 replicates in which no sheep were counted, the mean time for completion was 19 min (range = 15-25 min, SD = 5). In 13 replicates, 1-21 sheep were classified in a mean time of 30 min (range = 20 - 55 min, SD = 10). Replicates in which sheep were classified required an average of 58% more time than replicates in which no sheep were counted.

DISCUSSION

The 5 techniques for estimating numbers were generally in agreement on trends in population size for the CWR sheep herd during 1981-86, but the magnitudes of changes between years varied among techniques. Techniques based on maximum counts (MAX, MAX/C1, and MAXC/2) indicated that year-to-year changes in population size were proportionately greater than did the MEANC and LINC techniques.

None of the 5 numerical trend techniques we evaluated performed well when based on a single survey. The percentages of surveys that fell within 20% of annual values were higher for MEANC and LINC than for MAX, MAX/C1, and MAX/C2, but these differences were artifacts of methodology rather than differences in efficiency. Values within 20% of annual values could occur above or below the annual values for MEANC and LINC but only below for techniques based on maximum counts.

All techniques gave reasonably consistent results when based on 6 surveys. If we had been forced by logistical or financial constraints to conduct a single survey, we would have covered a larger proportion of the winter range in hopes of increasing the proportion of the population seen and scheduled a series of brief preliminary surveys of the CWR to insure that the intensive survey was conducted when sheep numbers in accessible parts of the winter range were high.

Sexing and aging individuals added >50% to survey time in 2 segments of the survey route. This additional investment in time increased population estimates over simple maximum counts <20%. Trends for maximum counts agreed closely with trends from techniques relying on aging and sexing individuals.

Values derived from the Lincoln Index (LINC) were consistently higher than maximum or mean counts, as expected. The high variability in values from single surveys (48-223% of those derived from respective annual multiple survey calculations) indicated that reliance on a mark-resighting model that requires only a single survey to make a population estimate would be unwise, at least for our sampling conditions (5-10% marked animals in a population of <200). Based on the formula given by Overton and Davis (1969:448) and a probability of resighting marked animals of 0.45 (Irby, unpubl. data), we would have had to mark 80% of the population to obtain narrow confidence limits ($\pm$10% at the 95% confidence level).

Use of the multiple survey approach yielded better results, but coefficients of variability (standard deviation / mean x 100, Steel and Torrie 1960:20) were greater than the 20% or less considered acceptable by White et al. (1982:50). More precise estimates may have been produced by increasing the number of marked animals (25% of the population should have been marked given the probabilities of resighting, survey numbers, and population size associated with the CWR (Rice and Harder 1977)) or utilizing more sophisticated models for analysis of data (Otis et al. 1978, Bartmann et al. 1987).

The 4 techniques used for estimating age/sex ratios produced similar lamb:ewe ratios. Trends in lamb:ewe ratios over time were also similar (decreases between 1981 and 1983; increases between 1983 and 1985; decreases between 1985 and 1986).

MAXR1 and MAXR2 generally produced higher ram:ewe and legal ram:ewe ratios than CUMR and MEANR. These differences were either related to differences in the proportion of the winter sampling period spent in accessible areas by ram and ewe bands (most individual collared ewes were sighted on a higher proportion of surveys than individual collared rams) or were an artifact of having more subclasses for identifying males than for identifying females. Year to year changes in ram and legal ram:ewe ratios were not as consistent among approaches as those indicated for lamb:ewe ratios.

A single survey would likely be adequate for obtaining lamb:ewe and ram:ewe ratios if a large proportion of the population (>50% of the estimates obtained using the LINC method for the CWR) could be classified during the period in which all age/sex classes were concentrated in the same area. The cumulative results of a series of partial counts would also give adequate results.

Estimates of the minimum number of legal rams surviving hunting season obtained by aging rams via horn annuli counts were higher than those obtained by classification of rams based on 3 horn shape classes (6-year mean = 15 vs. 12). This difference is important in the intensive management regime established in the CWR (Irby et al. 1986). Conducting horn annuli counts in larger, more remote, or less intensively managed herds may not be cost-effective.

MANAGEMENT RECOMMENDATIONS

Of the techniques we tested, those judged optimal for the CWR (an easily accessible, intensively managed herd with individuals habituated to close human approaches) were:

1) Trend - maximum count (MAXC) from 6 surveys during mid November - January. Although its usefulness is limited by lack of a means of calculating variance (Calculation may be feasible, but we were unable to find a statistician that knew of a suitable formula), MAXC (with 6 or more replicates) produced values that were relatively stable within a year, changed between years in directions that were consistent with changes in lamb production and herd health, did not require marked animals, and was not sensitive to errors in classification by age and sex. A multiple

survey, mark-resighting approach such as the multiple Lincoln Index (Bartmann et al. 1987) would give a better population estimate if adequate numbers of individually recognizable individuals could be maintained in the population. We do not have sufficient funds to mark a large proportion of the population, and, if we did, many of the non-consumptive users of the Cinnabar herd would be upset at marked animals spoiling their photographs of "wild" sheep.

2) Lamb:ewe and ram:ewe ratios - mean ratios (MEANR) derived from 6 surveys. This technique produced relatively precise results, and allowed us to calculate variances with which to assess year to year changes statistically. This technique may underestimate the actual proportion of rams in the population, but the direction of bias is known. Additional factors that should be considered in designing and analyzing sampling plans for age/sex ratios are given by Bowden et al. (1984).

3) Harvest quota - utilize maximum counts of males in individual age classes from at least 6 winter range surveys in which males are aged by horn annuli counts. The Cinnabar herd is utilized for 2 purposes (hunting and sheep viewing) that could easily conflict. Because we can get detailed information on ram ages, we believe it is worth the extra effort to determine numbers and ages of rams surviving to winter. This enables MDFWP to set quotas for the next year's hunt that will provide the greatest opportunity to harvest rams consistent with maintenance of ram numbers, age structure, and behavior patterns that will allow non-consumptive users ample opportunity to see and photograph mature rams.

Applications of this set of techniques to other herds may be inappropriate. Sheep occupying a winter range may belong to several bands with different seasonal range use patterns (Geist 1971, Festa-Bianchet 1986, Irby unpubl. data). Timing of movements on and off the winter range, movements within the winter range, and extent of movement among adjacent winter ranges could vary with different bands. If intensive management is a desirable option, winter range complexes should be observed for 3-5 years prior to initiating a routine sampling scheme. During this period, movement patterns, observability, seasonality of use, and variability among surveys should be determined. Settling on techniques without this information is likely to yield poor results.

LITERATURE CITED

Andryk, T. A., L. R. Irby, D. L. Hook, J. J. McCarthy and G. Olson. 1983. Comparison of mountain sheep capture techniques: helicopter darting versus net-gunning. Wildl. Soc. Bull. 11:184-187.

Bartmann, R. M., G. C. White, L. H. Carpenter and R. A. Garrott. 1987. Aerial mark-recapture estimates of confined mule deer in pinyon-juniper woodland. J. Wildl. Manage. 51:41-46.

Bowden, D. C., A. E. Anderson and D. E. Medin. 1984. Sampling plans for mule deer sex and age ratios. J. Wildl. Manage. 48:184-187.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological sample censuses. Univ. California Publ. Stat. 1:131-160.

Festa-Bianchet, M. 1986. Seasonal dispersion of overlapping mountain sheep ewe groups. J. Wildl. Manage. 50:325-330.

Geist, V. 1966. Validity of horn segment counts in aging bighorn sheep. J. Wildl. Manage. 30:634-635.

________. 1971. Mountain sheep: a study in behavior and evolution. Univ. Chicago Press, Chicago. 381 pp.

Irby, L. R., S. T. Stewart and J. E. Swenson. 1986. Management of bighorn sheep to optimize hunter opportunity, trophy production, and availability for nonconsumptive use. Bienn. Symp. North. Wild Sheep and Goat Counc. 5:113-127.

Keating, K. A. 1982. Population ecology of Rocky Mountain bighorn sheep in the upper Yellowstone River drainage, Montana/Wyoming. M.S. Thesis, Montana State Univ., Bozeman. 109 pp.

Lund, R. E. 1983. MSUSTAT, MS-DOS Version. Montana State University, Bozeman, MT.

Otis, D. L., K. P. Burnham, G. C. White, and D. R. Anderson. 1978. Statistical inference from capture data on closed animal populations. Wildl. Monogr. No. 62. 135 pp.

Oosting, H. J. 1956. The study of plant communities, 2nd ed. W. H. Freeman, San Francisco. 440 pp.

Overton, W. S. and D. E. Davis. 1969. Estimating the numbers of animals in wildlife populations. Pp 403-455 in R. H. Giles (Ed.), Wildlife Management Techniques, 3rd Ed. The Wildlife Society of Washington, D.C.

Rice, W. R. and J. D. Harder. 1977. Application of multiple aerial sampling to a mark-recapture census of white-tailed deer. J. Wildl. Manage. 41:197-206.

Steel, R. G. D. and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill, New York. 481 pp.

Trefethen, J. B., ed. 1975. The wild sheep in modern North America. Boone and Crockett, New York. 302 pp.

White, G. C., D. R. Anderson, K. P. Burnham and D. L. Otis. 1982. Capture-recapture and removal methods for sampling closed populations. Los Alamos National Laboratory. LA-8787-NESP. 236 p.

Bienn. Symp. North. Wild Sheep
and Goat Council 6: 204 - 209

SIMULATED FIELD TEST OF AGE AND SEX CLASSIFICATION CRITERIA FOR MOUNTAIN GOATS

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Abstract: A simulated field test of criteria for age and sex classification of mountain goats was conducted at the Sixth Biennial Symposium of the Northern Wild Sheep and Goat Council. After a 20 minute pictoral presentation of the horn, facial and pelage characteristics pertinent to field identification of 6 age/sex classes of mountain goats, a series of pictures of 13 mountain goats were projected. Participants were asked to identify the age/sex class of each goat on a test form. Sixty-seven percent of the answers were correct. Sex was correctly identified (81.0%) significantly more often than age (71.1%). Tests were stratified by the participants' previous experience observing or classifying mountain goats. Level of previous experience was reflected in accuracy of test scores regarding ages of goats, but was not significantly different among experience levels for accuracy of sex identification. Biases associated with the test, an explanation of test results, and applicability of these classification criteria to research and management of mountain goats are discussed.

The need for wildlife managers to evaluate reproductive success, subadult survivorship, sex ratios, and recruitment rates of mountain goat populations has been voiced by several authors (Hebert and Turnbull 1977, Bailey and Johnson 1977, and Macgregor 1977). Assessment of these parameters requires sufficient population composition data. Standardized criteria for collection of such data, both within and among states and provinces, will improve our understanding of mountain goat population dynamics and hierarchical behavior systems, facilitate comparisons of populations, and enhance management efforts.

A simulated field test of criteria for age and sex classification of mountain goats was conducted at the Sixth Biennial Symposium of the Northern Wild Sheep and Goat Council. The criteria consisted of quantitative justifications and narrative descriptions of six age/sex classes (kid, yearling, 2-year old male, 2-year old female, adult male, adult female) accompanied by pen and ink illustrations of each class (Smith 1988). The objective was to test the ability of biolgists, wildlife managers, students, and lay persons to apply these criteria in a simulated field situation.

METHODS

During a 20 minute slide discussion, the classification criteria were presented to the audience. At the beginning of the presentation, the audience was provided test forms (Fig. 1) and informed that they would be participating in a simulated field test after the presentation. The test

Simulated Field Classification of American Mountain Goats
Banff, Alberta April 14, 1988

Age/Sex Classes

K = Kid   2YM = 2 year-old male   AM = Adult male
Y = Yearling   2YF = 2 year-old female   AF = Adult female

1. ____________   7. ____________
2. ____________   8. ____________
3. ____________   9. ____________
4. ____________   10. ____________
5. ____________   11. ____________
6. ____________   12. ____________
    13. ____________

Have you had past experience observing (please circle) classifying mountain goats?

____ None
____ Some, non-technical (personal interest only)
____ Some, technical (a small part of my professional work)
____ Considerable, technical (regular part of my past or present work)
____ Other ____________

Do you believe that with more experience you could use these classification criteria to identify age/sex classes of mountain goats?

____ Yes   ____ No   ____ Unsure

Occupation/Affiliation: ____________

OPTIONAL
Name ____________
Address ____________

Fig. 1. Test form for simulated field classification of mountain goats.

consisted of a series of slides of close-up photographs of 13 different mountain goats. One to 3 mountain goats, which the audience members were asked to identify by age/sex class, appeared in each slide. A set of 1 to 3 slides (generally 2) offering different views (frontal and lateral) of the goats were shown. The audience was given approximately 30 seconds to classify the goat(s) on each set of slides.

The results of the tests were analyzed using one-way analysis of variance tests.

RESULTS

Eighty-three Canadians and Americans completed the test. Twenty-three (28%) had at least some previous experience classifying mountain goats in the field, although comments on the forms indicated the experience was generally limited to kids, yearlings, and adults and classifications were mostly from aircraft. Another 41 (49%) had some experience observing or censusing mountain goats; and 19 (23%) had no experience at all observing mountain goats (Table 1).

Table 1. Test scores from the simulate field test of age and sex classification of mountain goats.

Observer's previous level of experience	N	Percent correct answers ($\bar{x}$ + sd)		
		Age/sex class	Age class only	Sex only
Classifying Goats	23	76.3 ± 12.3	79.0 ± 11.4	86.8 ± 9.8
Observing or Censusing Goats	41	66.2 ± 13.8	70.7 ± 12.2	79.9 ± 16.1
None	19	57.6 ± 13.2	62.7 ± 12.9	76.5 ± 17.7
Total	83	67.0 ± 14.7	71.1 ± 13.3	81.0 ± 15.3

For the 83 tests combined, 67.0% of the 13 mountain goats were placed in the correct age/sex class. I also analyzed test answers to determine whether the age (kid, yearling, 2-year old, and adult) or the sex of the mountain goats were most difficult to correctly identify. For the 83 tests combined, sex was correctly identified (81.0%) significantly more often ($F = 19.624$, df = 1, $P < 0.001$) than was age (71.1%).

Next I compared test results by experience level of observers. There were significant differences between the three experience levels' mean test scores for age/sex class ($F = 10.542$, df = 2, $P < 0.001$), age class ($F = 9.590$, df = 2, $P < 0.001$), but not sex ($F = 2.665$, df = 2, $P < 0.08$). At all three levels of observer experience sex of goats was significantly more often identified correctly than age (no experience: F =

7.736, df = 1, $P < 0.009$; experience observing: F = 8.503, df = 1, $P < 0.001$; experience classifying: F = 6.125, df = 1, $P < 0.002$).

Kids and adult males were most often aged correctly. Two-year olds of both sexes were most often aged incorrectly (Table 2).

Table 2. Percent correct answers for each age/sex class from the simulated field test.

Age/sex class	Percent correct answers
Kid	80.8
Yearling	65.7
Two-Year Old Male	34.4
Two-Year Old Female	35.0
Adult Male	84.4
Adult Female	71.9

DISCUSSION

The purpose of this exercise was to test the ability of observers of varying experience levels to classify mountain goats by age and sex. The positive biases of the simulation compared to a field situation were:

1) Optimum environmental conditions for observers,

2) Stationary subjects to observe and classify, and

3) Similar observation conditions (facilitating valid comparisons between observers of varying experience levels).

The negative biases of the simulation were:

1) Limited exposure to the classification criteria,

2) Lack of in-hand illustrations and other instructive material for reference,

3) Observers were given a brief time and sometimes only view of the subjects they were asked to classify,

4) Fifty-four percent of the subjects were shown individually rather than in groups (which is more typical of field situations) that permits comparisons of subjects,

5) After the simulation, several participants stated that they wished they had moved closer to the front of the long, narrow conference room because horn characteristics were difficult to distinguish from the back of the room,

6) Non-responses were counted as wrong answers.

Sex of the mountain goats was correctly identified significantly more often than the age despite the fact that sex was marked incorrect not only when the wrong sex was given but also when the correct answer required the sex of the goat but a participant's answer did not include it (e.g., sex was marked wrong when participant's answer was "yearling" and correct answer was 2-year old female).

Accuracy of age identification was significantly related to the previous experience level of the observer. However, the relationship between previous experience and accuracy of sex identification was not significant at $\underline{P} = 0.05$, possibly because only 2 characteristics (horn curvature and basal circumference) require evaluation to determine sex whereas several criteria help discriminate age. More likely, the discrepancy between accuracy of age versus sex classification occurred because:

1) There are 4 age classes in Smith's (1988) classification versus 2 sexes,

2) Several participants who had previous experience classifying mountain goats told me that the simulation was difficult for them because they had previously only classified goats in summer (when pelage characteristics are radically different and body and horn sizes of sub-adult classes are smaller than in late fall, winter, and spring), and

3) The criteria for sex classification have been known and used for many years whereas very few technicians have classified all 4 age classes.

Although a computer simulation classified 91% of mountain goats correctly by age (Smith 1988), compared to only 71% by participants in this simulation, I believe that accuracies >90% can be achieved under field conditions. With more experience, more observation time, several views of subjects, comparisons with adjacent goats, and age specific behavioral information (Chadwick 1983, Geist 1964), observers can become adept at classifying ages of mountain goats. Likewise, sexually dimorphic behavior of mountain goats helps determine their sexes.

Finally, participants in this simulated field test were asked if they believed that with more experience they could use the classification criteria to identify age/sex classes of mountain goats. Four (4.8%) did not respond, 2 (2.4%) said no, 7 (8.4%) were unsure, and 70 (84.3%) answered yes.

APPLICATION

It is important that researchers and wildlife managers have access to techniques and training that enable accurate age/sex classification of mountain goats. Researchers can only understand population dynamics, the context of social behavior, and relationships between the two if they are able to distinguish the sexes, and subadult age classes from adults. Managers need data regarding a goat herd's composition as well as its size to determine if and how it may be harvested. Managers also need to provide adequate instructional materials and/or educational opportunities to hunting permittees so that flexible, innovative harvest regulations can be implemented. Hunters must be provided with the prerequisite knowledge for compliance with regulations.

LITERATURE CITED

Bailey, J. A. and B. K. Johnson. 1977. Status of introduced mountain goats in Sawatch Range of Colorado. Pp. 54-63 in W. M. Samuel and W. G. Macgregor (Eds.), Proc. First Internat. Mountain Goat Symp., Kalispell, MT. 243 pp.

Chadwick, D. H. 1983. A beast the color of winter. Sierra Club Books, San Francisco. 208 pp.

Geist, V. 1964. On the rutting behavior of the mountain goat. J. Mammal. 45:551-568.

Hebert, D. M. and W. G. Turnbull. 1977. A description of southern interior and coastal mountain goat ecotypes in British Columbia. Pp. 216-246 in W. M. Samuel and W. G. Macgregor (Eds.), Proc. First Internat. Mountain Goat Symp., Kalispell, MT. 243 pp.

Macgregor, W. G. 1977. Status of mountain goats in British Columbia. Pp. 24-28 in W. M. Samuel and W. G. Macgregor (Eds.), Proc. First Internat. Mountain Goat Symp., Kalispell, MT. 243 pp.

Smith, B. L. 1988. Criteria for determining age and sex of American mountain goats. J. Mammal. 69:395-402

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and Goat Council 6: 210 - 218

SEASONAL MOVEMENTS AND DISTRIBUTION PATTERNS OF A REINTRODUCED CALIFORNIA BIGHORN SHEEP HERD FOLLOWING TRANSPLANT IN THE SIERRA NEVADA, CALIFORNIA

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Abstract: Seasonal movements of 18 radio-collared California bighorn sheep (*Ovis canadensis californiana*) were monitored for 2 years following reintroduction in the Sierra Nevada, California. During the first year, summer and winter ranges were < 1 km apart. Rams remained with ewes on the summer range and herd movements were restricted to an area of 3 km^2. The second year, summer ranges of ewe groups remained approximately the same size but were displaced up to 7 km from the winter range. Rams greatly expanded their movements the second year; their range encompassed all of the areas used by the widely scattered ewe groups. Increased knowledge about the process of home range formation can assist managers planning future reintroductions.

California bighorn sheep originally occupied the Sierra Nevada wherever suitable rocky terrain with access to wintering areas existed (Jone 1950). Population numbers rapidly declined in the late 1800's apparently from overhunting, competition for forage with domestic sheep, and diseases transmitted by domestic stock (Buechner 1960, Wehausen 1980). Distribution in the Sierra currently is limited to 6 populations. Native herds of this subspecies have survived at Mt. Baxter, Sawmill Creek and Mt. Williamson (Wehausen 1980, C. D. Hargis, Unpubl. memo to the Sierra Nevada Bighorn Sheep Interagency Advisory Group, Inyo Natl. For., Lee Vining, 1986). Recent reintroductions of native California bighorn have been made at Wheeler Crest (1979), Mt. Langley (1980) (Andaloro and Ramey 1981) and Lee Vining Canyon.

On 5 and 6 March 1986, 27 California bighorn sheep were captured on the eastern slopes of Mt. Baxter, Inyo Co., California and transplanted 120 km north to Lee Vining Canyon, Mono Co. The Lee Vining reintroduction was the third such in a long-term program designed to reestablish geographically disjunct populations of bighorn sheep on historic ranges in the Sierra Nevada (Sierra Nevada Bighorn Sheep Interagency Advisory Group 1984).

To evaluate the success or failure of this reintroduction, the National Park Service initiated a 3-year monitoring program at the time of release. Primary objectives of monitoring are to (1) document natality and mortality within the new herd; (2) determine seasonal patterns of distribution and range use; (3) investigate the effects of habitat on survival and reproduction. Here, we report herd movements and distribution in the first 2 years following reintroduction.

We extend thanks the Goldman Foundation, the Sacramento Safari Club, and the Yosemite Association whose contributions made this project possible. Special thanks also to the Calif. Dept. of Fish and Game, USDA Forest Service and Bureau of Land Management for their assistance. Dr. R. H. Barrett provided helpful comments on the manuscript. Presentation of this paper was supported by Calif. Agric. Exp. Stn. Proj. 4236-MS.

STUDY AREA

The 46 km^2 study area is in the central Sierra Nevada of California, 5 km east of the range's main crest (Figure 1). It is bounded by Lundy Canyon on the north and Lee Vining Canyon on the south, and lies within Inyo National Forest. Elevation ranges from 2188 m at the eastern end of Lee Vining Canyon to 3758 m atop the summit of Mt. Warren.

The only significant human development in the area is State Highway 120 which winds along the north side of Lee Vining Canyon. Embankments along the 2-lane highway are used extensively by sheep throughout the year.

Weather on the study area is characterized by cold, harsh winters and warm, dry summers. Annual precipitation averages 69 cm per year and falls primarily as snow deposited between November and April. In 1986 and 1987, snowfall in Lee Vining Canyon was 150% and 25% of normal, respectively.

Low elevation winter ranges (2180-2590 m) support a pinyon-juniper woodland (Munz and Keck 1959). Summer ranges include two distinct plant communities: subalpine forest and alpine fell-field (Munz and Keck 1959).

METHODS

We installed radio collars equipped with mortality sensors on 25 of 27 tranplanted sheep at the time of their release. Seasonal distribution and movement patterns were determined by locating all sheep approximately 5 times a week using either aerial or ground based radio telemetry. Between 378 and 560 telemetry locations were recorded for each sheep. We plotted sheep locations on 7.5 min or 15 min topographic maps and recorded them as Universal Transverse Mercator grid coordinates (UTMs) for home range analysis. Home ranges were calculated using the modified minimum area method (Harvey and Barbour 1965).

Whenever possible, radio locations were confirmed by visual observations. During the past 2 years, individual sheep have each been observed between 97 and 230 times each. In addition to noting locations, we also recorded information on behavior, group size and habitat

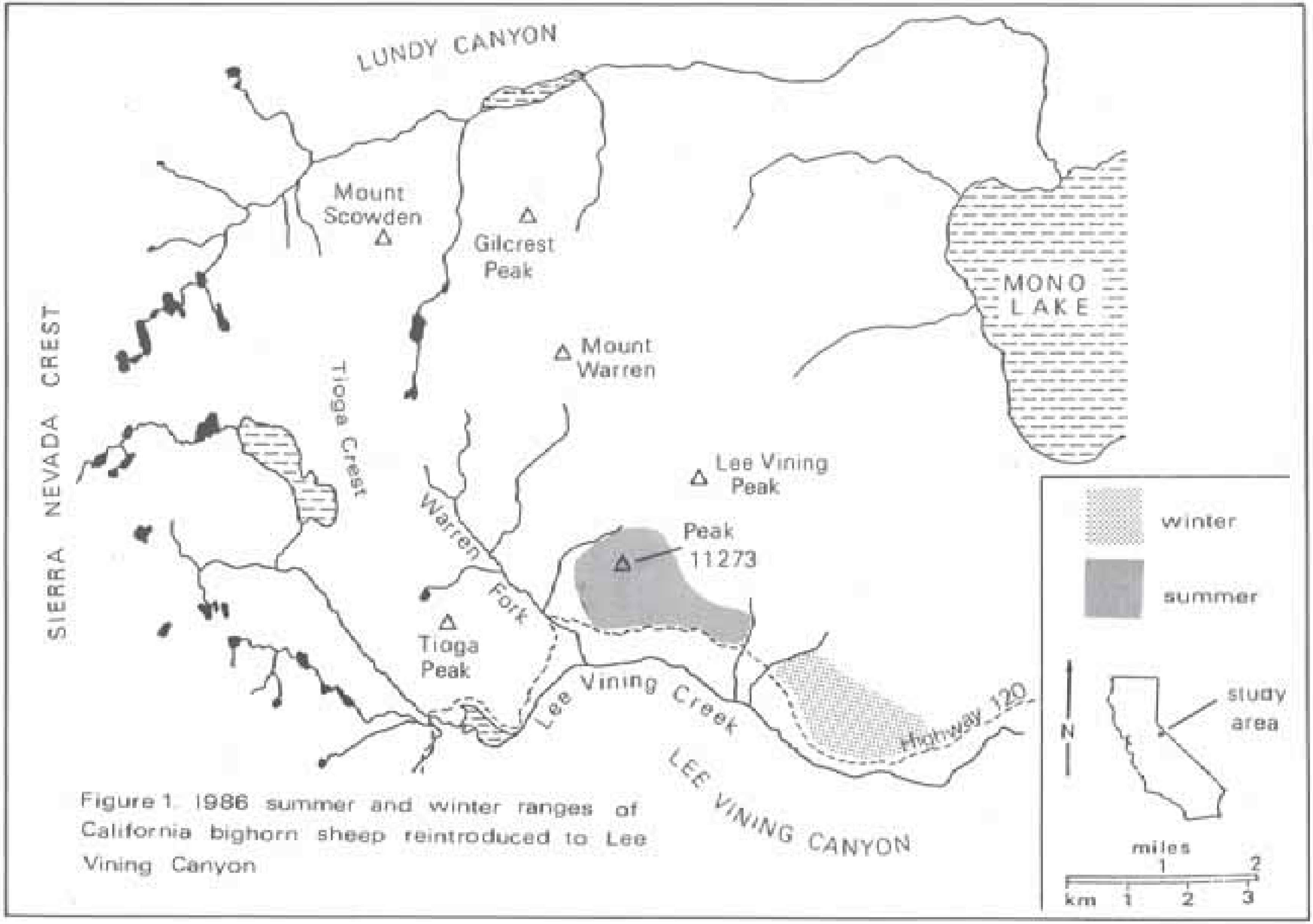


Figure 1. 1986 summer and winter ranges of California bighorn sheep reintroduced to Lee Vining Canyon

characteristics. Fecal pellets and associated bedsites also provided information about the location of use areas.

RESULTS

Twenty-seven California bighorn sheep were transplanted to Lee Vining Canyon (13 ewes, 7 rams, 3 female and 4 male lambs) and released in two groups (n = 14, 13) on successive days (5, 6 March 1986). Following the release, a series of severe storms swept the area and contributed to the deaths of 7 sheep. Between storms, surviving sheep moved down canyon in bands of 2 to 4 individuals. By 1 April, bands had coalesced to form a cohesive herd in the easternmost cliffs of Lee Vining Canyon. They remained there until late May (Figure 1). Individual ewes began to move up canyon to lamb in the third week of April but rejoined the herd on winter range following parturition.

Movement to spring range began in late May as ewes formed nursery bands. The herd remained on spring range for approximately 3 weeks and during that time, movements were restricted to a 0.5 km^2 area. Migration to summer range in the last week of June was abrupt. On the morning of 25 June 1986, 2 ewes left spring range and moved 2 km up canyon. They re-joined the herd at 1400 that afternoon and after 10 minutes of milling about, headed back up canyon followed by most of the herd. During the next week, the herd moved up through the south facing gullies of Peak 11273 and eventually arrived at what became their summer range (Figure 1).

A few individuals did not follow this general pattern. The most significant deviation was the foray by 2 rams into Yosemite National Park. In mid-May, 3 rams departed with winter range and moved 3.5 km up Lee Vining Canyon. Two of these rams crossed Warren Fork Canyon and traversed Tioga Crest. By mid-June they were in Yosemite National Park, 19 km west of the release site. Both rams returned to Peak 11273 on 14 July 1986 and rejoined the main herd, which had moved into that area.

Summer range was utilized from early July until mid-October 1986. During this time, use was concentrated in 2 core areas. One of these was the embankment along Highway 120. This site appears to be a mineral lick and was utilized repeatedly throughout the summer and autumn. The other core area, on Peak 11273, was used for bedding and foraging. On the basis of telemetry locations and visual observations we calculated summer range to be approximately 3 km^2.

Intermittent storms through September and October resulted in repeated movements between summer and winter ranges. Movements during this period also included what appeared to be exploratory forays. On 2 occasions, the herd suddenly moved 6 km north to previously unvisited areas but returned to the summer range after 2 or 3 days. In November 1986, the herd moved to an area midway between the 1986 summer and winter ranges and remained there until Spring 1987 (Figure 2).

Departure from the winter range in mid-April 1987, was initiated by ewes as they moved to lambing areas near the head of Lee Vining Canyon. The remainder of the herd: 5 rams, a ewe, and 5 yearlings, slowly joined

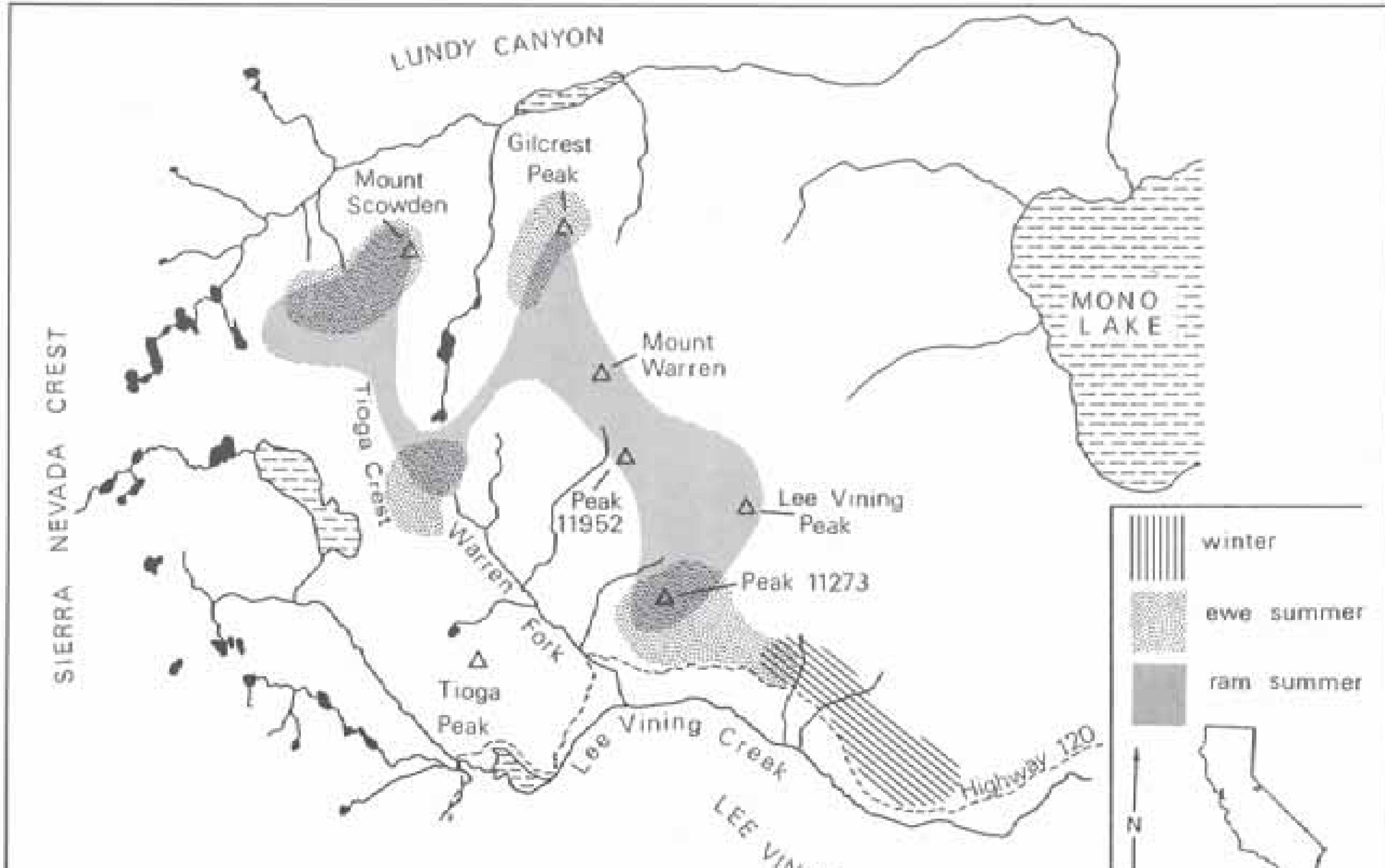


Figure 2. 1987 summer and winter ranges of California bighorn sheep reintroduced to Lee Vining Canyon

them over the next month. Following lambing, herd movements were restricted to 0.5 km^2 around Peak 11273 until late June.

As in 1986, migration to summer ranges was sudden and swift. On 30 June 1987, 2 ewes and their lambs left spring range heading north. By 7 July they had moved 6 km north of Lee Vining Canyon to the vicinity of Gilcrest Peak. This area had been visited by these ewes briefly during an Autumn 1986 foray. During the next 7 weeks, the band utilized the north and west sides of the peak (Figure 2).

On 6 July 1987, 2 rams, accompanied by a ewe and her lamb, also departed spring range and moved northwest, across Warren Canyon, to Tioga Crest. The rams had visited this area briefly in June 1986 while enroute to Yosemite. The band moved north for 3 days until reaching Mt. Scowden. Telemetry indicated that the band made extensive movements around Mt. Scowden before separating in mid-July. The ewe and lamb remained on Mt. Scowden until late August, confining their movements to the northwest side of the peak (Figure 2), while the rams travelled more extensively.

Not all ewes moved to new summer ranges. Three ewes and 2 lambs remained near Peak 11273 which had served as the herd's summer range in 1986. The center of their activities shifted, however, from the east side of Peak 11273 to a gully system on the peak's south face (Figure 2). The mineral lick along Tioga Road was used intensively and we observed frequent movements between these areas.

Ram migration began prior to the first week in June when 2 rams moved from Peak 11273 to the north end of Tioga Crest. In late July, they joined the rams that had moved to Mt. Scowden. All 4 rams formed a loosely knit band that continued to move between areas occupied by the widely separated ewe bands (Figure 2). Membership in the ram band shifted frequently. In mid-October all 4 rams reunited atop Peak 11952. They remained there until mid-November when they joined the ewe bands on winter range.

In September 1986, 3 ewes and 2 lambs emigrated from Lee Vining Canyon to Bloody Canyon, 13 km south. This band has remained there since that time, spending 2 winters at elevations of > 3100 m. Spring and Summer 1987 also saw range expansion by the Bloody Canyon band to an area of 8 km^2 with the winter range at its core.

DISCUSSION

The Lee Vining herd's restricted range use during the first year appears to be typical of reintroduced herds. On the basis of information from bighorn reintroductions in the United States and Canada, Geist (1971:121) concluded that transplanted bighorn sheep usually restrict habitat use to areas near the release site. We attributed the Lee Vining herd's restricted movements during the first year to the absence of traditional movement patterns coupled with disorientation in an unfamiliar area.

The degree of movement varied among individuals, however, as evidenced by the rams that forayed into Yosemite National Park and the ewes that moved to Bloody Canyon. This variability of movement has been reported for transplants of desert bighorn sheep (Ovis canadensis nelsoni) (McQuilvey and Pulliam 1981, Elenowitz 1983, Shaw 1986), Rocky Mountain bighorn (O. c. canadensis) (Bear 1979) and California bighorn (Andaloro and Ramey 1981, Hanson 1984). In a study of reintroduced pronghorn antelope (Antilocapra americana), Goldsmith (1988) attributed the high degree of variability in individual behavior to the expression of phenotypic variation in the absence of a social structure found in established herds. This conclusion may also hold true for reintroduced bighorn sheep.

Long distance migration to seasonal ranges the second year resembled movements by native bighorn populations and contrasted sharply with those of the first year. Geist (1971) proposed that migration patterns of native populations are based on traditions passed down through generations of bighorn sheep. In the absence of tradition, however, other explanations become necessary. Studies in California (Hanson 1984, Andaloro and Ramey 1981), Arizona (Shaw 1986), Colorado (Bear 1979), and New Mexico (Elenowitz 1983) all found that reintroduced sheep expanded their use of new areas during the second year following transplant. This may be attributable to increased familiarity with the region. The ewe's selection of summer ranges in those areas that had been visited previously lends support to this interpretation.

Another possible factor influencing movement patterns may have been differences in snowpack between the first and second year of the study. Snow did not pose a barrier to movements in either year because most had melted by the time the herd reached summer range. The large snowpack of 1986 produced snowbanks which lasted throughout the summer and their effect on the length of the plant growing season may have affected movement patterns. Plant growth in the Sierra Nevada is generally limited by the lack of available moisture (Major 1977). Winter snowpack has a major influence on the length of the growing season by providing water to plants during dry summer months (Billings and Bliss 1959). The large snowpack of 1986 may have allowed the new herd to obtain adequate forage in one location throughout the year. In contrast, 1987's below average precipitation may have necessitated long distance movements in search of food.

Predation may also have played a role in determining movements and distribution. In one instance, we witnessed the herd move to a new core area after being chased by a coyote (Canis latrans). In another case, a ewe-lamb band moved 2 km following the loss of a lamb to a puma (Felis concolor). J. Wehausen (Univ. California, White Mtn. Res. Stn., pers. commun.) observed abandonment of a wintering area by the Mt. Baxter herd when puma predation pressure there was high.

Bighorn sheep originally occurred throughout the Yosemite region but were extirpated prior to 1914 (Jones 1950). Evidence from recovered bighorn skulls indicates that native herds summered along the Sierra Nevada crest (Wehausen 1980). It is hoped that the reintroduced Lee Vining herd will eventually recolonize these areas. Monitoring of herd will continue for at least 1 more year. We expect this information will be useful to managers planning future reintroductions.

LITERATURE CITED

Andaloro, L. and R. R. Ramey II. 1981. The relocation of bighorn sheep in the Sierra Nevada of California. Environ. Field Pub. No. 7. Univ. California, Santa Cruz. 60 pp.

Bear, G. D. 1979. Evaluation of bighorn transplants in two Colorado localities. Colorado Div. Wildl. Spec. Rpt. No. 45, Fort Collins. 12 pp.

Billings, W. D. and L. C. Bliss. 1959. An alpine snowbank environment and its effect on vegetation, plant development, and productivity. Ecology 40:388-397.

Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present, and future. Wildl. Monog. 4. 74 pp.

Elenowitz, A. S. 1983. Habitat use and population dynamics of transplanted desert bighorn sheep in the Peloncillo Mountains, New Mexico. M. S. Thesis, New Mexico State Univ. Las Cruces. 158 pp.

Geist, V. 1971. Mountain sheep, a study in behavior and evolution. Univ. Chicago Press, Chicago, Ill. 383 pp.

Goldsmith, A. E. 1988. The behavior and ecology of pronghorn after reintroduction to Adobe Valley, California. Ph. D. Thesis, Univ. California, Berkeley. 112 pp.

Hanson, R. B. 1984. Grouping tendencies and home range development in an introduced herd of bighorn sheep (_Ovis canadensis californiana_). M. S. Thesis, California State Univ., Sacramento. 93 pp.

Harvey, M. J. and R. W. Barbour. 1965. Home range of Microtus ochrogaster as determined by a modified minimum area method. J. Mammal. 46:398-402.

Jones, F. L. 1950. A survey of the Sierra Nevada bighorn. Sierra Club Bull. 35:29-76.

Major, J. L. 1977. California climate in relation to vegetation. Pp. 11-74 _in_ Barbour, M. G. and J. Major, (Eds.), Terrestrial Vegetation of California. John Wiley and Sons, New York, N.Y. 1002 pp.

McQuilvey, R. P. and D. Pulliam. 1981. Results of a direct release desert bighorn sheep transplant in the Virgin Mountains of Nevada. Desert Bighorn Counc. Trans. 25:55-57.

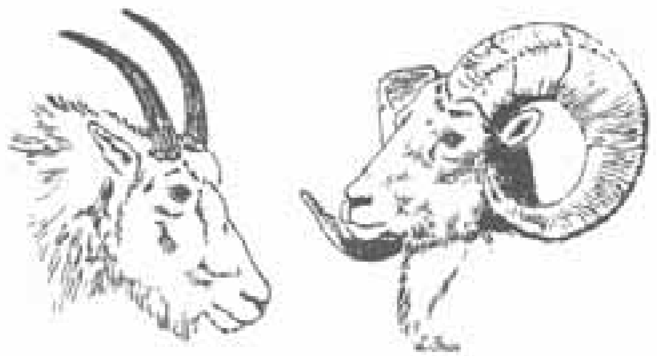
Munz, P. A. and D. D. Keck. 1959. A California flora. Univ. California Press, Berkeley. 1681 pp.

Shaw, H. G. 1986. Evaluation of desert bighorn reintroductions: a final report. Res. Branch Arizona Game and Fish Dept., Phoenix, Ariz. 13 pp.

Sierra Nevada Bighorn Sheep Interagency Advisory Group. 1984. Sierra Nevada Bighorn Sheep Recovery and Conservation Plan. Inyo Natl. For., Bishop, Calif. 17 pp.

Wehausen, J. D. 1980. Sierra Nevada bighorn sheep: history and population ecology. Ph. D. Thesis, Univ. Michigan, Ann Arbor. 240 pp.

Habitat and Nutrition



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A STRATEGY FOR PRESCRIBED BURNING BIGHORN SHEEP RANGE IN WINTER

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Abstract: The seasonal variation in the heat and moisture content of live tree foliage suggests a possible strategy for safely prescribing stand-replacing fires during the winter for establishing or maintaining high elevation sheep range. We discuss the possible burning prescriptions and ignition techniques that will produce crown fires in a mature forest stand without significantly reducing the organic soil profiles or adversely affecting the understory plant cover. The logistical, ecological and economic ramifications of our proposed strategy are also discussed.

Bighorn sheep (Ovis canadensis canadensis) range in Alberta can be described as semi-open to open alpine or subalpine plant communities adjacent to rugged escape terrain (Stelfox 1976, Bentz and Woodard 1988). Although this sheep species is known to use a variety of seasonal home ranges throughout the year (Geist 1971), most areas are dominated by graminoids forbs and short shrubs. Stelfox (1976) found that forbs and shrubs were nearly as important as grasses in fulfilling the year-round diet requirements of sheep. Perhaps more importantly, sheep remain almost exclusively on grasslands and rocky escarpments because of an apparent need for openness in close proximity to escape terrain (Risenhoover and Bailey 1985, Bentz and Woodard 1988).

Fires, prescribed or natural, induce habitats that are heavily used by bighorn sheep (Bentz and Woodard 1988). Stelfox (1976) pointed out that fires not only create new grasslands but periodically redistribute the biomass between groups of plant species by changing the environmental conditions on these disturbed sites. It has been suggested that burning may enhance the production, availability, and palatability of important forage species (Peek et al. 1979, Hobbs and Spewart 1984). Others have argued that periodic burning keeps seral grasslands from becoming dominated by climax coniferous tree cover (Geist 1971, Stelfox 1971, 1976). Some recent research has shown that on burned sites sheep use areas more distant to escape terrain than on adjacent unburned sites (Shannon et al. 1975, Bentz and Woodard 1988). These two studies concluded that this increase in use-distance is due to increased visibility. Recent work by Bentz (1981), Michalsky (1987), and Bentz and Woodard (1988) demonstrated this increase in use-distance is not related to differences in plant community composition or structure between burned and adjacent unburned areas. Regardless of the reasons for increased sheep use on burned areas adjacent to escape terrain, there is ample evidence to recommend the use of fire as a cultural tool to maintain or increase bighorn sheep range in Alberta or elsewhere (Thomas 1984).

Few adverse effects of burning on sheep or sheep range have been documented. Spowart and Hobbs (1985) "recommend that burns be large enough to prevent interspecific competition between ungulate species for available forage and that burn areas should be interspersed with adjacent unburned site to allow maximum nutritional alternatives to sympatric ungulate populations". Another report (Woodard et al. 1983) suggested that natural or prescribed fires burning under extremely dry conditions could have significant adverse impacts on soil profile. These impacts may occur as a direct result of burning, through the combustion of the organic profile, or as a result of soil erosion caused by heavy precipitation or extreme wind following burning. Most soil profiles at high elevation consist mainly of organic material, which will burn when dry. In the absence of complete combustion, the removal of the overstory canopy, and for a short-period the understory plant cover, may make soils on these steep slopes highly susceptible to wind and water erosion. Therefore, wildfires should be suppressed when they threaten these stands during dry conditions, and prescribed burning should be avoided when such conditions exist.

Little is known about fire behavior and the historical weather patterns for specific alpine sites. A shortage of high-elevation weather stations for documenting the micro-weather variations for the various aspects, elevations, physiographic changes and topographic variations makes it difficult for managers to predict how fires will behave under different fuel conditions. Most existing fire behavior models have not been validated for these sites. Also, most land managers do not have a wealth of practical experience in dealing with alpine and subalpine fires in this province. These factors tend to increase the risk of prescribed burning these high elevation sites, and this increased risk or uncertainty generally results in increasing costs. The amount of burning accomplished is often restricted due to the increase in costs associated with insuring prescribed fires are controllable, yet fulfill well defined objectives. The goal of this paper is to describe a burning prescription, which was developed from theory, that will allow managers to safely and cheaply prescribe a stand-replacing crown fire on a bighorn sheep range that has been overtaken by mature coniferous tree cover. The prescription attempts to minimize the effects of burning on the soil profile.

The Strategy

Historically, attempts at prescribing stand-replacing fires have been developed from identifying or describing fuel, weather, and topographic features that in combination with ignition procedures will enable a surface fire to develop into a self-perpetuating crown fire (Van Wagner 1977, Martin and Dell 1978). Generally, ground and surface fuels are allowed to dry to such an extent that when ignited under extreme conditions of wind (>20km/hr), slope (>30%), temperature (>15^{o}C), and relative humidity (<25%), fires spread rapidly. Under these conditions, flame lengths due to rapid reaction rates (fireline intensity (I_B), Byram 1959, Alexander 1982) are high; thus maximizing the probability that crowning will be sustained. Also, under these conditions, surface burning dries aerial fuels and when ladder fuels are present or when the fireline intensity is high enough, crowning will occur. Unfortunately, these types of fires usually consume the organic layers of the soil profile.

The result is a significant reduction in growth productivity of a site due to the loss in available growing media.

The goal of our strategy is to prescribe a self-sustaining crown fire which will burn in the absence of surface burning. There are no documented reports of sustained crowning occurring in the absence of surface burning but it is theoretically possible (Thomas 1967, Frandsen 1971, Van Wagner 1977). We suspect the absence of documented evidence is most likely due to the fact that when sustained independent crowning does occur, conditions are so dangerous that personnel are not close enough to observe its occurrence. Results from Van Wagner (1963) showed that moisture content significantly affects the probability of sustained burning. Christmas trees at less than 20% moisture content by oven-dry weight burned "with great violence when ignited by a match. Those at 50% moisture content burned readily, while trees over 100% could not be ignited using a point source of heat. Although these results and those of Quintilio (1977) might not pertain to the type of fire we are prescribing, they do represent the only data remotely applicable.

The conditions required for an independent crown fire have been described (Van Wagner 1977). In general, it is assumed that fuel moisture contents must be low, crown fuels must be continuous and have a low to moderate bulk density, energy levels must be normal to high, and the wind and slope components, which can significantly affect fire behavior must be extreme, >35 km/hr and >45%, respectively. Although there is a shortage of good fuel moisture and heat content data for coniferous tree species at this elevation, work by Fuglem and Murphy (1980) does suggest moisture contents may be low enough to produce desired conditions (Figure 1).

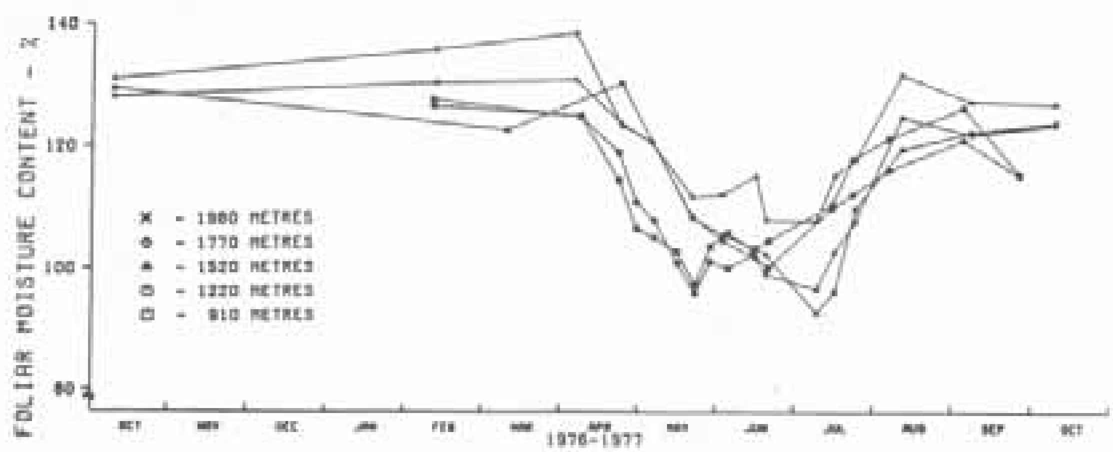

Figure 1. Foliar moisture content (dry weight moisture percent) of lodgepole pine at foothills sampling locations (each plotted value is the mean of six observations) (extracted from Fuglem and Murphy (1980); p. 15).

Results from their work, although limited by sampling intensity within and among years, and species type does clearly show the magnitude in foliar moisture content levels to be expected throughout the winter months for lodgepole pine at various elevations. These trends in moisture levels are consistent with other published work for other plant species (Russell and Turner 1975, Chrosciewicz 1986b). Although, the winter moisture contents reported by Fuglem and Murphy (1980) are considerably higher than those considered necessary for sustained burning (Van Wagner 1963), it is still possible that winter burning could be operationally feasible. We believe the sampling frequency in Fuglem and Murphy (1980) was not sufficient to detect significant moisture changes. It has been well documented that Chinook winds in combination with the higher ambient air temperatures commonly associated with them can dry live aerial fuels. In fact, if severe enough or sufficiently persistent, these winds can sufficiently dehydrate individual trees to the point that complete stands of conifers on the east side of the Rockies are killed; a condition known as "Red belt" in Alberta (Bella and Navratil 1987). Therefore, it seems logical to conclude that foliar moisture contents could be low enough to sustain an independent crown fire.

Data on the seasonal trends in foliar heat content in conifers also suggest winter burning may be possible (Little 1970, Philpot and Mutch 1971). Chrosciewicz (1986a) shows that the average high heat content of old white spruce foliage fluctuates from 20,400 kJ/kg in late May to 20,800 kJ/kg in mid-July back down to 20,300 kJ/kg by early September. Unfortunately, because of the limited time span in his data set it is impossible to determine what the heat content is during the winter months, although, it would seem highly unlikely that they would be much below the early September or late May values for old foliage. We expect very little energy in the form of extractives, tannins, oleoresins and carbohydrates are being added or removed from the live old foliage during the winter months because the cold temperatures and the frozen soil prevents very little biological activity from occurring in the tree. Further, we speculate the proportion of flammable biomass to water is increasing due to transpiration losses and the inability of the tree to translocate water from frozen soil, because although transpiration losses are minor during the winter period, there are losses due to respiration and even cooling if trees are subjected to warm, dry winds. But even if we are wrong, high heat contents of even 20,300 kJ/kg are significantly higher than 19,000 kJ/kg which is widely accepted as the average high heat content of most woody fuels (Byram 1959, Alexander 1982).

We speculate tree foliage will support crown fires at this elevation if the tree canopies are ignited from above under conditions of high winds (20-25 km/hr) or steep slopes (>45 %). The aerial drip torch or helitorch, which uses "SUREFIRE" (Fireflex Manufacturing's trade name for Calford G.; Lafferty 1984) or "PETRO GEL" (produced by Circle Park Holdings) appears to be the ignition system most suited to winter burning. Other aerial ignition systems such as the Aerial Ignition Device (AID; Lait and Muraro 1979) or the other types of fuses (Jukkala 1984) are not recommended because: (1) they will not adhere to the tree canopy like gelled gas, (2) they do not have the residence time of gelled gas, and (3) they can not produce flame temperatures equal to gelled gas (Brown 1984). These three factors must be considered when burning a porous and potentially moist fuelbed.

Even the wettest fuels will burn if enough heat is applied to dry the fuel below the moisture content of extinction level (Van Wagner 1963). High wind and steep slopes will increase reaction rates (I_B) thus increasing the probability of fire spread between tree crowns (Rothermel 1983, Alexander 1985). Woodard et al. (1983) reported on the value of this ignition technique during a spring fire which crowned under no wind; yet slope steepness varied from 25 to 55%. Their results showed that crowning could be induced with the use of the helitorch even though surface burning could not be sustained when surface fuels were strip-head fired (Martin and Dell 1978) with hand-held drip torches.

Historically, the use of the helitorch fuel was restricted by minimum ambient air temperatures required for fuels to gel. Temperatures below 15^{o}C greatly increase time required for a thorough setting of the "ALUMNI-GEL" and gas mixture. A peptizer was required when mixing this fuel between -25^{o}C and 15^{o}C. But even with a peptizer, which is an extremely toxic substance and thus dangerous to handle, gelling may take as long as 18 hours to achieve good consistency. This gelling time severely restricts the value of this product when temperatures are low. Current advances in the chemistry controlling the gelling now allows firing teams to achieve reliable product and results under any temperature condition >-25^{o} C if "SUREFIRE" or "PETRO-GEL" are used. Therefore, it seems reasonable to accept the premise that the energy levels needed to initiate combustion are available, and these chemicals and delivery systems are reliable for winter burning.

OTHER CONSIDERATIONS

Chinook winds occur frequently in Alberta and the effects of these warm, downslope winds should be considered when developing burning prescriptions. Burning should not be attempted during the Chinook condition. Flying aircraft in mountainous terrain is extremely dangerous during chinooks. Therefore, we do not recommend burning or even flying when wind speeds exceed 25 km/hr. Gradient winds should also be accounted for when determining the location and timing of ignition. The strength and direction of these winds will significantly affect the direction and rate of fire spread as well as the probability of long range spotting. We recommend prescribing burns when surface upslope winds are the strongest during the burning period. Strong upslope winds in combination with steep slopes will greatly enhance the establishment and maintenance of independent crowning. Upslope winds also permit helicopter flying when winds are even a little stronger (perhaps up to 30 km/hr). Also, fuel-free mountain tops or ridges will provide natural fuelbreaks. The adoption of this strategy will enable wildland managers to better control the downslope perimeter of the disturbed area. There seems to be little need to burn areas >300 m from escape terrain (Oldemeyer et al. 1971, Bentz and Woodard 1988). Spotting is unlikely if burning occurs when the forest floor is frozen in the burned site. It is not uncommon for south and southwest slopes to go snow-free as a result of solar radiation and Chinook winds while other aspects are still snow covered. Hence, we believe the probability of fires escaping the target area is extremely low even if large firebrands (>2 cm in dia.) are carried aloft. As a result, very few if any firefighters would be required to contain the fires we are proposing here.

COSTS

Costs of prescribed burning varies among individual burns based on the size of the area to be burned and the desired results. These two factors directly affect: (1) the amount of labour and equipment required to construct needed fireguards, (2) the size of suppression or control forces, (3) the number of helicopters required, (4) the size of the overhead and mixing teams, and (5) the amount of mop-up or surveillance time required. With our strategy, all of the above costs are significantly reduced. In addition, the number of "false starts" (when prescribed fires are cancelled because of failures to satisfy burning prescriptions but usually after firefighters and equipment have been located, moved or diverted) are reduced. "False starts" significantly contribute to the costs of prescribed burning. We also anticipate that it will be easier to predict prescribed weather conditions, because of the broader burning prescriptions (Brown 1984). Yet, we anticipate winter burning costs may be a little higher at first due to a lack of experience in forecasting weather at this elevation and for this period. Fire weather forecasters have not paid much attention to the weather at these elevations during this season. Therefore, we anticipate the number of "false starts" in accomplishing winter burns will drop off significantly after we have gained a little experience.

ECOLOGICAL EFFECTS

Vegetation

Winter burning of coniferous stands of trees is not a common practice in Alberta or elsewhere. Therefore, we as managers or scientists lack the information necessary to determine what effect this type of stand disturbance will have on the understory plant community. We expect our prescription will not significantly reduce the preburn cover and composition of the grasses, herbs and short shrubs if burning occurs when the litter fuels and duff are frozen. This prescription objective will maximize the probability that these plants will be killed or severely disturbed as a direct result of burning or exposure to thermal radiation; thus giving the competitive advantage to the more desired grasses and herbs.

Perhaps the major limitations of this prescription is that it will not reduce organic soil layers, or if heat is needed to break the seed dormancy of preferred plant species; this will not occur. In our opinion, if either of these two objectives are desired then a subsequent spring burn could be more safely and cheaply executed in the absence of the overstory canopy cover. Burning during early spring conditions with snow in the adjacent unburned stand would reduce the need for expensive fire-guarding. The burned area would most likely go snow free earlier, due to removal of the overstory tree canopy cover, and the fire could be more easily contained to the treatment area.

Sheep

Winter conditions can severely stress individual sheep or even a whole population of sheep in a specific area. Managers are usually careful not to impose additional stresses at this time of year because of the likely increase in average mortality levels. The presence of helicopters and people on or near occupied winter range may add to the stress experienced by the sheep. Depending on the condition of individuals in the herd this additional stress may prove fatal. Therefore, herd condition should be considered when timing burns. Early spring burns, particularly on south and southwest aspects, may provide more early spring forage than would otherwise be available. Thus, even if burning activities do increase stress levels in a population the earlier "green-up" of plants may compensate for any adverse impacts. In some areas, where the available sheep range is quite large and affords alternate and distance wintering sites, burns may be prescribed or located to minimize the stress on sheep.

SUMMARY AND CONCLUSIONS

Prescribing crown fires in mature, coniferous stands adjacent to escape terrain during the winter months may provide an inexpensive, yet effective, solution to maintaining or establishing Rocky Mountain bighorn sheep winter range. The prescription strategy presented relies on surface fuels being frozen, high upslope winds, steep slopes, uniform and continuous tree cover, and a helitorch ignition system, which uses some type of gel-gas mixture. We anticipate no control problems and all other costs associated with prescribed burning should be minimized with this strategy. Based on current fire behavior knowledge our prescription is extremely safe because it is extremely conservative. We believe qualified fire behavior officers may feel comfortable burning without snow on other aspects, particularly if the soil and ground are still frozen.

If our strategy fails, it will be because the trees will not sustain crowning independent of surface burning. We do not interpret this to be a problem. The deposition of flammable gel on live trees will kill plant tissue. Depending on the amount of live tissue killed in each individual tree, whole stands of trees may be killed without the need for wide-spread crowning. Our goal is not to prescribe a catastrophic "BONFIRE" but rather to open up the stand by killing the overstory tree cover.

Managers may find ignition costs prohibitive if large amounts of gelled-gas and helicopter time are required to kill stands that will not support crowning. But these costs will have to be very high to off-set the expense of not getting the job done because helicopters and firefighters were not available when burning is possible or when faced with paying for suppression crews to control prescribed burns and we have not even discussed the costs of "false starts". We conclude by saying "our strategy may not work, BUT in our opinion it is worth a try because from our experience with prescribed burning, the costs and possible losses are negligible compared to other alternatives".

LITERATURE CITED

Alexander, M. E. 1982. Calculating and interpreting forest fire intensities. Can. J. Bot. 60:349-357.

_________. 1985. Estimating the length-to-breadth ratio of elliptical forest fire patterns. Pages 287-304 in L.R. Donoghue, and R.E. Martin, eds. Weather - the drive train connecting the solar engine to forest ecosystems. Proc. Eight Conf. Fire and For. Meteorol. Published by Soc. Am. Foresters, Bethesda, MD.

Bella, I. E. and S. Navratil. 1987. Growth losses from winter drying (red belt damage) in lodgepole pine stands on the east slopes of the Rockies in Alberta. Can. J. For. Res. 17:1289-1292.

Bentz, J. A. 1981. Effects of fire on the subalpine range of Rocky Mountain bighorn sheep in Alberta. M.S. Thesis, Univ. Alberta, Edmonton. 192 pp.

___________ and P. M. Woodard. 1988. Vegetation characteristics and bighorn sheep use on burned and adjacent unburned areas in Alberta. Wildl. Soc. Bull. 16:186-193.

Brown, J. K. 1984. A process for designing fire prescriptions. pp. 17-30 in R. W. Mutch (Tech. Coord.), Prescribed fire by aerial ignition. Proc. Intermountain Fire. Counc. Workshop, Missoula, MT. 217 pp.

Byram, G. M. 1959. Combustion of forest fuels. Pages 61-89. in K.P. Davis, ed. Forest fire: control and use. McGraw-Hill, New York, N.Y.

Chrosciewicz, Z. 1986a. Foliar heat content variations in four coniferous tree species of central Alberta. Can. J. For. Res. 16:152-157.

_________. 1986b. Foliar moisture content variations in four coniferous tree species of central Alberta. Can. J. For. Res. 16:157-162.

Frandsen, W. H. 1971. Fire spread through porous fuels from the convection of energy. Combust. Flame 16(1):9-16.

Fuglem, P. L. and P. J. Murphy. 1980. Foliar moisture content and crown fires in Alberta. Conifers. Alberta Energy Nat. Resour., ENR Rep. No. 158. 47 pp.

Geist, V. 1971. Mountain sheep: a study in behavior and evolution. Univ. Chicago Press, Chicago, IL. 383 pp.

Hobbs, N. T. and R. A. Spowart. 1984. Effects of prescribed fire on nutrition of mountain sheep and mule deer during winter and spring. J. Wildl. Manage. 48:551-560.

Jukkala, A. H. 1984. State-of-the-art in aerial ignition equipment in the USDA Forest Service. pp. 159-166 in R. W. Mutch (Tech. Coord.), Prescribed fire by aerial ignition. Proc. Intermountain Fire Counc. Workshop, Missoula, MT. 217 pp.

Lait, G. R. and S. J. Muraro. 1979. The PFRC aerial ignition system: Mark II. Environ. Can., Can. For. Serv. Res. Rep. BC-X-167. 27 pp.

Little, C. H. A. 1970. Seasonal changes in carbohydrates and moisture content in needles of balsam fir (Abies lasiocarpa). Can. J. Bot. 48:2021-2028.

Martin, R. E. and J. D. Dell. 1978. Planning for prescribed burning in the Inland Northwest. USDA For. Serv. Gen. Tech. Rep. PNW-76. 67 pp.

Michalsky, S. J. 1987. Prescribed crown fire effects on a subalpine bighorn sheep range at Ram Mountain, Alberta, Canada. M.S. Thesis, Univ. Alberta, Edmonton. 89 pp.

Oldemeyer, J. L., W. J. Barmore and D. L. Gilbert. 1971. Winter ecology of bighorn sheep in Yellowstone National Park. J. Wildl. Manage. 35:257-269.

Peek, J. M., R. A. Riggs and J. L. Lauer. 1979. Evaluation of fall burning on bighorn sheep winter range. J. Range Manage. 32:430-432.

Philpot, C. W. and R. W. Mutch. 1971. The seasonal trends in moisture content, ether extractives, and energy of ponderosa pine and Douglas-fir needles. USDA, For. Serv. Res. Pap. INT-102. 21 pp.

Quintilio, D. 1977. Lodgepole pine flammability. Can. Dep. Environ., Forestry Reports 5(2):7.

Risenhoover, K. L. and J. A. Bailey. 1985. Foraging ecology of mountain. J. Wildl. Manage. 49:797-804.

Rothermel, R. C. 1983. How to predict the spread and intensity of forest and range fires. USDA For. Serv. Gen. Tech. Rep. INT-143. 161 pp.

Russell, R. N. and J. A. Turner. 1975. Foliar moisture trends during bud swelling and needle flush in British Columbia. Bi-Mon. Res. Notes, Can., For. Serv. 31:24-25.

Shannon, N. H., R. J. Hudson, V. C. Brink and W. D. Kitts. 1975. Determinants of spatial distribution of Rocky Mountain bighorn sheep. J. Wildl. Manage. 39:387-401.

Spowart, R. A. and N. T. Hobbs. 1985. Effects of fire on diet overlap between mule deer and mountain sheep. J. Wildl. Manage. 49:942-946.

Stelfox, J. G. 1971. Bighorn sheep in the Canadian Rockies: a history 1800-1970. Can. Field Nat. 85:101-122.

__________. 1976. Range ecology of Rocky Mountain bighorn sheep in Canadian National Parks. Can. Wildl. Serv. Rep. Series. No. 39. 49 pp.

Thomas, L. 1984. Use of prescribed fire by aerial ignition for improvement of habitat for bighorn sheep. pp. 137-142 in R. W. Mutch (Tech. Coord.), Prescribed fire by aerial ignition. Proc. Intermountain Fire Counc. Workshop, Missoula, MT. 217 pp.

__________. 1967. Some aspects of the growth and spread of fire in the open. Forestry 40:139-164.

Van Wagner, C. E. 1963. Flammability of Christmas trees. Dep. Forestry Publ. No. 1034, Ottawa. 19 pp.

__________. 1977. Conditions for the start and spread of crown fire. Can. J. For. Res. 7:23-34.

Woodard, P. M., J. A. Bentz and T. VanNest. 1983. Producing a prescribed crown fire in a subalpine forest with an aerial drip torch. Fire Manage. Notes 44(4):24-28.

Bienn. Symp. North. Wild Sheep
and Goat Council 6: 229 - 239

DESIGN, IMPLEMENTATION, AND INITIAL RESPONSE OF SELECTED HABITAT TREATMENTS WITHIN THE URAL-TWEED BIGHORN SHEEP RANGE

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Abstract: In response to the decline of the Ural-Tweed bighorn sheep (*Ovis canadensis canadensis*) herd between the 1960's and the 1970's, 2 separate but related habitat improvement projects were initiated. One is a Bonneville Power Administration (BPA) funded project to mitigate loss of bighorn habitat due to the completion of the Libby Dam hydroelectric project, and the other, a USDA, Forest Service (USFS) helicopter timber sale designed to improve bighorn sheep and other big game species habitat along Koocanusa Reservoir. Between 1984 and 1987, approximately 1753 ha of habitat have received some degree of treatment within the 9220 ha bighorn sheep range. Helicopter logging, slashing, prescribed fire, and fertilization are being used in various combinations to create a number of treatments located throughout the range. The initial phase of treatments (1938 ha total) is planned for completion in 1989. The types of treatments are discussed along with initial vegetation and animal monitoring efforts.

The Ural-Tweed bighorn sheep population, one of the few remaining native herds in northwestern Montana, occupies the steep slopes along the east side of Koocanusa Reservoir (Brown 1979, Yde et al. 1986). The range occupied by sheep is a series of broken, timbered, steep slopes (elevation 760-1680 m) with intermingled small grass/shrub openings. Several factors lead to a decline in the population from an estimated 150-250 animals in the 1960's to approximately 25-40 animals in the late 1970's. Construction of the Libby Dam hydroelectric facility on the Kootenai River resulted in the inundation of approximately 1740 ha of bighorn sheep winter and spring habitats. Additionally, approximately 240 ha of habitat were lost with the associated construction of Montana Highway 37. Thus, approximately 18% of the total initial range (11200 ha) has been irretrievably lost (Yde and Olsen 1984). Fifty years of active fire suppression has also allowed ecological succession to progress. This resulted in increased encroachment of Douglas-fir (*Pseudotsuga menziesii*) into the open ponderosa pine (*Pinus ponderosa*)-bunchgrass community (vegetation names follow Hitchcock and Cronquist, 1973). Pre-treatment tree densities ranged from 2470-3700 stems/ha for trees larger than 2.5 cm dbh and 90% of the stems were between 2.5 and 10 cm dbh. Dense stands of lodgepole pine (*Pinus contorta*) are also present as a result of several historic burns.

All previous studies conducted on the Ural-Tweed range determined the sheep preferred the bunchgrass communities under open stands of ponderosa pine and Douglas-fir (Ensign 1937, Brink 1941, Brown 1979). These compare favorably to studies conducted on other bighorn populations (Couey 1950, Smith 1954, Geist 1971, Risenhoover and Bailey 1985, Shannon et al. 1975). The quality of the Ural-Tweed range for bighorn sheep has historically been maintained by fire which produced the open bunchgrass communities. This has been documented by the abundance of fire scarred trees in the area (Brown 1979) and through aerial photos taken in 1949 which show evidence of numerous fires in the area adjacent to the Kootenai River.

As a result of a study completed by Brown (1979), and the availability of mitigation funds through the Northwest Power Planning Act of 1980, habitat treatments totalling 1946 ha have been initiated on the Ural-Tweed range. A USFS helicopter logging operation designed to selectively harvest 18 million board feet (mmbf) of mature ponderosa pine, Douglas-fir, and western larch (Larix occidentalis) was initiated on 1381 ha of primary bighorn sheep use areas. Secondly, 557 ha of selected habitats have been scheduled for treatment using funds provided by BPA (contract #84-38) as mitigation for the Libby Dam hydroelectric project. Monitoring of the vegetation and animal response to these treatments has also been funded by BPA (contract #84-39).

The habitat treatments described in this paper are the initial efforts of a long-term approach to managing the Ural-Tweed bighorn sheep range. A long-range habitat management plan outlining a program of habitat treatments needed to maintain the productivity and suitability of the range is currently being developed. This plan will outline future treament areas, treatment schedules, and the need for retreatment. Treatments and retreatments will be scheduled to approximate the natural fire cycle.

METHODS

Treatments

The primary goal of all the treatments was to stimulate production of understory vegetation while maintaining mature ponderosa pine and Douglas-fir trees. In an attempt to achieve this objective, 4 basic habitat treatments--selective timber harvest, slashing, prescribed burning, and fertilization--have been utilized singly or in combination. Size of treatment units ranged from 6-255 ha.

Although the primary emphasis for both the BPA and USFS projects was habitat improvement for bighorn sheep, due to the extensive nature of the treatments the designs incorporated considerations for other wildlife species. The units were well distributed throughout the entire sheep range to enhance habitat diversity and create a habitat mosiac (Fig. 1). Habitat diversity was enhanced on a unit basis by leaving untreated small drainages, selected conifer covered benches, and patches of deciduous trees. Prescribed fires further enhanced diversity due to the varying intensities that resulted from discontinuous fuels, variable fuel loadings, and the burning prescriptions. Selected treatment units were actually designed to primarily benefit mule deer (Odocoileus hemionus) and moose (Alces alces). This was done in an attempt to reduce the interspecific competition between big game ungulates on important bighorn sheep wintering areas.

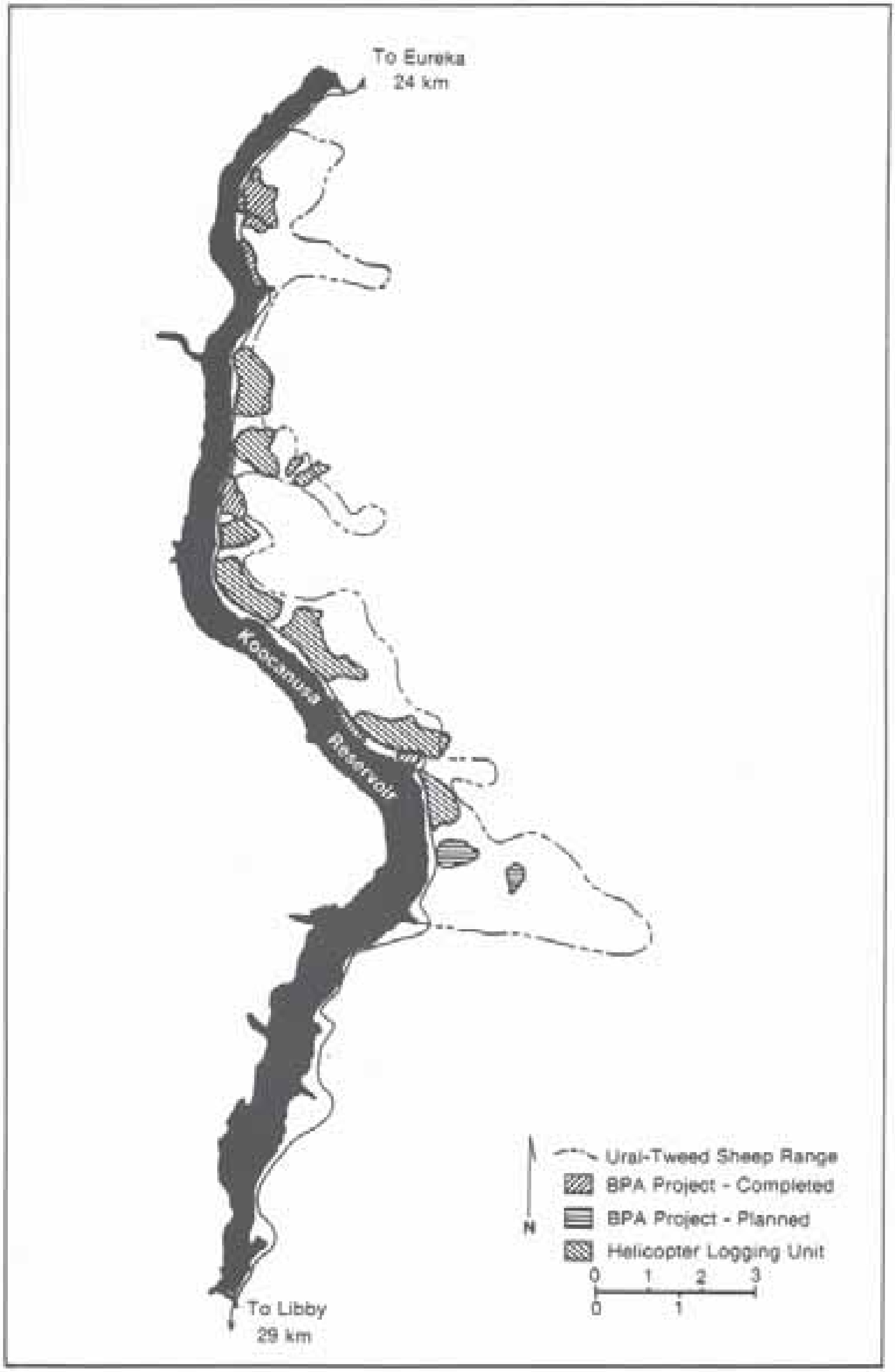

Fig. 1. Map of the Ural-Tweed bighorn sheep range delineating BPA-funded habitat treatments and helicopter logging units.

Selective timber harvest.--A large timber sale containing 9 separate units was specifically designed to benefit bighorn sheep with considerations for other big game species. Selective harvest of merchantable sized trees was used to open the overstory canopy while retaining mature and overmature, fire resistant ponderosa pine and Douglas-fir. Based on a study of habitat utilization by the sheep population (Brown 1979), the objective of the harvest was to leave 37-74 mature trees/ha.

Seasonal timing restrictions on logging activity were incorporated into the sale contract. Timber harvest and removal was timed to reduce disruption of bighorn sheep during lambing/nursery and rutting seasons. Helicopters were used to extract the trees to landings adjacent to Highway 37. Therefore, soil disturbance was negligible and access to the area was not increased by construction of roads and skid trails. Slashing and prescribed fire were used after timber harvesting to complete the treatment on each unit.

Slashing.--Slashing (sawing down trees) treatments have been used on both BPA and USFS projects to achieve one or more of the following objectives:

1. Increase the fuel loading to create a desired fire intensity or behavior;
2. Directly reduce the conifer overstory--primarily regeneration or subdominant trees; and
3. Protect specific tree species and individuals from the effect of heating or consumption.

Slashing was done manually within treatment areas. Broadcast slashing (conifers slashed to a specified dbh limit over the entire treatment unit except for areas designated to be untreated to increase habitat diversity) was the most common slashing treatment, but other variations have also been used. Sometimes more than 1 slashing treatment was combined within a given unit. One variation was strip slashing in which alternating strips 15-23 m wide were slashed with an objective of creating sufficient fuel to generate a fire that would carry into the unslashed strip and thin the canopy. Strip slashing was utilized in areas of dense, small dbh conifers to create a heavy fuel loading. Another variation used was hand piling slashed conifers away from fire sensitive black cottonwood trees (*Populus trichocarpa*) to prevent them from being killed or injured by the follow up prescribed burn.

Slashing was accomplished by USFS saw crews or through contracting with a private company. Slashing was conducted during all seasons of the year depending on the suitability of weather, terrain, and availability of crews. Slash was allowed to dry for at least one summer and normally 1 year or more before burning.

Prescribed burning.--Prescribed burning was normally the final phase of all habitat treatments except when a fertilization treatment was used. Burning was used to meet one or more of the following objectives:

1. Rejuvenate decadent stands of shrubs, grasses, and forbs;
2. Reduce the conifer overstory--primarily seedling,

sapling, and pole sized subdominate trees, and
3. Reduce slash accumulation from previous treatments.

A specific burning prescription was written using the BEHAVE program (Andrews 1986) after the objectives for a unit were defined. This fire behavior computer program defines a range of climatic conditions and fuel moistures under which a fire would achieve specific objectives. Spring and late fall burns were planned for areas containing the important fire sensitive browse species bitterbrush (Purshia tridentata). Soil moisture is usually sufficient during these periods to reduce the damage to plant root collars (Noste and Bushey 1987). These cooler season burns were also utilized when slashing had created heavy fuel loading and minimal damage (<10% mortality) to the remaining trees was desired. Late spring and early fall burns were scheduled in areas where more intense fires were needed for slash reduction or to produce 15 to 75% mortality in conifers remaining. Late August burning was utilized in areas where fuel loadings were light and discontinuous. Under warmer and drier conditions, burning produced the desired results of slash reduction and 25-75% mortality of the remaining conifers.

Aspect, fuel loading, soil type, presence or absence of fire sensitive species, and desired level of conifer mortality were utilized in selection of the burning season. Either hand or aerial ignition was used depending on the terrain and the size of the unit. Drip torches or, infrequently, fusees were used for hand ignition. Aerial ignition was accomplished either with a PREMO MARK III aerial ignition device or with a helitorch.

Natural fuel breaks were utilized with only 2 exceptions where short hand-dug fire lines were built. State of Montana air quality guidelines for smoke managment were followed.

Fertilization.--Several open, rocky, steep areas exist within the sheep range that do not lend themseleves to slashing and burning type treatments. These areas contain a scattered stand of grasses dominated by rough fescue (Festuca scabrella), Idaho fescue (F. idahoensis), and bluebunch wheatgrass (Agropyron spicatum). Due to the discontinuous fuels and broken topography these areas can not be effectively treated with fire. The objective of the fertilization treatments was to improve the short-term forage quality.

A 10 ha trial plot was established in 1986 using an aerial application of 225 kg/ha of nitrogen (20-0-0). A flat, rocky bench with a vegetation composition similar to the steep, broken areas was chosen as a trial plot. The topography of the plot will facilitate monitoring of the vegetation response which could not be logistically accomplished on the majority of the proposed units.

Vegetation Monitoring

Vegetation composition, productivity, and structure have been monitored to determine response to the treatments (Yde et al. 1986). Transects were established in both pre- and post-treatment areas, as well as in paired control areas. Food habits, diaminopimelic acid (DAPA), fecal nitrogen, and crude fiber analyses have been conducted in an attempt to provide an indication of changes in diet composition and quality.

Animal Monitoring

A combination of radio-telemetry, visual observations, and browse utilization/pellet group transects were used to monitor bighorn sheep and mule deer response to the treatments. Five to 15 radio-collared bighorn sheep have been monitored annually from 1985 through 1987. In 1987-1988, 26 mule deer have been radio-collared. Additionally, fecal analysis--DAPA, fecal nitrogen, crude fiber, food habits--, body size, horn growth, and population growth are being monitored to determine the response of the bighorn sheep population. Yde et al. (1986) discusses the monitoring in detail.

RESULTS

Approximately 1753 ha of the 1938 ha planned for the initial phase of habitat treatment have recieved at least partial treatment by 1987. Nineteen percent of the total sheep range (9220 ha) has been treated. When the total planned area of 1938 ha has been completed, 21% of the sheep range will have been treated. Table 1 details the treatment type, season, year, and size of each unit. Table 2 gives the costs associated with the treatments. Juxtaposition of the treatment units are illustrated in Fig. 1.

Eighteen mmbf of timber sale was harvested between 1985 and 1987. The sale of this timber helped achieve treatment objectives as well as providing funds through the Knutson-Vandenburg Act of 1930 to complete the various treatments.

Slashing and prescribed burning treatments were used on 6 BPA units (328 ha total). All units were slashed by 1987. Slashing was prescribed for all 9 timber sale units (1381 ha total). To date it has been completed on 6 of the units with the remainder scheduled for 1988.

As a final phase of combinations with other basic treatment types, prescribed burning has been completed on 10 units totalling 1025 ha through 1987 with 5 more units totalling 684 ha scheduled in 1988 and 1989. Prescribed burning alone has been selected for 3 units of the BPA project. One 22 ha burn was accomplished in 1986 and 2 more totalling 121 ha are planned for 1988.

A 10 ha trial fertilization plot was established in spring 1986. Five more fertilization units are planned for a total of 64 ha if the results are favorable. Visual observations of the trial plot after one year showed a favorable response.

Due to the recent or partial completion of treatments on several units, sufficient post-treatment data has not been gathered to allow a comparative analysis between pre- and post-treatment conditions. Vegetative and animal response will be analyzed and reported at a later date.

Table 1. Habitat treatments and unit sizes on the Ural-Tweed bighorn sheep range in northwestern Montana.

Unit name	Treatment by year	Size (ha)
BPA contract		
South Sheep Creek	slash 1984/burn late spring 1987	49
North Stonehill	slash 1985/burn late summer 1987	113
Tenmile	slash 1985/burn spring 1988	40
McGuire-Tweed	slash 1986/burn late summer 1987	57
Rocky Gorge	slash & handpile 1985/burn fall 1985	12
South Stonehill	strip slash 1985/burn late summer 1987	57
Lower Stonehill	prescribed burn spring 1986	34
Lower Sutton Face	prescribed burn spring 1988	40
Volcour	prescribed burn late summer 1988	81
Stonehill-pilot	fertilize spring 1986	10
Sutton	fertilize 1988	28
Tweed	fertilize 1988	10
Allen Gulch	fertilize 1988	12
Sheep Creek	fertilize 1988	6
Pack Rat	fertilize 1988	8
	subtotal	557
USFS Helicopter Timber Sale[a]		
McGuire Creek	harvest/slash 1987/burn spring 1988	237
Rocky Gorge	harvest/slash 1985/burn spring 1987	255
Packrat Gulch	harvest/slash 1987/burn late summer 1987	141
Peters Gulch	harvest/slash 1988/burn spring 1989	62
Peck Gulch	harvest/slash 1988/burn spring 1989	230
Tenmile	harvest/slash 1985/burn spring 1987	180
Tweed Creek	harvest/burn late summer 1987	121
Sheep Creek	harvest/slash 1988/burn fall 1988	113
Allen Gulch	harvest/slash 1987/burn fall 1988	42
	subtotal	1381
	total	1938

[a]All harvesting was completed between 1985-1987.

DISCUSSION

A number of effects have been observed from the various treatments used on the bighorn sheep range. Many of these have biological, logistical, political, and social implications for future treatments.

It became apparent very early in the project that flexibility was needed in scheduling treaments. Unfavorable weather often caused prescribed burns to be postponed or rescheduled, and narrow burning

Table 2. Costs associated with habitat treatments between 1984 and 1987 on the Ural-Tweed bighorn sheep range in northwestern Montana.

Treatment	Cost ($U.S./ha)[a]
spring burn	37-89
late summer or fall burn	74-198
slash	99-326
strip slash	158
slash and hand pile	252
fertilization	316
selective timber harvest	247[b]

[a]Average cost/ha for period 1984-1987.

[b]Cost for preparation and administration. Purchaser paid $760 U.S./ha of which $705/ha was available in Knudtson-Vandenburg funds for follow up treatments.

prescription "windows" increased the probablility of delays. In some cases, burns have been delayed 2-3 years.

Large treatment units (40-250+ ha) were used with a few exceptions. These were well distributed throughout the range. Large units are expected to benefit bighorn sheep by reducing intraspecific and interspecific competition. A habitat mosiac was obtained within each of the units due to the variations in topography, fuel loadings, and vegetative conditions throughout a large unit. This mosiac helped ensure the suitability of the unit for bighorn sheep use following treatment. Also, the per hectare costs of prescribed burning were reduced.

Aerial ignition was demonstrated to be the most efficient and practical technique for prescribed burning large units and rugged terrain. A 6-8 person crew could safely ignite approximately 40 ha on gentle to moderately rough terrain in one daily burning period while 400+ ha could be safely ignited in any sort of terrain in the same amount of time using the PREMO MARK III aerial ignition device. Rapid ignition capability also permitted us to take advantage of short-lived, yet favorable weather conditions to complete several burning units.

The PREMO MARK III aerial ignition device worked well where fine fuels (such as grasses, litter, and slash with dead conifer needles) were available. The helitorch was more efficient at igniting larger fuels and it also was capable of generating an intense fire more rapidly. Hand ignition worked well in all fuel types and was the most precise method. It was especially valuable in heavy fuel loadings where the pattern and rate of ignition was critical to meet an objective of retaining most of the mature overstory conifers.

The response of bitterbrush in the Lower Stonehill unit demonstrated that bitterbrush stands of this species can successfully be treated with fire. A high soil moisture content at the time of the spring burn plus a low fire intensity seemed to contribute to good resprouting of the mature plants. An estimated 75% of the bitterbrush plants resprouted following burning.

Retention (or lack thereof) of needles on conifer slash is critical to achieving fire intensity, and fire intensity is directly related to achievement of desired objectives. It was much easier to generate the fire intensities needed to meet objectives where the pine and fir needles had dried but not fallen off the limbs. Treatments on the Ural-Tweed bighorn sheep range as well as elsewhere on the Rexford Ranger District of the Kootenai National Forest have demonstrated that Douglas-fir will retain a majority of its needles for a maximum of 1 year after slashing and ponderosa pine and lodgepole pine will retain needles for up to 3 years. In one case in heavy lodgepole pine slash on a BPA treatment unit, green needles were still present near the ground after 1 year. Because of the difference in needle retention, units with predominately Douglas-fir slash were much more critical for scheduling and accomplishing the prescribed burn than those units with ponderosa pine or lodgepole pine.

Needle retention is also directly related to the visual effects of prescribed burning. Since all of the treatment units are visible from Koocanusa Reservoir and a major highway, visual effects were important. Standing dead conifers with "red" needles are visually objectionable to much of the public, but it is a short-term impact since the needles drop over a 1-3 year period.

In both the BPA and USFS projects, fuel loadings created by slash were directly related to the ability to achieve a desired level of conifer mortality. This was true for all size classes of trees. On treatments where an objective was to remove sapling and pole sized conifers (13-26 cm dbh), it was generally necessary to slash most of those trees to achieve the desired results. Where the intermediate sized trees were common, the fire intensity created by slash from timber harvest or smaller conifers was not adequate to achieve the desired mortality levels.

Large ponderosa pine on the South Sheep Creek unit that were stressed by a late spring burn were observed to become more susceptible to attack by mountain pine beetle (Dendroctonus ponderosae) and western pine beetle (Dendroctonus brevicomus). These trees were stressed immediately prior to the major flight of the pine beetles. The objective of the slashing and prescribed burn treatment was to kill 20-30% of the mature overstory and that was the initial result. However, after the infestation by the pine beetles, the mortality increased to 50-60%. The total mortality was significantly increased over that caused by the prescribed burning alone and the secondary (indirect) effects need to be considered in defining future treatment objectives.

Use of timber harvesting to achieve wildlife objectives increased public acceptance of the project because the local economy is based on forest products. Social and political support is needed for the long term habitat management of the Ural-Tweed bighorn sheep range. Another benefit from using timber harvesting was that the sale generated additional funding through the Knutson-Vandenburn Act of 1930. The Knutson-Vandenburg funds were used to accomplish the follow-up slashing and burning phases to complete the total treatment.

To summarize, the BPA and USFS projects have demonstrated a variety of treatments successfully used to manage the vegetation over a large proportion of the Ural-Tweed bighorn sheep range. Gathering of quantitative data on the vegetative and animal response to the treatments is ongoing and will be reported at a later date.

LITERATURE CITED

Andrews, P. A. 1986. BEHAVE: fire behavior prediction and fuel modeling system--BURN subsystem, Part 1. General Technical Report INT-194. Ogden, UT: U.S. Dept. of Ag., Forest Service, Intermountain Research Station. 130 pp.

Brink, B. W. 1941. Summary report of the Ural-Tweed sheep project, October 15, 1940-June 15, 1941. U.S.D.A., Forest Service Rept. 33 pp.

Brown, G. W. 1979. Ural-Tweed bighorn sheep investigation, October 1, 1976-May 31, 1979. Montana Dept. Fish, Wildl. and Parks, Wildl. Manage. Div., Project Completion Rept., in cooperation with U.S. Army Corps of Engineers. Contract No. DACW67-76-C-0083. 94 pp.

Couey, F. M. 1950. Rocky mountain bighorn sheep in Montana. Montana Dept. Fish and Game, Bull. No. 2. Helena. 90 pp.

Ensign, W. W. 1937. Winter game study of Warland District, 1936-1937, with detailed study of the Ural-Tweed band of mountain sheep. U.S.D.A., Forest Service, Rept. 21 pp.

Hitchcock, C. L., and A. Cronquist. 1973. Flora of the Pacific Nortwest. University of Washington Press. Seattle, WA. 730 pp.

Noste, N. V., and C. L. Bushey. 1987. Fire response of shrubs of dry forest habitat types in Montana and Idaho. Gen. Tech. Rep. INT-239. Ogden, UT: U. S. Dept. of Ag., Forest Service, Intermountain Research Station. 22 pp.

Geist, V. 1971. Mountain sheep-a study in behavior and evolution. Univ. Chicago Press, Chigago, IL. 383 pp.

Risenhoover, K. L., and J. A. Bailey. 1985. Foraging ecology of mountain sheep: implications for habitat management. J. Wildl. Manage. 49(3):797-804.

Shannon, N. H., R. J. Hudson, V. C. Brink, and W. D. Kitts. 1975. Determinants of spatial distribution of Rocky Mountain bighorn sheep. J. Wildl. Manage. 39:387-401.

Smith, D. R. 1954. The bighorn sheep in Idaho, its status, life history, and management. Idaho Dept. Fish and Game, Wildl. Bull. No. 1, Boise, ID. 154 pp.

Yde, C., B. Summerfield, and L. Young. 1986. Ural-Tweed bighorn sheep-wildlife mitigation project-annual report. U.S. Department of Energy, Bonneville Power Administration Project No. 84-38 and 84-39. 35 pp. & appendices.

Yde, C. A., and A. Olsen. 1984. Wildlife impact assessment and summary of previous mitigation related to hydroelectric projects in Montana, Vol. One-Libby Dam. Montana Dept. Fish, Wildl. and Parks Rept. in cooperation with Bonneville Power Administration, Proj. No. 83-464. Helena, MT. 91 pp. & appendices.

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and Goat Council 6: 240 - 253

SEASONAL FOOD HABITS OF A POPULATION OF BIGHORN SHEEP IN NORTHWESTERN MONTANA AS DETERMINED BY MICROHISTOLOGIC EXAMINATION OF FECAL MATERIAL

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Abstract: Food habits of Rocky Mountain bighorn sheep (*Ovis c. canadensis*) inhabiting a heavily timbered range in northwestern Montana were studied in 1978 and 1986 using microhistologic examination of fecal material. Monthly and seasonal trends in utilization of major forage groups were very similar between years. Sheep diets consisted of graminoids (66%), browse (27%) and forbs (7%) on an annual basis. Three major grasses, rough fescue (*Festuca scabrella*), Idaho fescue (*Festuca idahoensis*) and bluebunch wheatgrass (*Agropyron spicatum*) in decreasing order of importance accounted for 51% of the annual diet.

Bighorn sheep utilize a wide variety of forage species throughout their distribution in North America (Todd 1972). On a smaller geographic scale, Rocky Mountain bighorn sheep within Montana demonstrate notable differences in annual and seasonal food habits (Constan 1972, Frisina 1974, Stewart 1975, Tilton 1977, Brown 1979), generally reflective of diverse habitats ranging from relatively dry grassland types in south-central portions of the state to more mesic timbered ranges in north-western Montana. Extrapolation of food habits data from one region to another or between seasons in the same area may be misleading and inappropriate for developing site specific environmental impact statements or habitat management plans (Cooperrider et al. 1980).

The Ural-Tweed population of bighorn sheep is the only native herd remaining in northwestern Montana. Their present distribution is a long, narrow band of steep, heavily timbered terrain along the east shore of Lake Koocanusa between Libby and Eureka, Montana. Inundation of the Libby Reservoir impoundment area in conjuntion with fire suppression over the past 50 years has greatly reduced available habitat for this herd. Ponderosa pine (*Pinus ponderosa*)/bunchgrass disclimax communities, previously maintained by natural fires, are gradually being replaced by densely stocked stands of Douglas-fir (*Pseudotsuga menziesii*).

Wildlife mitigation associated with the Libby Dam project has provided an opportunity to study the ecology of these sheep with an overall objective of developing habitat and population management plans. One aspect of these investigations, summarized here, was to analyze sheep food habits as they relate to habitat enhancement projects.

The U.S. Army, Corps of Engineers, and Bonneville Power Administration provided funding for the 1978 and 1986 projects, respectively.

METHODS

Food habits data were collected and analyzed for 1978 and 1986. Fecal pellet groups from 240 bighorn sheep were collected at a rate of 20 per month for the period 1 January - 31 December 1978. Only known sheep pellet groups were collected. Monthly composited samples consisted of 2 randomly-selected pellets from each of the 20 pellet groups collected for that month. Composited samples were submitted to the Composition Analysis Laboratory, Colorado State University, Fort Collins, Colorado for determination and quantification of plant fragments through identification of plant epidermal tissue (Sparks and Malechek 1968). For each composited sample, 10 microscope slides were prepared; 20 fields per slide (= 200 fields, were examined at 100X under a binocular microscope to determine relative densities of plant residues. A reference list of plants common on the study area was sent to the Composition Analysis Laboratory to assist in identification of plant fragments to the species level.

Fecal sample collections for the study period 1 January - 31 December 1986 range from 4-26 pellet groups per month with the exception of March when no samples were obtained. A total of 149 pellet groups was collected from known sheep defecations. Monthly composited samples consisted of 5 randomly-selected pellets from each pellet group collected for a given month. Samples for 1986 were sent to the Wildlife Habitat Management Laboratory, Washington State University, Pullman, Washington, for analysis. Three hundred microscope fields at 100X were examined for each monthly composite sample. Research by Todd and Hansen (1973) and Dearden et al. (1975) suggests that the microhistological technique is a valid, reliable and economical method for determining ungulate food habits.

RESULTS AND DISCUSSION

Percent occurrence of individual plant species in the diet of Ural-Tweed bighorn sheep by month, season and year is shown in Tables 1 and 2. Forage species utilized by these sheep were grouped into conventional categories; graminoids (grasses and grass-like plants), browse (woody shrubs and trees), and forbs (herbaceous annuals). For convenience, mosses and lichens were included with forbs. Monthly trends in utilization of these 3 major forage classes were remarkably similar for 1978 and 1986 (Fig. 1). In both years browse consumption increased and grass use declined sharply in February and again in mid-summer (Figs. 2 and 3). The mid-summer inverse relationships between browse and grass consumption was slightly out of phase between the 2 years in that it occurred in July of 1978 and 1 month later in 1986. Between year differences in phenological development of the forage species involved is the most probable explanation for this observation. The 1978 and 1986 data sets continued to demonstrate agreement between use of forage class by sheep on a seasonal basis. For both years, grass use peaked in autumn and reached lowest levels in summer. Browse consumption was lowest and highest for autumn and winter, respectively. Forbs in the diet gradually increased during spring, peaked in August and declined in autumn for both years in accordance with the annual growth and development of herbaceous forage

Table 1. Food habits of bighorn sheep from the Ural-Tweed sheep range based on microhistological examination of fecal samples, 1978.

Taxa	Percent of diet by month												By season				By Year
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	
Agropyron spicatum	7.8	2.3	2.7	5.4	3.5	--	--	3.9	6.0	9.0	9.6	9.7	4.3	3.0	4.0	9.4	5.2
Bouteloua gracilis	--	--	--	--	--	--	--	--	--	0.4	0.2	--	Tr	Tr	Tr	0.2	0.1
Bromus tectorum	1.1	0.2	0.3	0.2	0.6	1.1	0.3	1.4	2.1	1.6	0.2	--	0.5	0.6	1.3	0.6	0.8
Calamagrostis rubescens	0.3	--	--	--	--	--	--	--	--	--	--	--	0.1	Tr	Tr	Tr	Tr
Carex spp.	--	0.3	2.7	2.1	2.1	5.4	--	0.9	1.2	0.6	0.2	0.4	1.0	3.2	0.7	0.4	1.3
Danthonia spp.	--	0.5	0.6	--	--	1.3	--	--	0.7	0.6	--	--	0.4	0.4	0.2	0.2	0.3
Elymus glauca	--	--	--	--	0.2	--	--	--	--	--	--	--	Tr	0.1	Tr	Tr	Tr
Festuca idahoensis	7.7	10.7	17.6	12.7	3.4	4.5	10.0	9.9	13.7	13.5	13.7	12.7	12.0	6.9	11.2	13.3	10.8
Festuca scabrella	69.1	25.0	41.1	50.9	30.6	40.3	23.4	23.2	54.9	54.1	54.8	50.6	45.1	40.6	31.8	55.2	43.2
Koleria cristata	1.1	0.7	--	--	0.2	1.1	0.8	3.1	2.5	1.2	0.5	1.3	0.6	0.4	2.1	1.0	1.0
Oryzopsis asperifolia	0.5	--	0.2	--	--	0.6	0.3	--	0.2	--	--	--	0.2	0.2	0.2	Tr	0.2
Poa spp.	--	--	--	0.3	--	0.6	0.3	2.6	3.4	4.9	1.4	2.3	Tr	0.3	2.1	2.9	1.3
Sitanion hystrix	--	--	--	--	--	--	--	0.2	--	--	--	--	Tr	Tr	0.1	Tr	Tr
Stipa richardsonii	0.5	--	0.2	--	0.2	--	--	0.2	--	0.8	0.2	--	0.2	0.1	0.1	0.3	0.2
Graminoids Total	88.1	39.7	65.4	71.6	40.8	54.9	35.1	47.4	84.7	86.7	80.8	77.0	64.4	55.8	55.7	81.5	64.4
Amelanchier alnifolia	4.0	5.9	3.7	8.6	36.4	4.0	3.9	--	--	--	--	--	4.5	16.3	1.3	Tr	5.5
Artemisia frigida	--	--	--	0.2	--	--	--	--	--	--	--	--	Tr	0.1	Tr	Tr	Tr
Atriplex spp.	--	--	1.0	--	--	--	--	--	--	--	--	--	0.3	Tr	Tr	Tr	0.1
Berberis repens	1.4	0.3	4.0	--	--	--	1.1	--	0.2	2.4	3.3	3.4	1.9	Tr	0.4	3.0	1.3
Ceanothus sanguineus	--	--	--	--	--	--	--	--	0.8	1.0	--	--	Tr	Tr	0.3	0.3	0.2
Ceanothus velutinus	--	--	--	--	--	--	--	--	--	--	10.3	14.0	Tr	Tr	Tr	8.1	2.0
Chrysothamnus viscidiflorus	--	--	--	--	--	--	--	0.5	0.3	--	--	--	Tr	Tr	0.3	Tr	0.1
Cornus stolonifera	--	--	--	--	--	--	--	--	--	--	0.2	--	Tr	Tr	Tr	0.1	Tr
Holodiscus discolor	1.7	5.7	5.4	--	0.9	11.5	18.2	0.2	--	--	--	--	4.3	4.1	6.1	Tr	3.6
Pachistima myrsinites	--	0.2	0.8	--	--	--	0.3	--	--	0.2	--	--	0.3	Tr	0.1	0.1	0.1
Physocarpus malvaceous	--	--	0.2	0.5	0.9	12.1	23.4	1.4	--	0.4	0.4	--	0.1	4.5	8.3	0.3	3.3
Picea engelmannii	--	--	1.1	2.8	6.5	1.3	0.6	1.2	0.7	1.4	--	--	0.4	3.5	0.9	0.5	1.3
Pinus ponderosa	0.5	1.2	1.4	--	--	--	--	2.6	3.8	4.2	0.7	0.7	1.0	Tr	2.1	1.9	1.3
Potentilla gracilis	--	--	--	--	--	--	--	7.0	1.4	--	--	0.4	Tr	Tr	2.8	0.1	0.7
Prunus virginiana	0.3	--	--	--	--	--	--	--	--	--	--	--	0.1	Tr	Tr	Tr	Tr
Pseudotsuga menziesii	3.5	37.7	13.6	3.8	3.5	3.1	--	--	--	0.8	3.7	1.9	18.3	3.5	Tr	2.1	6.0

Table 1. (Continued).

Taxa	Percent of diet by month												By season				By Year
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	
Purshia tridentata	0.3	4.7	0.2	--	--	2.8	2.2	--	--	--	--	--	1.7	0.9	0.7	Tr	0.9
Rosa spp.	--	--	--	--	--	--	--	2.1	--	--	--	--	Tr	Tr	0.7	Tr	0.2
Rubus spp.	--	--	--	--	--	--	--	--	0.8	0.2	0.4	0.2	Tr	Tr	0.3	0.3	0.1
Salix spp.	--	--	--	--	--	--	--	5.7	0.3	0.4	0.7	1.1	Tr	Tr	2.0	0.7	0.7
Shepherdia canadensis	0.2	--	--	1.1	8.5	1.2	4.2	0.7	--	--	--	--	0.1	3.6	1.6	Tr	1.3
Spirea betulifolia	--	--	--	--	--	4.2	--	--	--	--	--	--	Tr	1.4	Tr	Tr	0.4
Symphoricarpos albus	0.2	4.5	1.7	--	--	--	4.8	0.7	--	--	--	--	2.1	Tr	1.8	Tr	1.0
Vaccinium spp.	--	--	0.5	--	--	--	--	--	--	0.2	--	--	0.2	Tr	Tr	0.1	0.1
Browse Total	12.1	60.2	33.6	37.0	56.7	40.2	58.9	22.1	8.3	11.2	19.7	21.7	35.3	38.0	29.8	17.5	30.1
Astragalus spp.	--	--	--	--	--	--	--	0.2	--	--	--	--	Tr	Tr	0.1	Tr	Tr
Dryas spp.	--	--	1.4	0.3	--	--	--	--	--	--	--	--	0.5	0.1	Tr	Tr	0.1
Erigeron spp.	--	--	--	--	--	--	--	2.1	0.5	0.4	--	0.4	Tr	Tr	0.9	0.3	0.3
Geum triflorum	--	--	--	--	0.9	0.6	--	15.2	0.8	1.4	--	0.4	Tr	0.5	5.3	0.6	1.6
Gilia spp.	--	--	--	--	0.4	--	--	--	--	--	--	--	Tr	0.1	Tr	Tr	Tr
Lupinus sericeus	--	--	--	11.1	--	1.9	1.1	12.7	5.6	0.2	--	--	Tr	4.3	6.5	0.1	2.7
Oenothera spp.	--	--	--	--	0.4	--	--	--	--	--	--	--	Tr	0.1	Tr	Tr	Tr
Phlox spp.	--	--	--	--	--	0.6	--	--	--	0.6	--	0.4	Tr	0.2	Tr	0.3	0.1
Viola spp.	--	--	--	--	0.2	--	--	--	--	--	--	--	Tr	0.1	Tr	Tr	Tr
Unknown forbs	0.2	0.2	0.2	--	0.6	1.3	4.8	--	0.2	--	--	--	0.2	0.6	1.7	Tr	0.6
Lichens	0.2	--	--	--	--	--	--	--	--	--	--	--	0.1	Tr	Tr	Tr	Tr
Forbs & Bryophytes Total	0.4	0.2	1.6	11.4	2.5	4.4	5.9	30.2	7.1	2.6	--	1.2	0.7	6.1	14.4	1.3	5.6

Table 2. Food habits of bighorn sheep from the Ural-Tweed sheep range based on microhistological examination of fecal samples, 1986.

Taxa	Percent of diet by month												By season				By Year
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	
Agropyron spicatum	10.9	5.7	--	4.4	5.2	6.0	13.6	1.8	12.0	18.3	5.0	14.4	8.3	5.2	9.1	12.6	8.8
Agrostis interrupta	--	--	--	1.7	1.9	--	--	--	1.0	--	--	--	Tr	1.2	0.3	Tr	0.4
Bromus inermis	0.7	1.4	--	1.5	--	0.4	--	--	--	0.2	--	--	1.1	0.6	Tr	0.1	0.4
Bromus tectorum	0.8	1.4	--	0.9	0.8	1.7	0.9	--	0.8	0.3	--	0.8	1.1	1.1	0.6	0.4	0.8
Calamagrostis rubescens	5.5	4.5	--	8.2	13.0	2.3	10.2	8.9	4.3	4.4	3.5	9.8	5.0	7.8	7.1	5.9	6.6
Carex spp.	--	0.6	--	1.3	4.9	5.2	Tr	2.0	3.8	1.8	1.4	Tr	0.3	3.8	2.5	1.1	2.1
Dactylis glomerata	--	--	--	0.6	0.3	--	--	--	--	--	--	--	Tr	0.3	Tr	Tr	0.1
Danthonia spp.	--	--	--	3.9	0.3	2.3	--	--	1.6	3.2	1.8	4.4	Tr	2.2	0.5	3.1	1.6
Elymus glaucus	--	--	--	--	0.5	--	--	--	--	--	0.5	16.7	Tr	0.2	Tr	5.7	1.6
Festuca idahoensis	12.5	9.4	--	11.7	13.0	7.7	20.4	11.1	6.4	16.4	8.2	17.6	11.0	10.8	12.6	14.1	12.2
Festuca scabrella	39.8	29.4	--	20.7	7.5	17.4	18.0	8.3	23.4	18.4	31.8	7.2	34.6	15.2	16.6	19.1	20.2
Koeleria cristata	2.4	1.2	--	1.6	1.1	1.8	1.2	2.6	2.3	2.8	3.2	--	1.8	1.5	2.0	2.0	1.8
Oryzopsis asperifolia	--	--	--	--	2.1	2.0	--	--	--	--	--	--	Tr	1.4	Tr	Tr	0.4
Phleum pratense	--	--	--	1.8	2.2	--	--	--	--	7.4	0.8	9.4	Tr	1.3	Tr	5.9	2.0
Poa spp.	2.4	2.3	--	14.3	14.0	10.5	5.5	3.8	8.3	--	8.9	--	2.4	12.9	5.9	3.0	6.4
Sitanion hystrix	--	--	--	--	--	--	--	--	--	--	--	3.8	Tr	Tr	Tr	1.3	0.3
Stipa richardsonii	0.5	0.6	--	5.1	3.3	1.6	1.2	0.8	3.0	1.7	1.0	--	0.6	3.3	1.7	0.9	1.7
Graminoida Total	75.5	56.5	--	77.7	70.1	58.9	71.0	37.3	68.7	74.9	66.1	84.1	66.0	66.9	59.0	75.0	67.3
Amelanchier alnifolia	1.8	15.6	--	0.5	1.0	1.0	--	0.5	0.7	--	3.8	2.6	8.7	0.8	0.4	2.1	2.5
Arctostaphylos uva-ursi	--	--	--	--	1.4	0.7	--	--	--	--	--	--	Tr	0.7	Tr	Tr	0.2
Berberis repens	4.0	1.7	--	--	--	--	--	1.5	0.9	2.0	4.7	2.3	2.9	Tr	0.8	3.1	1.6
Ceanothus sanguineus	0.2	2.0	--	--	--	--	2.3	0.4	9.4	0.3	--	1.7	1.1	Tr	4.0	0.7	1.5
Ceanothus velutinus	5.1	0.7	--	0.9	--	--	1.6	2.9	0.6	4.0	1.5	1.2	2.9	0.3	1.7	2.2	1.7
Holodiscus discolor	--	--	--	--	0.6	1.2	--	2.4	--	0.8	1.1	--	Tr	0.6	0.8	0.6	0.6
Linnaea borealis	--	--	--	--	--	--	--	--	--	--	1.0	--	Tr	Tr	Tr	0.3	0.1
Physocarpus malvaceus	--	--	--	2.1	0.8	5.2	1.8	24.4	0.5	--	--	--	Tr	2.7	8.9	Tr	3.2
Pinus contorta	--	0.3	--	--	--	--	--	--	--	--	0.2	--	0.2	Tr	Tr	0.1	Tr
Pinus ponderosa	0.1	0.2	--	--	0.7	--	--	--	0.7	4.7	--	1.2	0.2	0.2	0.2	2.0	0.7
Populus spp.	--	--	--	--	--	2.7	--	--	--	0.2	0.6	--	Tr	0.9	Tr	0.3	0.3
Prunus virginiana	0.2	5.5	--	--	--	--	--	0.4	--	--	0.3	0.6	2.9	Tr	0.1	0.3	0.6
Pseudotsuga menziesii	7.1	3.2	--	2.2	0.6	1.5	--	0.6	1.5	5.0	3.4	1.7	5.2	1.4	0.7	3.4	2.4

Table 2. (Continued).

Taxa	Percent of diet by month												By season				By Year
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	
Purshia tridentata	--	--	--	--	--	--	--	--	--	--	0.3	0.6	Tr	Tr	Tr	0.3	0.1
Rosa spp.	1.5	6.4	--	0.8	10.4	--	0.8	2.7	2.5	0.5	4.5	0.7	4.0	3.7	2.0	1.9	2.8
Rubus spp.	--	0.6	--	1.6	0.8	1.0	--	--	--	--	--	--	0.3	1.1	Tr	Tr	0.4
Salix spp.	0.8	1.5	--	1.2	--	1.6	0.2	0.9	0.3	--	0.5	0.3	1.2	0.9	0.5	0.3	0.7
Shepherdia canadensis	0.3	0.8	--	2.5	1.2	7.3	4.9	6.7	0.3	--	0.5	1.1	0.6	3.7	4.8	0.5	2.3
Spirea betulifolia	0.4	1.4	--	1.3	--	0.9	--	--	--	--	--	--	0.9	0.7	Tr	Tr	0.4
Symphoricarpos albus	--	0.2	--	--	--	--	2.5	1.1	--	0.6	0.9	0.7	0.1	Tr	1.2	0.7	0.5
Thuja plicata	--	--	--	--	--	--	--	--	--	--	1.1	--	Tr	Tr	Tr	0.4	0.1
Tsuga heterophylla	--	--	--	--	--	--	--	--	--	--	4.3	--	Tr	Tr	Tr	1.4	0.4
Vaccinium spp.	0.3	0.4	--	--	--	1.1	--	--	--	0.6	--	--	0.4	0.4	Tr	0.2	0.2
Browse Total	21.8	40.5	--	13.1	17.5	24.2	34.1	44.5	17.4	18.7	28.7	14.9	31.2	18.3	25.3	20.8	23.2
Achillea millefolium	--	--	--	--	0.6	2.8	2.5	0.4	0.7	--	--	--	Tr	1.1	1.2	Tr	0.6
Allium cernuum	--	--	--	--	--	--	--	--	0.7	--	--	--	Tr	Tr	0.2	Tr	0.1
Antennaria spp.	--	--	--	0.3	1.1	--	--	--	--	--	--	--	Tr	0.5	Tr	Tr	0.1
Arnica cordifolia	--	--	--	--	1.2	0.1	0.7	1.1	1.6	--	--	--	Tr	0.4	1.1	Tr	0.4
Arenaria spp.	--	--	--	--	--	--	--	--	0.5	--	--	--	Tr	Tr	0.2	Tr	Tr
Aster spp.	--	--	--	0.2	0.3	0.4	--	3.4	0.3	--	--	--	Tr	0.3	1.2	Tr	0.4
Balsamorhiza sagittata	--	--	--	--	--	1.0	--	--	0.2	--	--	--	Tr	0.3	0.1	Tr	0.1
Campanula rotundifolia	--	--	--	0.2	--	--	--	--	--	--	--	--	Tr	0.1	Tr	Tr	Tr
Cerastium spp.	--	--	--	0.2	--	--	--	--	0.2	--	--	--	Tr	0.1	0.1	Tr	Tr
Cornus canadensis	--	--	--	--	--	1.3	--	--	--	0.5	--	--	Tr	0.4	Tr	0.2	0.2
Erigeron spp.	--	--	--	--	--	--	0.6	0.8	--	--	--	--	Tr	Tr	0.5	Tr	0.1
Eriogonum spp.	--	--	--	--	--	0.3	--	--	--	--	--	--	Tr	0.1	Tr	Tr	Tr
Fragaria spp.	--	--	--	--	--	--	--	1.7	0.2	--	0.2	--	Tr	Tr	0.6	0.1	0.2
Galium boreale	--	--	--	--	0.7	--	--	0.4	--	--	--	--	Tr	0.2	0.1	Tr	0.1
Geranium spp.	--	--	--	--	--	--	--	0.3	--	--	--	--	Tr	Tr	0.1	Tr	Tr
Geum triflorum	--	0.6	--	--	--	--	3.4	1.4	0.6	--	--	--	0.3	Tr	1.8	Tr	0.5
Heuchera cylindrica	--	--	--	0.5	0.9	--	--	--	--	--	--	--	Tr	0.5	Tr	Tr	0.1
Hieracium spp.	--	0.1	--	--	0.1	0.4	0.2	2.1	0.2	--	0.2	--	0.1	0.2	0.8	0.1	0.3
Lupinus sericeus	--	--	--	--	0.3	1.4	1.4	1.1	--	--	--	--	Tr	0.6	0.8	Tr	0.4
Penstemon spp.	--	--	--	0.9	--	--	0.8	--	--	--	--	--	Tr	0.3	0.3	Tr	0.2

Table 2. (Continued).

Taxa	Percent of diet by month												By season				By Year
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	
Phlox spp.	--	--	--	0.5	--	1.6	--	--	--	--	--	--	Tr	0.7	Tr	Tr	0.2
Potentilla spp.	--	--	--	--	0.5	--	0.8	0.5	0.9	--	--	--	Tr	0.2	0.7	Tr	0.2
Pteridium aquilinum	--	--	--	--	--	0.7	--	--	--	--	--	--	Tr	0.2	Tr	Tr	0.1
Pyrola spp.	--	--	--	0.8	0.3	--	--	--	0.3	--	0.9	--	Tr	0.4	0.1	0.3	0.2
Sedum lanceolata	0.2	--	--	--	--	--	--	--	--	--	--	--	0.1	Tr	Tr	Tr	Tr
Smilacena stellata	--	--	--	1.2	0.3	0.3	--	--	1.9	--	--	--	Tr	0.6	0.6	Tr	0.3
Taraxacum officinale	--	--	--	0.2	--	2.4	0.6	0.8	0.7	--	--	--	Tr	0.9	0.7	Tr	0.4
Thalictrum spp.	--	--	--	0.2	--	0.8	--	--	--	--	--	--	Tr	0.3	Tr	Tr	0.1
Trifolium spp.	--	--	--	--	3.4	2.0	--	--	--	--	--	--	Tr	1.8	Tr	Tr	0.5
Vicia americana	--	--	--	--	--	--	1.1	0.6	0.2	--	--	--	Tr	Tr	0.6	Tr	0.2
Viola spp.	--	--	--	1.0	--	--	--	--	--	--	--	--	Tr	0.3	Tr	Tr	0.1
Xerophylum tenax	--	--	--	--	--	--	--	--	1.1	--	--	--	Tr	Tr	0.4	Tr	0.1
Unknown forbs	--	--	--	1.2	1.2	1.4	0.2	0.6	0.2	0.2	--	--	Tr	1.3	0.3	0.1	0.5
Lichens	1.6	2.3	--	0.9	2.5	--	2.6	3.0	2.8	4.2	3.1	0.7	2.0	1.1	2.8	2.7	2.2
Mosses	0.9	--	--	0.9	--	--	--	--	0.6	0.8	0.8	0.3	0.5	0.3	0.2	0.6	0.4
Forbs & Bryophytes Total	2.7	3.0	--	9.2	13.4	16.9	14.9	18.2	13.9	5.7	5.2	1.0	2.9	13.2	15.7	4.0	9.5

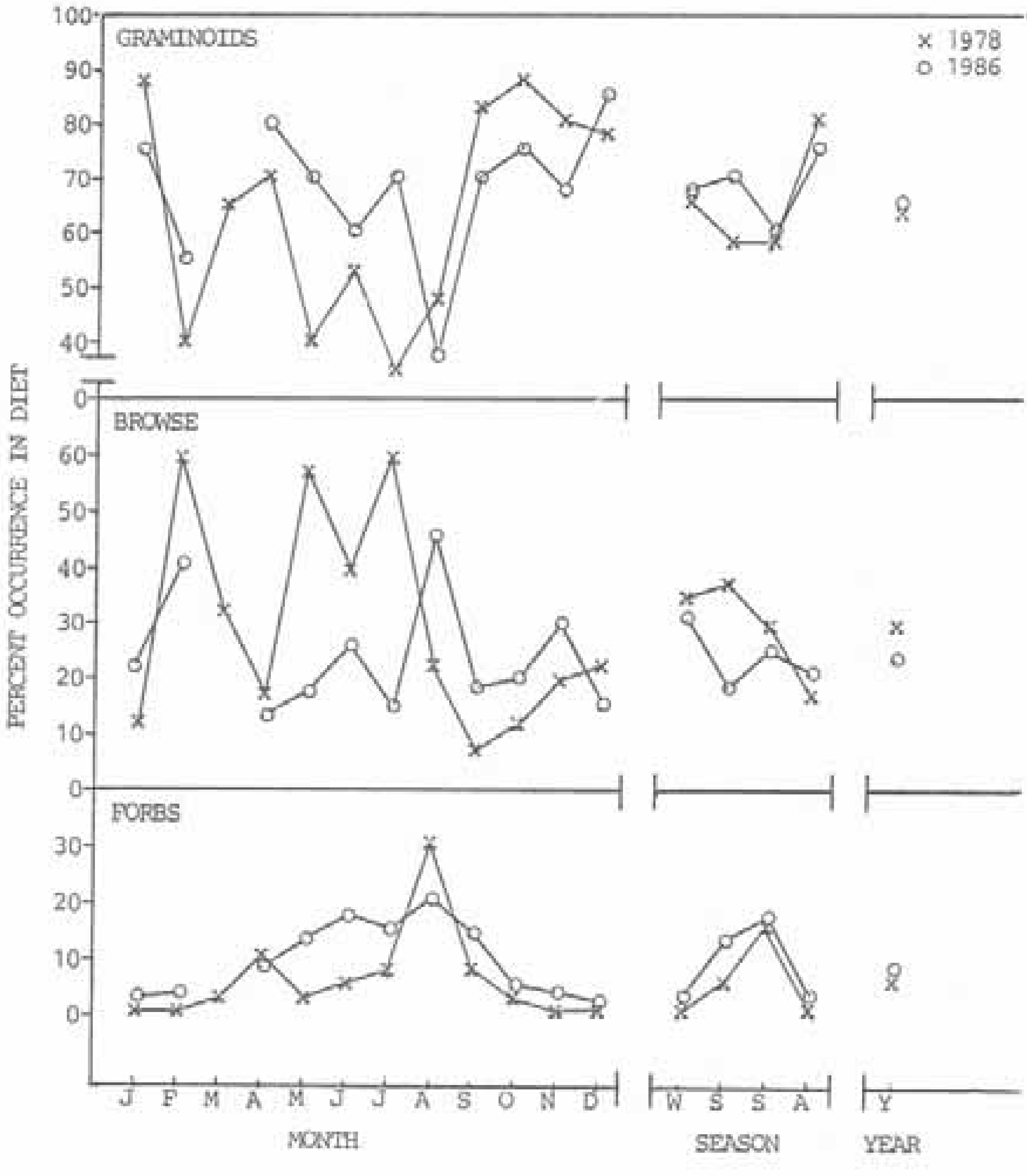

Figure 1.Use of graminoids, browse and forbs by bighorn sheep on the Ural-Tweed sheep range, northwestern Montana.

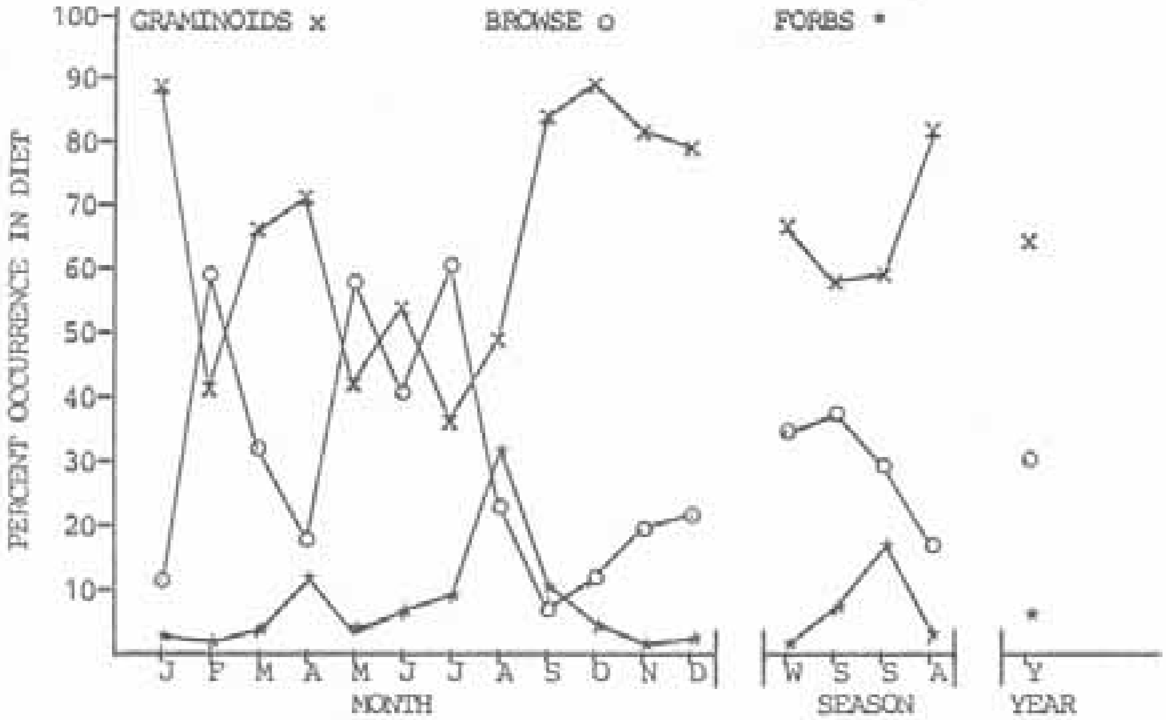

Figure 2.Forage class use by bighorn sheep on the Ural-Tweed range, 1978

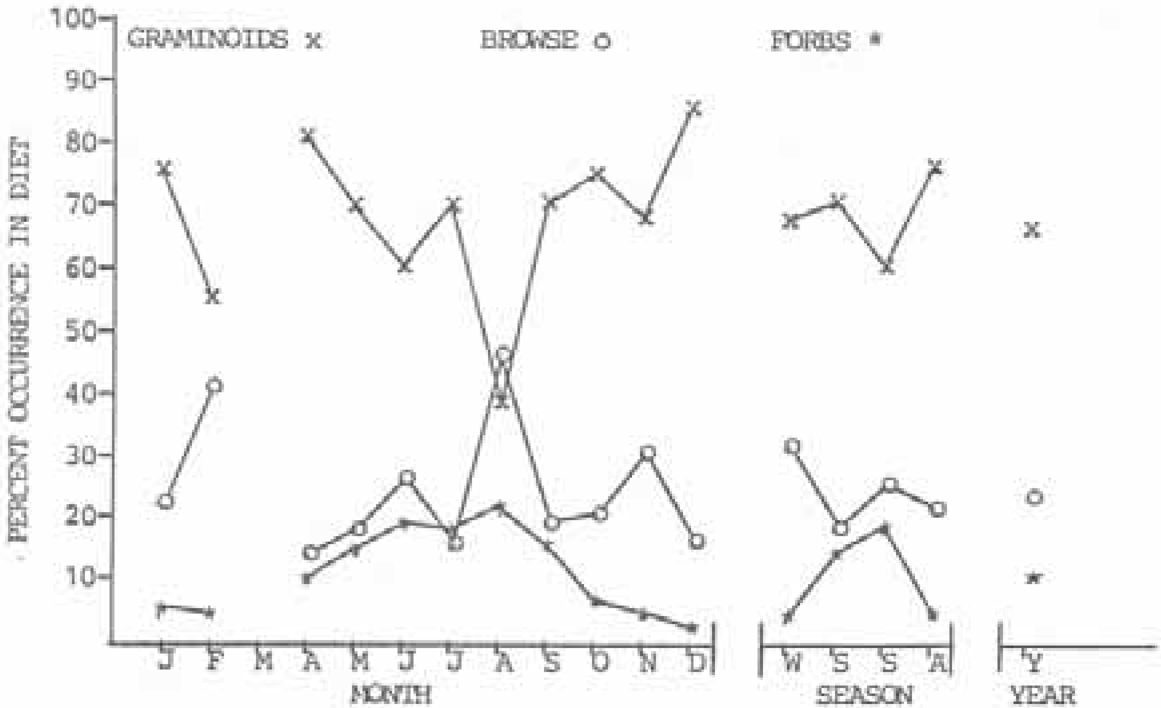

Figure 3.Forage class use by bighorn sheep on the Ural-Tweed range, 1986

species. Between year comparisons for annual usage of the three major forage groups also showed agreement in that diets consisted of graminoids, 64 and 67%, browse, 30 and 23%, and forbs, 6 and 10% for 1978 and 1986, respectively.

Overall similarities in patterns of forage use between years suggested that pooling of the 2 data sets was acceptable and would provide a generalized expression of food habits for Ural-Tweed sheep (Fig. 4). Using combined data, graminoids, browse and forbs contributed 66%, 27% and 7%, respectively, to the annual diets of bighorn sheep on this range. Seasonally, graminoids provided 65, 62, 57 and 78%; browse contributed 34, 28, 28, and 19%; and forbs supplied 1, 10, 15 and 3% to the diets of these sheep for winter, spring, summer and fall, respectively. Food habits studies from other bighorn sheep populations in Montana have shown winter diets consisting of graminoids, browse and forbs in the following ratios: 36, 43 and 21% for the Sun River herd (Frisina 1974); 38, 51 and 11% for the Thompson Falls herd (Tilton) 1977; 44, 30 and 27% for West Rosebud sheep (Steward 1975); 61, 22 and 17% for Yellowstone National Park sheep (Oldemeyer 1971); and 72, 8 and 17% for Gallatin Canyon sheep (Constan 1972). The proportions of grasses in the diets of Sun River sheep for spring (94%) and fall (92%) and for West Rosebud sheep for spring (80%), summer (61%) and fall (82%) were considerably higher and browse use much lower than that recorded on this study. On an annual basis, forbs contributed much more to the diets of Sun River sheep (21%) and West Rosebud sheep (22%) than for Ural-Tweed sheep (7%).

A preference index for individual forage species selected by sheep was not calculated because availability of these plants for grazing throughout the year was unknown. However, a relative ranking of important forage species was established through percent occurrence of those species in the monthly, seasonal and annual diet as well as their constancy in the diet - number of months a particular species occurred in the sample (Table 3). Each of three major grasses, rough fescue, Idaho fescue and bluebunch wheatgrass, in decreasing order of importance, occurred in the diets of these sheep every month of the year and collectively accounted for 51% of their annual forage intake. Five other grasses, each appearing in the samples 11 or 12 months of the year, and collectively contributing 9.6% to the annual diet of these sheep were bluegrasses (Poa spp.), pinegrass (Calamagrostis rubescens), Junegrass (Koleria cristata), needlegrass (Stipa richardsonii) and cheat grass (Bromus tectorum) in drecreasing rank order. Douglas-fir and serviceberry (Amelancheir alnifolia) individually appeared in fecal samples 11 months of the year and ranked fourth and fifth as important forage species for these sheep.

Microhistological analysis of fecal material showed rough fescue to be the single most important dietary component for bighorn sheep through all seasons of the year. Pitt and Wikeem (1978) identified rough fescue as the preferred forage species by sheep for spring and summer months on native rangeland in south-central British Columbia. Other investigators working with sheep in the Rocky Mountains have identified bluebunch wheatgrass as the primary grass species of importance to bighorn sheep (Demarchi 1967, Frisina 1974, Tilton 1977). Pitt and Wikeem (1978) suggest the high use of bluebunch wheatgrass may only reflect the abundance and availability of this forage on some ranges rather than an

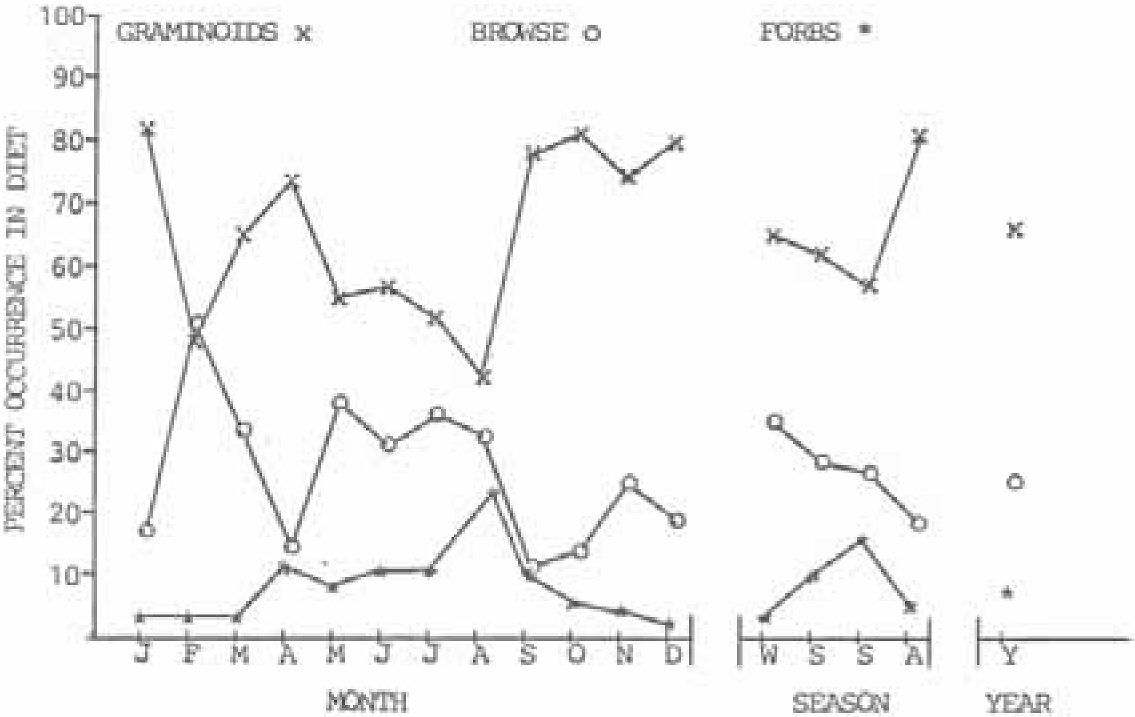

Figure 4.Bighorn sheep forage class utilization on the Ural-Tweed sheep range, 1978 and 1986 combined.

Table 3. Forage taxa of bighorn sheep with at least 1% seasonal or annual use (1978 and 1986 combined). Species are listed in descending order of use based on microhistological examination of fecal samples.

Taxa	1978 and 1986 Combined									
	Percent of diet by season				By year	Number of months in diet				Total
	Win	Spr	Sum	Aut		Win	Spr	Sum	Aut	
Festuca scabrella	40.9	27.9	25.2	36.2	32.5	3	3	3	3	12
Festuca idahoensis	12.6	8.8	11.9	13.7	11.8	3	3	3	3	12
Agropyron spicatum	5.4	4.1	6.6	11.0	6.7	3	3	3	3	12
Pseudotsuga menziesii	13.1	2.5	0.3	2.8	4.7	3	3	2	3	11
Amelanchier alnifolia	5.8	8.6	0.9	1.1	4.1	3	3	3	2	11
Poa spp.	0.8	6.6	4.0	2.9	3.6	2	3	3	3	11
Physocarpus malvaceous	0.1	3.6	8.6	0.1	3.1	1	3	3	2	9
Calamagrostis rubescens	1.7	3.9	3.6	3.0	3.0	2	3	3	3	11
Holodiscus discolor	3.0	2.4	3.5	0.3	2.3	3	2	2	2	9
Ceanothus velutinus	1.0	0.1	0.9	5.2	1.8	2	1	3	3	9
Shepherdia canadensis	0.2	3.6	2.8	0.3	1.7	2	3	3	2	10
Carex spp.	1.0	3.5	1.6	0.7	1.7	2	3	3	3	11
Berberis repens	2.6	—	0.6	3.1	1.6	3	0	3	3	9
Lupinus sericeus	—	2.4	3.7	Tr	1.5	0	3	3	1	7
Rosa spp.	1.3	1.9	1.4	1.0	1.4	2	2	3	3	10
Koleria cristata	0.9	1.0	2.1	1.5	1.4	2	3	3	3	11
Geum triflorum	0.1	0.2	3.8	0.3	1.1	1	2	3	2	8
Pinus ponderosa	0.8	0.1	1.2	1.9	1.0	3	1	2	3	9
Lichens	0.7	0.6	1.4	1.3	1.0	2	2	3	3	10
Danthonia spp.	0.3	1.3	0.4	1.7	0.9	2	3	1	3	9
Phleum pratense	—	0.7	—	2.9	0.9	0	2	0	3	5
Stipa richardsonii	0.3	1.7	0.9	0.6	0.9	3	3	3	2	11
Symphoricarpos albus	1.4	—	1.5	0.4	0.8	3	0	2	3	8
Ceanothus sanguineus	0.4	—	2.2	0.5	0.8	2	0	3	2	7
Elymus glauca	—	0.1	—	2.9	0.7	0	1	0	2	3
Bromus tectorum	0.7	0.9	0.9	0.5	0.7	3	3	3	3	12
Picea engelmannii	0.4	1.8	0.5	0.2	0.7	1	3	3	1	8
Salix spp.	0.4	0.5	1.2	0.5	0.6	2	2	3	3	10
Unknown forbs	0.1	1.0	1.0	Tr	0.5	3	3	3	1	10
Purshia tridentata	0.9	0.5	0.4	0.1	0.5	3	1	1	2	7
Potentilla gracilis	—	—	1.4	0.1	0.4	0	0	2	1	3
Spirea betulifolia	0.3	1.1	—	—	0.3	2	2	0	0	4
Prunus virginiana	1.0	—	0.1	0.1	0.3	2	0	1	2	5

actual preference for this species by sheep. Rough fescue is well recognized as a highly nutritious forage plant on western rangelands and should be emphasized along with Idaho fescue and bluebunch wheatgrass in habitat improvement projects on the Ural-Tweed sheep range.

Bighorn sheep on western Montana sheep ranges demonstrate a high incidence of browse in their diets compared to some sheep in other western states. Use of browse is particularly high during winter months. Schallenberger (1965) reported the winter diet of Sun River sheep consisted of 43% browse, 36% grass and 21% forbs, and suggested winter severity with above average snowpack may have been responsible for the high incidence of browse in the diet of these sheep. Tilton (1977) concluded that the scarcity of grassland on the winter range was responsible for high percentage of browse (51%) in the winter diet of sheep from Thompson Falls. This herd was exhibiting all the signs of a high quality expanding population during Tilton's study, suggesting that a high browse component in the diet was not necessarily a detriment to these sheep. The high incidence of Douglas-fir and other browse in the diet of Ural-Tweed sheep during February 1976 corresponded with peak snowpack and frozen crust conditions on the winter range, which probably explained the change from grasses to browse in the diet. Matthews (1973) found that browse was conspicuously lacking and severely overutilized on the Wildhorse Island sheep range, and concluded that this was the major factor limiting further growth of the sheep population. Availability of high quality browse contributes to a diverse forage base on sheep winter ranges in northwestern Montana and is an attribute to sheep populations in this area.

The occurrence of forbs in the diet of Ural-Tweed sheep was minimal in comparison to that recorded in other studies where they were found to be the preferred forage class during spring and summer months (Pitt and Wikeem 1978, Johnson and Smith 1980). There is no alpine habitat, and very few sub-alpine meadows exist on the Ural-Tweed sheep range. Much of the historic summer range is presently occupied by dense stands of lodgepole pine (Pinus contorta) resulting from fire suppression activities following large scale fires in the early 1900's. Lack of abundant forbs on the summer range of these sheep may prevent them from entering the fall in optimum condition. Summer range habitat enhancement projects should focus on improving the abundance and availability of palatable forb species.

LITERATURE CITED

Brown, G. W. 1974. Distribution and population characteristics of bighorn sheep near Thompson Falls in northwestern Montana. M. S. Thesis, Univ. of Montana, Missoula. 134 pp.

Brown, G. W. 1979. Ural-Tweed bighorn sheep investigation. Montana Dept. Fish and Game, Helena. Proj. Compl. Rpt. 93 pp.

Constan, K. J. 1972. Winter foods and range use of three species of ungulates. J. Wildl. Manage. 36:1068-1076.

Cooperrider, A. Y., S. A. McCollough and J. A. Bailey. 1980. Variation in bighorn sheep food habits as measured by fecal analysis. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:29-41.

Dearden, B. L., R. E. Pegau and R. M. Hansen. 1975. Precision of microhistological estimates of ruminant food habits. J. Wild. Manage. 39:402-407.

Demarchi, D. A. 1967. An ecological study of Rocky Mountain bighorn sheep winter ranges in the East Kootenai Region of British Columbia, British Columbia Fish and Wildl. Br., Victoria. Prog. Rpt. 51 pp.

Frisina, M. R. 1974. Ecology of bighorn sheep in the Sun River area. M. S. Thesis, Montana State Univ., Bozeman. 68 pp.

Johnson, B. K. and D. R. Smith. 1980. Food habits and forage preferences of bighorn sheep in alpine and subalpine communities. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:1-17.

Matthews, J. W. 1973. Ecology of bighorn sheep on Wildhorse Island Flathead Lake, Montana. M. S. Thesis, Univ. of Montana, Missoula. 88 pp.

Oldemeyer, J. C., W. J. Barmore and D. L. Gilbert. 1971. Winter ecology of bighorn sheep in Yellowstone National Park. J. Wildl. Manage. 35:257-269.

Pitt, M. D. and B. M. Wikeem. 1978. Diet preference of California bighorn sheep on native rangeland in south-central British Columbia. Bienn. Symp. North. Wild. Sheep and Goat Counc. 1:331-341.

Schallenberger, A. D. 1966. Food habits, range use and interspecific relationships of bighorn sheep in the Sun River area of west central Montana. M. S. Thesis, Montana State Univ., Bozeman. 44 pp.

Sparks, D. R. and J. C. Malechek. 1968. Estimating percentage dry weight in diets using a microscope technique. J. Range Manage. 21:264-265.

Stewart, S. T. 1975. Seasonal ecology of bighorn sheep in the Beartooth Mountains. M. S. Thesis, Montana State Univ., Bozeman. 130 pp.

Tilton, M. E. 1977. Habitat selection and use by bighorn sheep (*Ovis canadensis*) on a northwestern Montana winter range. M. S. Thesis, Univ. of Montana, Missoula. 121 pp.

Todd, J. W. 1972. A literature review on bighorn sheep food habits. Spec. Rpt. No. 27. Colorado Div. Wildl., Denver. 21 pp.

Todd, J. W. and R. M. Hansen. 1973. Plant fragments in the feces of bighorns as indicators of food habits. J. Wildl. Manage. 37:363-366.

Bienn. Symp. North. Wild Sheep
and Goat Council 6: 254 - 267

HOME RANGES, HABITAT USE AND PRODUCTIVITY OF BIGHORN SHEEP IN THE NEVER SUMMER MOUNTAINS, COLORADO

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Abstract: A study of distribution, movements, habitat use and productivity of bighorn sheep (*Ovis canadensis canadensis*) in the Never Summer Mountains of north-central Colorado was initiated in 1986. A concern was the continuing use of the herd for transplant stock despite lack of population data. Results from the first 2 field seasons indicated existence of 3 subpopulations in the west-side study area. These subpopulations shared a common mineral lick-lambing-nursery range. Habitat use, movement patterns and home ranges were determined for the south Never Summer subpopulation using radio telemetry. Home ranges were traditional. Plant phenology influenced habitat use. Bighorn preferred subalpine areas in late May and June, and moved to alpine ranges later in a wet than in dry summer. Sheep shifted habitat use from south and west aspects during early summer to north and east aspects in late summer. An extended lambing period (from late May through mid-July) was observed both years and maternal care of yearlings was noted in 1987. Population estimates for the west-side area have doubled since 1976 (120 to 240 bighorn). Observed production and recruitment indicated continued population growth.

Bighorn sheep were originally abundant in the Never Summer Mountains in what is now portions of Rocky Mountain National Park, the Arapaho and Routt National Forests, and the Colorado State Forest. Initial declines were caused by losses if low elevation winter ranges in Middle Park and restriction of bighorn to alpine winter ranges by 1920 (Goodson 1978, 1980). Further declines were attributed to competition with domestic sheep grazed in the Never Summer Range in the 1920's (Goodson 1978, 1980). A major die-off of bighorn was reported in the Never Summer Range from 1925 to 1930. The east slope of the Never Summer Range was included within Rocky Mountain National Park in 1930 and domestic sheep were excluded from the park; however, grazing continued on adjacent lands until the early 1970's. The initial die-off of bighorn was followed by continued decline through the 1960's.

In 1968, Harrington (1978) estimated the bighorn population of the Never Summer Mountains, Mt. Ida; and Specimen Mountain at 96 sheep, approximately 5% of original estimates, (Ratcliff 1941). During 1974-1976, Goodson (1978) reported an increase in abundance (to approximately 120 sheep), and an increasing trend. Trapping operations conducted by the Colorado Division of Wildlife from 1979 to 1984, on Baker Mountain at the southern end of the Never Summer Range, removed 52 bighorn from the population and provided sheep for reintroduction to vacant historical range in other areas. However, the trapping operations also initiated concern about potential effects on the Never Summer population. Earlier studies, (Goodson 1978 and Harrington 1978), documented range areas used by sheep and gross movement patterns. However, little was known about specific movements or interchange of sheep on winter range areas. A question arose as to what effect the transplants might have on the segment of the population wintering on Baker Mountain.

The effects of the transplanting program on the total population was also in question. The most recent survey of the herd (Goodson 1978) indicated a minimum population of 106 sheep. Although a ground census in 1982 tallied 215 sheep, this total was questionable. Bighorn were counted on Specimen Mountain the day after counts in the Never Summer Range and could have moved between these areas. An aerial count in 1984 found only 69 sheep. A ground count the same year tallied 73.

This study was designed to answer these questions and also provide basic information on the ecology and dynamics of the Never Summer population. Objectives are to determine:

1. Distribution and seasonal habitat use,
2. Distinct herd segments and their fidelity to seasonal ranges,
3. Migration routs and movement patterns of the Baker Mountain herd segment,
4. Sex-age structure and size of population segments.

Support for the study was provided by Rocky Mountain National Park. The Colorado Division of Wildlife cooperated in trapping bighorn and in the 1987 aerial census.

STUDY AREA

The study area was located within Rocky Mountain National Park and the adjacent Arapaho and Routt National Forests and Colorado State Forest. It encompassed the Never Summer Mountain Range from Cascade Mountain on the south to Iron Mountain on the north, and included the Colorado River valley and Specimen Mountain to the east (Fig. 1). Elevations range from 2746 m in the Colorado River valley to 3933 m on Mt. Richthofen. The mountains are formed of precambrian metamorphic shists and gneiss intruded by large masses of granite and pegmatite. Recent volcanic activity in the Lulu Mountain area altered the structure and resulted in an ash flow that formed Specimen Mountain. The present topography is rugged with many rock outcrops and talus slopes.

The vegetation of the study area represents the subalpine forest and the alpine tundra climax regions. The subalpine forest is characterized by an Engelmann spruce (Picea engelmanni)/Subalpine fir (Abies lasiocarpa) forest association interspersed with lodgepole pine (Pinus contorta), limber pine (Pinus flexilis), and aspen (Populus tremuloides) stands. Above 3230 to 3400 m is the alpine tundra, a complex mosaic of low growing plant associations.

Climate is mountain continental with sudden and extreme changes

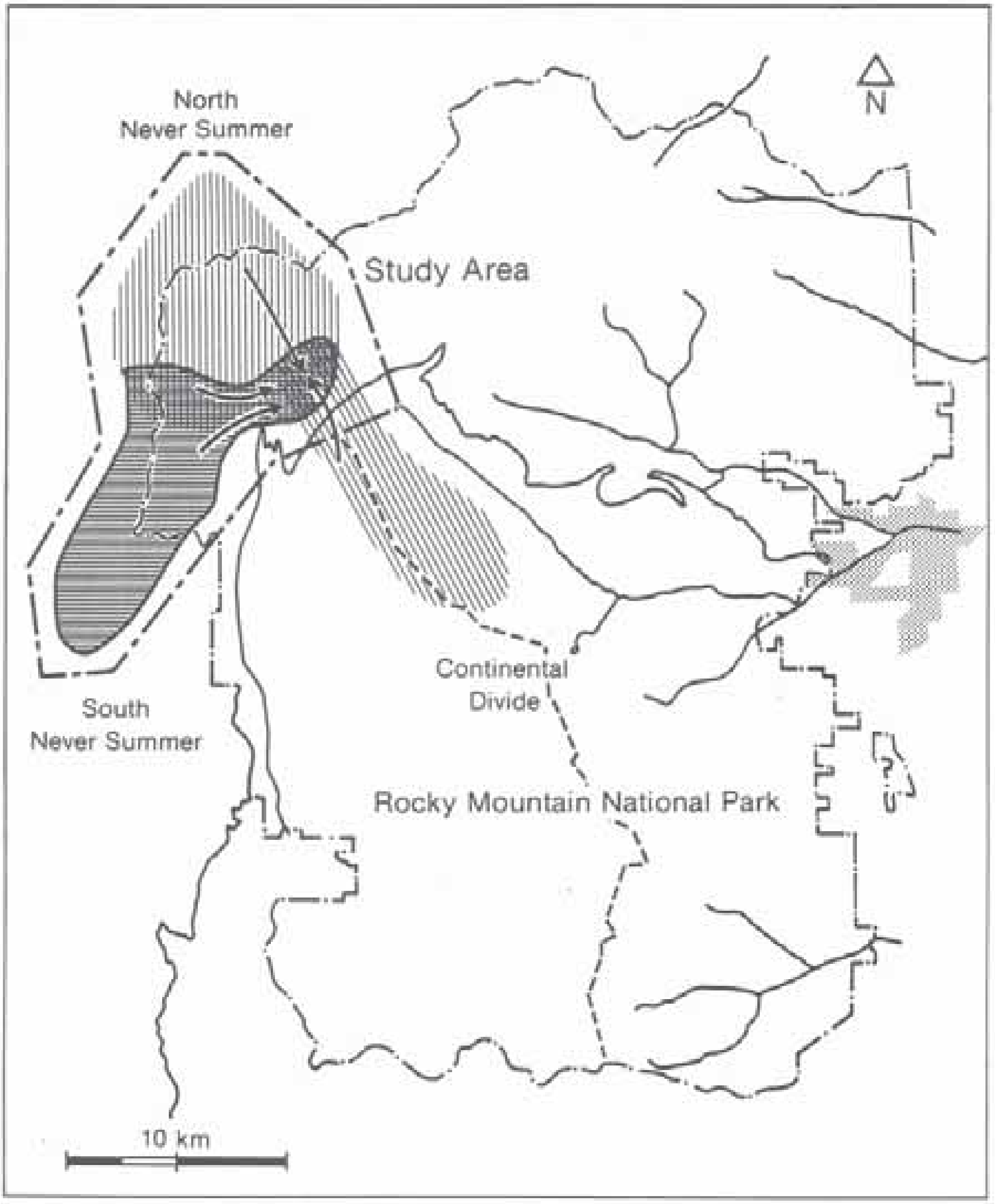

Figure 1. Location of the study area in relation to ranges of bighorn sheep subpopulations on the west side of Rocky Mountain National Park, Colorado.

possible in any season. Above tree line, the mean monthly temperature varies from -14 C in January to 8 C in July. Mean annual precipitation varies from 75 cm in the subalpine zone to 99 cm above tree line. The alpine ridges are generally cleared of snow by the prevailing westerly winds. In the subalpine zone, maximum snowdepths exceed 1.5 m in lee areas most winters.

METHODS

Eight bighorn, seven ewes and one yearling ram were captured and radio-collared in late March 1986. Two ewes (one adult and one yearling), were ear-tagged during the trapping operation. In addition, there were five ewes with old white collars and white eartags in the population in 1986. All of the marked bighorn were tagged on Baker Mountain in the southern part of the Never Summer Range.

During the two field seasons, May 28 to September 19, 1986, and May 20 to October 12, 1987, visual locations of individual radio-collared sheep were made 1.5 times per week on average. Numbers of observations of radio-collared individuals varied from 18 to 29 ($\bar{x}$=22) in 1986, and 21 to 32 ($\bar{x}$=27) in 1987. During each field day, radio signals of sheep which were not sighted were monitored if possible. The direction of the signal, its strength, and the indicated location of the sheep were recorded. During 1986, 279, and during 1987, 334 observations of bighorn groups, including those with and without radio-collared members, were recorded. For each of these observations the following data were recorded, if possible:

1. Identity of marked sheep
2. Location
3. Habitat
4. Behavior
5. Association or lack of association with a lamb or yearling
6. Sex-age classification of group
7. Weather
8. Movements

Aspect, slope, elevation and UTM coordinates of areas used by bighorn groups were estimated from locations mapped on U.S.G.S. 7.5 Minute topographic maps.

The population estimates for the west-side area, (including the north and south Never Summer and Continental Divide subpopulations) were based on coordinated ground counts in 1986 and 1987. In 1987 one helicopter flight by the Colorado Division of Wildlife coordinated with ground counts on Specimen Mountain provided a maximum count of west-side bighorn. A Lincoln Index was used to estimate the total number of ewes in the population. The number of lambs, yearlings, 2-year-olds, and adult rams (over 2 years of age) were estimated by ratios of members of these classes to adult ewes.

For the south Never Summer subpopulation an estimate of the total number of adult ewes utilized observations compiled for each of the four months. For each month, the number of adult ewes was estimated by a

Lincoln Index relating observations of marked non-radioed ewes to total observations of non-radioed ewes. The 7 radio-collared ewes were added to these estimates. The mean of the four monthly estimates was used. The numbers of bighorn in other age and sex categories were estimated by the ratios of members of those classes to adult ewes. However, for this subpopulation, adult rams were estimated by maximum counts per horn curl class.

RESULTS AND DISCUSSION

Distribution and Movements

Differences in weather patterns between the 1986 and 1987 field seasons influenced distribution and movement patterns of bighorn sheep. Snowdepths during the first winter, 1985-1986 were nearly twice normal in the study area. When field work began on May 28, 1986, much of the study area was covered by over 60 cm of snow, and all radio-collared bighorn were still on their winter range on Baker Mountain. Snowdepths during the second winter, 1986-1987, were about one-half normal and by May 20, 1987, when field work commenced, most of the study area was snow free. Four of the eight radio-collared bighorn crossed the Colorado River valley from their winter range on Baker and Bowen Mountains (where they were located in December and March) to Shipler Mountain before May 20, 1987.

The major lambing area in 1986 was Baker Mountain. Five of 6 radio-collared ewes which had lambs in 1986, lambed on Baker Mountain (Fig. 2). One radio-collared ewe lambed in July on Shipler Mountain. In 1987, Shipler Mountain was the major lambing area (Fig. 2). Two of three radio-collared ewes, that had lambs, lambed on Shipler Mountain. No observations of lambs were made on Baker Mountain or an adjacent tundra ridge during June 1987, while 72 observations of lambs were made on Shipler and Specimen Mountains during the same period. One marked ewe lambed on Baker Mountain in July. These data indicate that the Baker ewe-group has alternative lambing areas, use of which possibly depends on snow conditions. Other workers (Geist 1987), Shannon et al. 1975 and Seip 1983) have reported that snowdepth and hardness limit habitat use and movements of mountain sheep.

Summer 1986 was short, cool and wet with extensive snow cover continuing into July, and autumn snows began in late September. Summer 1987 was long, warm and dry with early snowmelt and pleasant weather continuing into October. The distribution of the radio-collared bighorns as a group was essentially the same in 1986 and 1987 (Fig. 2); however, individual sheep moved more and used more areas within the group range in 1987 than in 1986. In 1986, the typical pattern, followed by seven of eight radio-collared bighorn, was a single trip to the Shipler-Specimen area in June, or June and early July, followed by movement back to the Never Summer Mountains. In August and September, use was concentrated in the southern end of the range in the cirques south and north of Bowen Mountain. Only the three radio-collared ewes that lambed early were observed in the Crater of Specimen Mountain.

In 1987, movements were more extensive. Early use of Shipler and Specimen Mountains was followed by movement to the Never Summer Mountains,

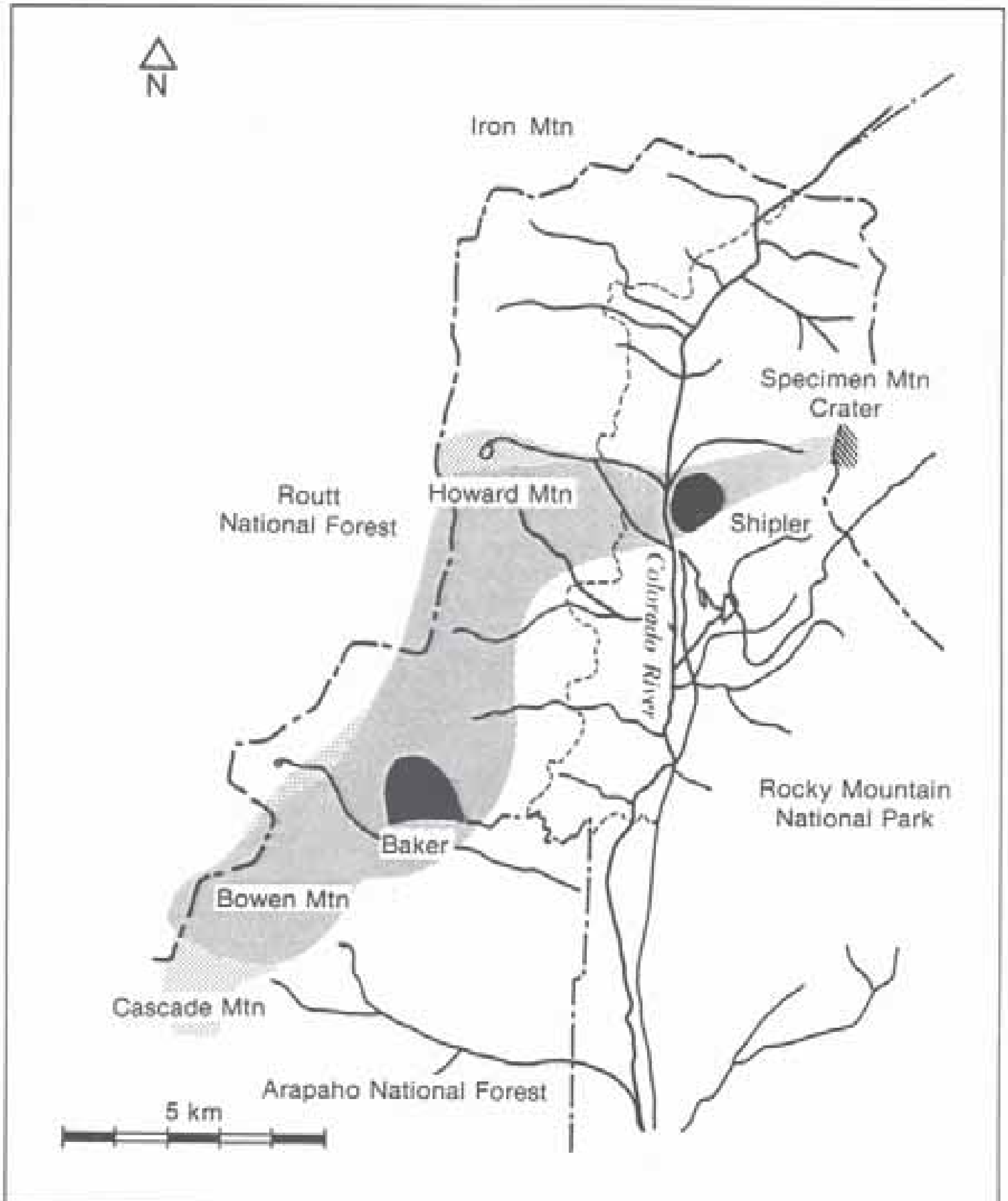

Figure 2. Home ranges of the south Never Summer ewe group during 1986 (medium shading), and 1987 (light shading), as indicated by radio-tracking 7 ewes. Dark shading indicates lambing areas on Baker and Shipler Mountains. Hatched area indicates the Crater of Specimen Mountain.

then return to Specimen and Shipler Mountains in August, and movement back to the Never Summer Mountains. In 1987, all radio-collared bighorn were observed in the Crater of Specimen Mountain during late May-June or June-early July. All but one radio-collared ewe used the Specimen-Shipler Mountain area again for a period in August. In September 1987, bighorn again concentrated use near Bowen Mountain.

Range Fidelity

Range Fidelity of radio-collared ewes was indicated by their use of the same distinct group range both field seasons (Fig. 2). In 1987, a radio-collared ewe was observed once on the mountain crest north of Howard Mountain. However, in 1987, as in 1986, no radio-collared ewes were observed further north on the Never Summer crest. These observations support the preliminary conclusion from 1986 data that the Baker ewe-group has a home range and movement pattern distinct from those of the north Never Summer and Continental Divide ewe-groups. Traditional use of seasonal ranges by bighorn ewe groups has also been observed by Geist (1971) and Festa-Bianchet (1986).

Several radio-collared ewes appear to have individual preferences for certain areas of the group range. Ewe #838 was the only radio-collared ewe which used Mineral Point (the east ridge of Bowen Mountain). She was there from June 10 to June 26, 1986 and from June 10 to July 1, 1987. In 1987, she lambed on Mineral Point. Ewe #863 was one of only two radio-collared ewes observed west of Bowen Mountain in 1986. In 1987, she was the only radio-collared ewe observed west of Bowen Mountain. She used a peak west of Bowen and Cascade Mountains extensively in August and September. Ewe #912 was observed on the steep west slope of Shipler Mountain more than any other marked ewe during both field seasons, and lambed there in 1987.

Seasonal Habitat Use

Bighorn moved through all vegetation types present on the study area, from riparian meadow and shrub types on the Colorado River through lodgepole pine and aspen association, to the spruce-fir forest and alpine tundra. The sheep foraged and rested below tree line in openings created by avalanche paths or associated with rockslides, boulderfields, or cliffs. Both above and below tree line use was restricted to areas close to steep and/or rock-covered escape terrain.

In 1986 and 1987, bighorn shifted use of aspects and elevations from early to late summer (Figs. 3 and 4). From late May through July 14, most observations of groups of bighorn including radio-collared sheep were on south, southwest or west aspects. From July 15 through September, use by bighorn shifted to north, northeast, east, and southeast aspects (Fig. 3). In 1986, groups including radio-collared bighorn used lower elevations more during June and July than during August and September (Fig. 4). In 1987, a warmer and drier year, bighorn moved to higher elevations earlier than in 1986 (Fig. 4). The mean elevation of observations was below tree-line during July in 1986, but was above treeline during July 1987 (Fig. 4). Shifts in use of elevations and aspect suggest plant phenology was an important factor in determining gross patterns of habitat use. Smith

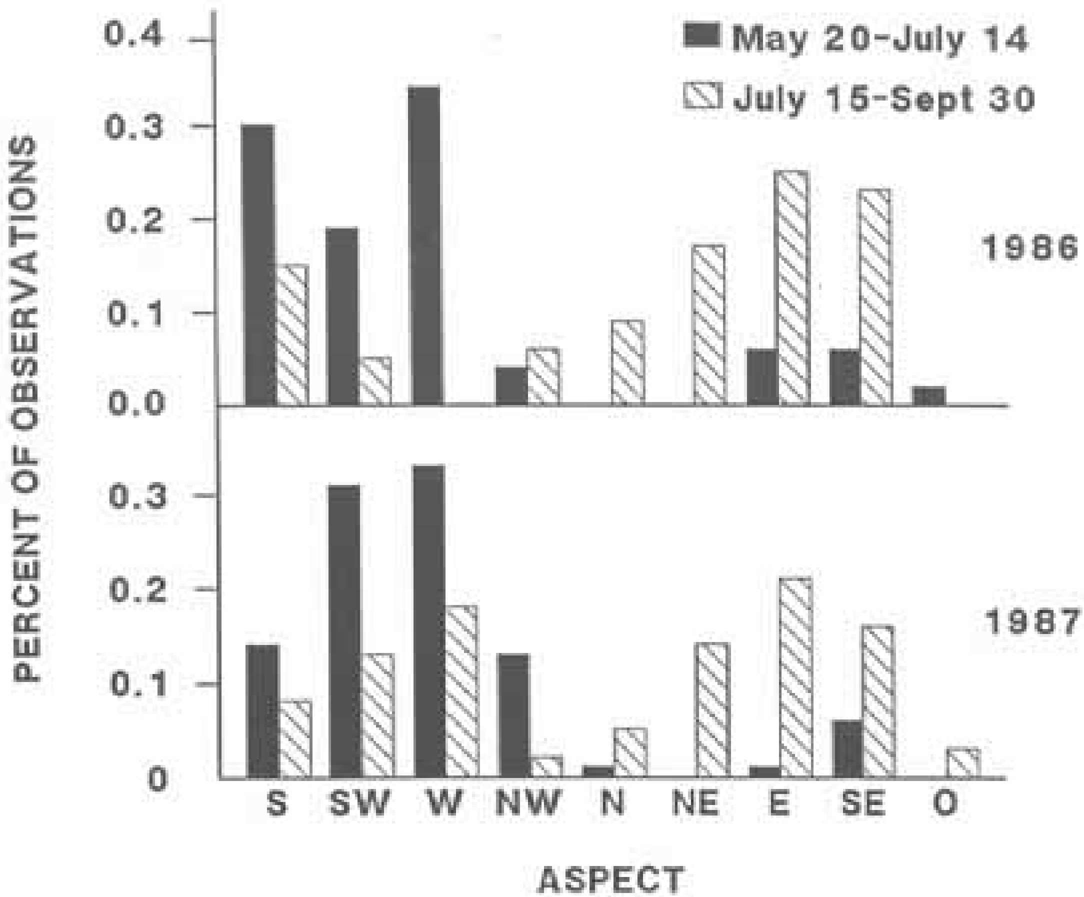

Figure 3. Changes in use of aspects by bighorn groups (including one or more radio-collared sheep) from early to late summer, 1986 and 1987, Rocky Mountain National Park and adjacent areas. N (number of groups of bighorn observed) = 53 early summer, 65, late summer, 1986; 70 early summer, 62 late summer, 1987.

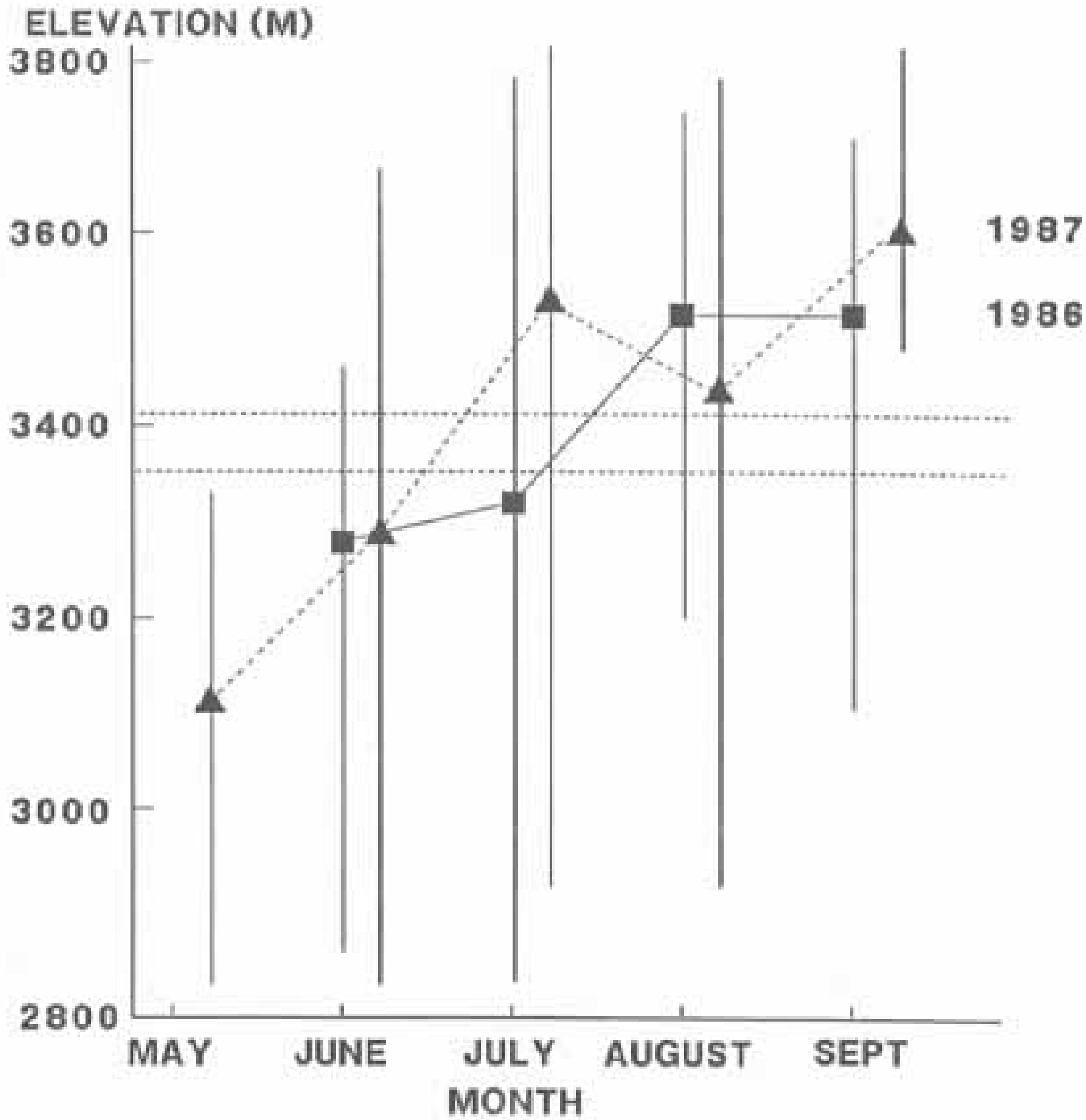

Figure 4. Changes in use of elevations by bighorn groups (including one or more radio-collared sheep) during late May through September, 1986 and 1987, Rocky Mountain National Park and adjacent areas. N (number of bighorn groups observed) = 118, 1986; 132, 1987. Solid vertical lines indicate ranges of observations. Dashed horizontal lines indicate the zone of treeline.

(1954), Shannon et al. (1975), Johnson and Smith (1980), and Seip (1983) also found plant phenology influenced habitat selection by bighorn sheep. Hebert (1973) documented the nutritional advantage to bighorn of foraging on early phenological stages of plants.

Lamb Production and Yearling Recruitment

Lamb production by marked ewes was lower in 1987 (L:E = .46) than in 1986 (L:E = .75). Despite the fewer lambs observed,the extended lambing period during 1986 was repeated in 1987. Estimated birth dates of the three lambs born to marked ewes for which dates could be closely estimated were May 23, June 28, and July 9. Combining data from 1986 and 1987, twelve lambs were born from May 23 to July 9 (Fig. 5). Festa-Bianchet (1988) observed a similar extended lambing period in Alberta bighorn ewes. He reported poor condition in autumn and low survival of lambs born after June 10. In this study, both early and late-born lambs of marked ewes were in good condition when fieldwork ended in mid-September (1986) or early October (1987). Assuming that association of a ewe with a yearling indicates survival of her lamb of the previous year, at least one of three late-born lambs of radio-collared ewes survived its second summer. Using the same assumption, at least two of three early-born lambs of radio-collared ewes survived for the same period.

The three radio-collared ewes which did not have lambs in 1987 but which had lambs in 1986, were observed in close association with yearlings during part or all of the 1987 field season (Table 1). These observations are supplemented by occasional observations of unmarked ewes suckling yearlings on the study area each summer. The maternal care of yearlings observed in 1987 may indicate an adaptation to the short growing season experienced by bighorn living at high elevations.

Table 1. Observations of three radio-collared bighorn ewes associated with yearlings in 1987.

Collar #	Lambing date 1986	Size of yearling	Period of association	Suckling observed # times
737	7/9	Small	5/26-9/22	2
784	5/31	Large	7/01-7/21	0
863	5/31	Large	6/02,7/01-7/15	1

No definite reproductive pattern was evident from the first 2 field seasons. Of the marked ewes, 3 raised lambs both years, 2 raised lambs neither year, and 5 raised a lamb in either 1986 or 1987.

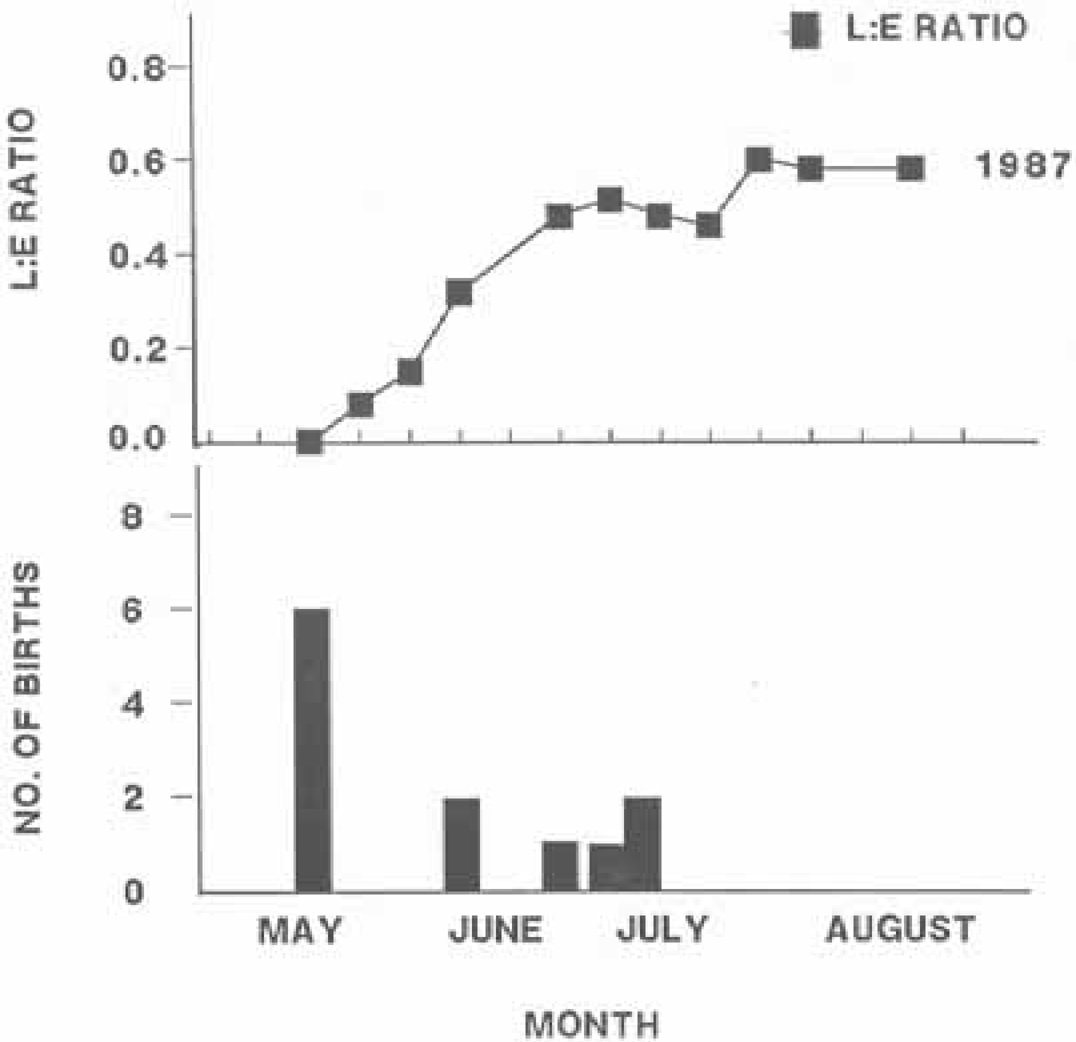

Figure 5. Distribution of birth dates of lambs born to marked bighorn ewes, (data from 1986 and 1987 combined), and weekly lamb:ewe ratios for groups containing marked ewes, 1987, Rocky Mountain National Park and adjacent areas, Colorado.

Estimates of lamb:ewe, and 2-year-old:ewe ratios for groups including marked ewes were lower in 1987 (L:E = .52, 2-yr-old:3 = .20), than in 1986 (L:E = .62, 2-yr-old:E = .36). Yearling-ewe ratios were similar for both years (.27, 1987 and .28, 1986). For groups of unmarked ewes observed on Specimen in 1987, including both north Never Summer and Divide ewes, ratios were L:E = .66, Y:E = .26, and 2-year-old:E = .22.

Reasons for lower production in the Baker ewe-group in 1987 may include the short, cool growing season in 1986, a high proportion of first breeding 3-year-old ewes in the population, (indicated by the 2-year-old to ewe ratio in 1986), or good lamb production in 1986. Lamb production in the marked subsample of ewes was greater than average for the Baker group in 1986 and less in 1987. This fact and the alternate year reproduction of half of the marked ewes suggest that a tendency toward alternate year reproduction may influence annual lamb production.

Population Estimates

South Never Summer group.--The total number of adult ewes in the subpopulation was 38 (C.L. 34-42) in 1986, and 33 (C.L. 29-38) in 1987 based on the Lincoln Index (Table 2). In 1986 the sex-age ratios observed during June and July, and in 1987 those observed June 29 - July 4, when groups including marked ewes were concentrated, were used to estimate size of lamb and yearling classes (Table 2). The results indicated a decline in the total population based on the lower number of adult ewes. Since the confidence limits do not confirm a decline, it may reflect sampling error. A decline would not be expected since production and recruitment in 1986 were excellent and the following winter was mild. The rams in this subpopulation were all young (1/2 curl or less) and traveling with ewe groups. At this time of year older rams were concentrated in the northern Never Summer area and were therefore not included in this subpopulation.

Total west-side area.--Fifty-one adult females were counted on the coordinated ground and helicopter count on June 25-26, 1987. The count included 9 of the 13 marked ewes. These marked ewes provided an estimate of the ewe population, using the Lincoln Index, of 74 adult ewes. Using observed sex-age ratios based on the total classified sheep and the estimate of total ewes, a total population of 238 bighorn was estimated (Table 2). This estimate may be low because only one of 3 subpopulations of ewes and juveniles contained an adequate marked sample.

In 1986, the estimate for the west-side population, using the same methods with the ground counts, was 200. The difference, between the 1986 and 1987 estimates, is due to a 21% increase in the estimate of total ewes (61 to 74) (Table 2). an increase in the total number of ewes was expected since production and recruitment were excellent the first year. However, part of the estimated increase in adult females may have been due to a greater number of ewes moving into the Specimen Mountain area where they were more easily counted. Radio-collared ewes used the Specimen Mountain area more in 1987 than in 1986.

The number of adult rams (3-years or older) was estimated to be 61 and 74 in 1986 and 1987 respectively, based on a 1:1 ratio to adult ewes. This 1:1 ratio was observed in 1986. In 1987 the observed ratio was 1.3:1; however, this total included marked rams from the east-side populations. Therefore, the ratio from 1986 was used.

The west-side bighorn population, including the north and south Never Summer and Continental Divide subpopulations, has approximately doubled in size (from 120 to 240 sheep) since 1976. Possible reasons for the increase include removal of domestic sheep from bighorn ranges outside of Rocky Mountain National Park during the early 1970's and restrictions on visitor use on Specimen Mountain (Stevens 1982).

Table 2. Population estimates for the south Never Summer subpopulation of bighorn sheep and for the total west-side population (including the north and south Never Summer and Continental Divide herds) in 1986 and 1987.

Herd	Year	Ewes	90% C.L.	Lambs[a]	Yearlings	Female 2-yr-olds	Male 2-yr-olds	Rams	Total
South Never Summer	1986	38	(34-42)	24	11	6	8	5	92
South Never Summer	1987	33	(29-38)	17	9	5	2	4	70
West-Side	1986	61		38	18	22		61[b]	200
West-Side	1987	74		39	30	21		74[b]	238

[a] The number of lambs, yearlings, 2-year-olds and rams are estimated by ratios of members of these classes to adult ewes, except for rams of the south Never Summer herd. These were all young rams (one-half curl or less) and were estimated by maximum counts per horn curl class.

[b] The observed ram:ewe ratio was 1:1 in 1986. The observed ram:ewe ratio in 1987 was 1.3:1; however, the ram total included marked rams from east-side populations of bighorn, so the 1:1 ratio was used in estimating the 1987 ram population.

LITERATURE CITED

Festa-Bianchet, M. 1986. Seasonal dispersion of overlapping mountain sheep ewe groups. J. Wildl. Manage. 50(2):325-330.

Festa-Bianchet, M. 1988. Birthdate and survival in bighorn lambs (Ovis canadensis). J. Zool. Long. 214:653-661.

Geist, V. 1971. Mountain Sheep: A study in behavior and evolution. U. Chicago Press, Chicago. 383 pp.

Goodson, N. J. 1978. Status of bighorn sheep in Rocky Mountain National Park. M. S. Thesis, Colorado State University, Ft. Collins, CO. 190 pp.

Goodson, N. J. 1980. Bighorn sheep in north-central Colorado: Past, present, and future. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:190-210.

Hebert, D. B. 1973. Altitudinal migration as a factor in the nutrition of bighorn sheep. Ph.D. Thesis. Univ. of British Columbia, Vancouver. 355 pp.

Johnson, B. K. and D. R. Smith. 1980. Food habits and forage preferences of bighorn sheep in alpine and subalpine communities. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:1-17.

Ratcliff, H. M. 1941. Progress report on the bighorn sheep study, Rocky Mountain National Park. On file, Office of the Research Biologist, Rocky Mountain National Park, Estes Park, Colorado. 13 pp. (typewritten).

Seip, D. R. 1983. Foraging ecology and nutrition of Stones' sheep. Ph. D. Thesis. Univ. of British Columbia, Vancouver. 175 pp.

Shannon, N. H., R. J. Hudson, V. C. Brink and W. D. Kitts. 1975. Determinants of spatial distribution of Rocky Mountain bighorn sheep. J. Wildl. Manage. 39(2):387-401.

Smith, D. R. 1954. The bighorn sheep in Idaho, status, life history and management. Idaho Fish and Game Dept. Wildl. Bull. #1. 154 pp.

Stevens, D. R. 1982. Bighorn Sheep Management in Rocky Mountain National Park. Third Bienn. Symp. North. Wild Sheep and Goat Counc. 3:244-253.

Bienn. Symp. North. Wild Sheep
and Goat Council 6: 268

EFFECT OF INTERSPECIFIC DISTURBANCE ON FORAGING BEHAVIOR OF BIGHORN SHEEP AT A WILD HORSE RANGE

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Abstract: The foraging behavior of Rocky Mountain bighorn sheep (*Ovis c. canadensis*) was analyzed from June 1986 to November 1987 as part of a multi-year wildlife research program at Bighorn Canyon National Recreation Area. Objectives of the research program were: to determine population size, age and sex composition and to analyze health of the herd; to analyze seasonal food habits and dietary overlap of sheep and wild horses; to analyze seasonal habitat utilization and activity pattern and to identify areas sensitive to human use; and to evaluate the total habitat potential of the area for mountain sheep. The setting of the 120,000 acre recreation area is a precipitous canyon land and 72-mile long reservoir in south-eastern Montana and north-central Wyoming. Portions of the recreation area have been federally designated as a wild-horse preserve. Access to the wild-horse range and southern portion of the recreation area is by secondary highway. The focus on the research program is a recolonized population which originated from the post-release dispersal of 6 sheep in 1975. Reproductive performance was optimal and the population currently numbers 50-60 sheep. In attempt to isolate a critical factor from an array of factors which could potentially limit future expansion of the herd, we quantified behavioral stress in different habitats. The habitat variable of interest was the presence/absence of wild horses or humans. Foraging behavior was analyzed in habitat that sheep used exclusively (precipitious habitat), in habitat sheep used in common with horses and/or humans (roadside habitat), and in habitat that sheep used with horses (non-precipitous habitat greater than 400-m from the road). Vegetative associations were similar in the 3-habitats. We analyzed time spent in 3 behavioral categories during foraging periods: foraging (ingesting or searching for food), social, or alert. We considered alert behavior to be an interruption of maintenance activity (IMA). Throughout the study IMA levels were highest at the roadside and lowest at the precipitous-lakeshore. IMA levels were intermediate but low at habitat used in common with horses, showing that humans had a greater effect on the behavior of ewes than did wild horses. Though IMA levels were high due to vigilance and flight response, roadsides supported succulent forage and received heavy use by lactating ewes during peak-summer tourism. The utility of roadside habitat to ewes will be discussed. Data supporting our hypothesis will be presented. Rams and wild-horses associated extensively. In every instance, IMA levels were lower when rams foraged with horses than when rams foraged with conspecifics. Rams never exhibited alert or social behaviors when foraging with horses. The same was true for ewes and yearlings which were observed in association with horses on one occasion. We will discuss several plausible explanations for these unexpected results.

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A MAGNESIUM-DRIVEN HYPOTHESIS OF DALL SHEEP MINERAL LICK USE: PRELIMINARY TESTS AND MANAGEMENT RELEVANCE

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Abstract: A major collection and analysis of soil and "mineral lick" samples throughout North America and a review of the literature relating to geology and mineral nutrition by Jones and Hanson (1985) has produced a magnesium-centered hypothesis which appears to have as viable a physiological rationale as the more commonly accepted sodium model. Central to the magnesium model was rediscovery that the aldosterone mechanism decreases magnesium absorption from the gut. Mineral lick use data from 2 licks in Interior Alaska were reanalyzed to test some predictions of the magnesium hypothesis which may be relevant to Dall sheep population monitoring at mineral licks. Results were inconclusive. However, when considering mitigation of mineral lick loss, the more comprehensive physiology associated with the magnesium model suggests inclusion of magnesium (and possibly other divalent cations) may be significantly more beneficial than providing only sodium.

Many wild ungulates eat soil from specific sites at certain times. The sight of wild animals, particularly those sought as human food, eating dirt (geophagy) has always interested humans. Early hunters found these sites were good places to take game, and modern hunters also found animals at licks were relatively easy prey.

It seems likely the first human investigation involved eating some of the soil. At least one early "taste tester" in eastern North America used the word, LICK, in reference to, "A salt spring...furrowed out in a most curious manner by the buffalo and deer which lick that earth on account of the saline particles with which it is impregnated," (Imlay 1792 quoted in Jakle 1969:688). This report probably reflected common usage and interpretation or coined the term "salt lick." It is the first recorded speculation as to why North American ungulates eat dirt. Subsequently, more sophisticated chemical analyses were employed in an effort to understand why animals ate dirt or licked rocks at these special places. The subject eventually developed a rich literature (Jones and Hanson 1985, Tankersley 1987). Implicit in efforts to understand "why" has been the assumption that mineral lick using species eat dirt because they have a physiological need for some nutrient it holds. As Seton (1901) wrote:

> "...But all went listlessly after the Wise One, whose calm decision really inspired confidence. When far below the safety-line, the leader began to prick up her ears and gaze forward. Those near her also brightened up. They were neither hungry nor thirsty, but their stomachs craved something which they felt was near at last. A wide

slope ahead appeared, and down it a white streak. Up to the head of this streak the Wise One led her band. The needed no telling; the bank and all about was white with something that the Sheep eagerly licked up. Oh! it was the most delicious thing they had ever tasted! It seemed they could not get enough; and as they licked and licked, the dryness left their throats, the hotness went from eye and ear, the headache quit their brains, their fevered itching skins grew cool and their stomachs sweetened, their listlessness was gone, and all their nature toned. It was like a most delicious drink of life- giving cordial, but it was only common salt.

This was what they had needed--and this was the great healing Salt-lick to which the leader's wisdom had been their guide.

A corollary assumption, that the beneficial mineral nutrients attract the users to the lick, appears to have also played a major part in the speculation concerning why ungulates use licks.

This thinking has been evident in experimental approaches to answering the "why" question. Experimental efforts have included "cafeteria style" feeding trails (Stockstad et al. 1953, Fraser and Reardon 1980), as well as composition analyses of mineral lick materials by numerous authors (see Hanson and Jones 1985). May of these observations have been interpreted as supportive of sodium ion as the major attractant and functional nutrient in ungulate mineral licks.

Sodium is certainly a required nutrient and is necessary for many physiological functions in the mammalian body (Forbes 1962). Furthermore, the role ascribed to sodium as the major attractive-nutritional component of mineral licks appeared increasingly certain with the inference from Epstein (1972) that herbivore diets are likely to be low in sodium because few if any plants require or store this element. This perspective gained additional support from the writings of Hebert and Cowan (1971) and Weeks and Kirkpatrick (1976) relating sodium/potassium homeostasis to the high potassium load herbivores receive when consuming emerging vegetation in spring. Hebert and Turnbull (1977) proposed a sodium flow model based on mountain goat (Oreamnos americanus) sodium intake and fecal loss in spring-summer. These authors used data from moose, deer, and domestic livestock sodium flux, and suggested that mountain goats can become sodium deficient during this period. Similarly, Thompson (1982) reported accelerated sodium loss from mountain goats during the spring-summer period exceed the plausible intake from available sources. However, he also reported that sodium requiremetns for mountain goats appear to be far below recommended levels for comparable domestic ruminants.

However, the lack of readily identifiable, specific symptoms of sodium deficiency in wild or domestic ungulates, the seeming abundance of available sodium in wild ungulate habitats (cured winter forage burns with a characteristic yellow "sodium flame"), its apparent absence from some licks, and the spectacular capacity for sodium retention by the mammalian kidney lead several authors to discount sodium as the prime nutritional component in mineral lick soils (French 1945, Cowan and Brink 1949, Murie 1951, Heimer 1974).

Some investigations have centered on nutritional function, while others focused on the search for an attractant in mineral lick soils. These differences in approach have lead to some confusion, and even some contention about the most reasonable justification for protecting ungulate mineral licks in wildlife management. Protection is often justified simply on the basis that the level of use mineral licks sustain obviously demonstrates their nutritional necessity. This approach has minimum acceptability with developers who argue there is no proof of nutritional dependence.

Whatever the reason animals are attracted to licks, I suggest the model produced by Jones and Hanson (1985) as well as the literature reviewed above presents a consistently strong case for nutritional necessity. I further suggest that the case for nutritional dependence on mineral licks holds the greatest potential for their preservation for wildlife use in the face of human development.

The work done by Jones and Hanson (1985) suggests a significant addition to the sodium model for mineral lick attraction and ungulate benefit. These authors analyzed samples collected by a variety of unspecified methods from 276 ungulate mineral licks throughout North America, characterized the solid types within the regions surrounding these mineral licks, and reviewed the literature of plant physiology relating to mineral content as well as the physiological literature about mammalian ion regulation. They concluded magnesium was the most important functional nutrient in lick soils, and appeared to ascribe the role of attractant to it as well.

The Magnesium Model

In the mammalian body, magnesium functions primarily inside cells, most notably as an enzyme activator and/or a cofactor in energy metabolism. There is no known body reserve of magnesium. Consequently, it is not difficult to produce low serum magnesium levels in domestic livestock (colloquially referred to as grass tetany, milk fever, or wheat poisoning depending on circumstances) because herbivore diets and environments are seldom rich in available magnesium. Captive bighorn sheep also showed decreasing concentrations of serum magnesium from October through May (Hebert, unpubl. data). In captive bighorn sheep maintained on forage gathered from their seasonal and winter ranges, mean serum magnesium levels in these bighorn sheep declined from an average of about 2 mg per 100 ml to 0.3 mg per 100 ml throughout the winter months. The data Hebert so generously provided did not indicate whether bighorns recovered their early winter magnesium levels without magnesium supplements. Still, the measured decrease in serum magnesium concentration was striking, and appears to demonstrate the absence of homeostatic mechanisms for magnesium in bighorn sheep.

Jones and Hanson (1985) present strong arguments that support their working hypothesis that North American ungulates get magnesium, which prevents tetany caused by low serum magnesium levels, from mineral licks. I am unaware of any reports of tetany in wild ungulates; however, several gross symptoms associated with many accounts of "capture myopathy" mimic those of grass tetany in domestics. These symptoms include ataxia, inability to stand, and death. Consequently, it is possible that hypomagnesemic tetany may be more common in wild ungulates than we have appreciated because it might easily be misdiagnosed as "capture myopathy."

In recent years, the term "capture myopathy" has become synonomous with vitamen E-selenium deficiency or White Muscle Disease. This unfortunate confusion in terms (the first clinical report of a capture myopathy in bighorn sheep was not synonomous with White Muscle Disease; Spraker 1976) has shifted thinking toward selenium deficiency whenever a captured animal fails to walk away after handling. There could be simpler and more treatable causes; hypomagnesemic tetany could be among them.

Potassium intake affects magnesium homeostasis.--Effects of the generally limiting magnesium levels in sheep diets are amplified by its low concentration relative to potassium in forage. High levels of potassium in emerging spring forage lead to imbalances of sodium and potassium in the body fluids of mineral lick-using species (Weeks 1974).

Normally, potassium and sodium are kept in balance in the mammalian body through chemoreceptors which monitor the ratio of these 2 ions in cerebro-spinal fluid. When this balance is tipped in favor of potassium (potassium ingestion or sodium loss), a hormone called aldosterone is secreted by the adrenal cortex. This hormone acts to restore balance by increasing active transport of sodium ions back into the body from plasma filtered in the kidney. Aldosterone increases activity of the sodium/potassium exchange pump in the distal convoluted portion of the nephron (Ruch and Patton 1965). Because the sodium/potassium pump exchanges sodium ions in the filtered plasma for potassium ions from body fluids, urinary potassium excretion increases as sodium is retained. That is, the mammalian system is adapted to conservation of sodium through the renal aldosterone mechanism. Mechanisms for potassium homeostasias apart from sodium have not been found.

Unfortunately, sodium-potassium homeostasis leads to magnesium loss because aldosterone has the side-effect of limiting magnesium absorption from the gut (Levin 1976). Hence, when spring herbivore diets (which are rich in potassium) distort the sodium/potassium ratio in spinal fluid, magnesium balance is compromised. Sheep appear to rectify this imbalance by eating sodium- and magnesium-rich soils at mineral licks. Ingestion of sodium acts to restore the sodium/potassium ratio and lower aldosterone levels. High magnesium intake counters decreased absorption caused by increased aldosterone and sets the stage for rapid recovery once aldosterone secretion returns to normal levels.

Jones and Hanson (1985) cite work by Grunes et al. (1970) that demonstrates forages with high amounts of potassium relative to magnesium and calcium lead to net magnesium and calcium loss in domestic ungulates. This appears to occur through the mechanism reviewed above. Consequently, lowered serum magnesium follows with the danger of metabolic dysfunction (which produces the symptoms of grass tetany common in metabolically stressed domestic livestock) due to lowered enzyme activity resulting from insufficient quantities of intracellular magnesium. Threshold levels have not been determined for wild ungulates. Jones and Hanson suggest that North American ungulates, including Dall sheep (Ovis dalli), have adapted to seasonal mineral lick use to forestall these potentially fatal symptoms. Among Dall sheep, mineral lick use typically coincides with emergence of spring vegetation (and a presumed potassium load) as well as parturition and the onset of lactation (which require expenditure of copious quantities of magnesium and calcium as well as sodium). Thus, Hanson and Jones (1985) suggested mineral lick drive is best understood as a result of acute or impending magnesium deficiency. A broader view would also include sodium loss even though specific symptoms are less striking.

Mineral licking drive may vary with plant ionic composition.--The ratio of potassium to magnesium-plus-calcium in emerging vegetation varies even though measurable soil concentrations are constant. Thomas and Hipp (1968) report empirical evidence that the ratio of potassium to magnesium-plus-calcium in plant tissue decreased with declining soil moisture. When soil moisture is high, the relative chemical activity (chemically active concentration), of monovalent cations, such as potassium with an oxidation state of plus 1, increases. Consequently, plants absorb more potassium. In drier circumstances, the chemical activity of the divalent cations (magnesium and calcium with higher oxidation states) is relatively greater, and absorption of these cations is favored. This is due to a factor called the dilution effect which occurs in the outer layers of the soil colloidal system (Wicklander 1964).

Other hypotheses involving low soil temperatures and subsequently elevated concentrations of ammonium ions in the soil during early plant growth have also been suggested as causative factors in lowering magnesium plus calcium concentrations in plant tissue (Wilcox and Hoff 1974). These mechanisms are consistent with low Alaskan soil temperatures and the general paucity of nitrogen-fixing bacteria in Alaskan alpine soils. These postulated mechanisms may contribute to hypomagnesemia as well.

Model Synopsis and Relevance

I think the physiological and empirical evidence supporting the magnesium hypothesis argues that wildlife managers should include emphasis of magnesium in nutritional justifications for mineral lick preservation. Sodium may well be the attractant, and ingestion of sodium concentrates will act to re-establish sodium/potassium ratios in spinal fluid and reduce aldosterone secretion. This will have the added beneficial effect of allowing increased absorption of the magnesium concentrates from the sheep gut.

Wildlife biologists have been divided over the importance of "attractants to" and "nutritional function of" mineral licks for many years. Historically, the attractant school has prevailed, and sodium has been the "ion of choice". There is little doubt that Dall sheep in Alaska prefer salt blocks to the soil of all mineral licks where salt ($NaCl$) blocks have been made available. Still, the evidence supporting involvement of the bivalent cations, particularly magnesium, suggests managers should adopt a more comprehensive view of mineral nutrition when justifying protection of mineral licks for ungulate use.

In summary, the magnesium hypothesis predicts that the ratio of potassium to magnesium-plus-calcium in sheep forage varies with available moisture at the time of plant emergence. In drier years, the ratio of these alkaline earth cations to potassium will favor magnesium absorption and licking drive should be reduced. Hence, the hypothesis predicts that mineral lick use, if a constant, linear function of magnesium-generated licking drive, should always be less in drier years.

Mineral Lick Use by Dall Sheep Has Been Predictable

Seasonal use of mineral licks by Dall sheep in Alaska has been particularly well documented (Heimer 1973, Curby 1981, Spindler 1983, Tankersley 1984). Heimer (1973) shows a minimum of 94% fidelity among ewes to the mineral lick where they were marked. He suggests this predictability could be exploited for population monitoring purposes.

If magnesium homeostasis drives Dall sheep mineral lick use, lick drive should vary with moisture availability to plants. If so, population monitoring at mineral licks would only be effective in years when high potassium to magnesium-plus-calcium ratios occur in plants. That is, during dry springs or after winters with little snow, high mineral lick fidelity might not be expected among Dall sheep. The purpose of this paper, besides advocating a broader view of mineral nutrition as it is influenced by mineral licks, is to explore this possibility and discuss its management relevance to using Dall sheep fidelity to mineral licks for population monitoring.

MATERIALS AND METHODS

Dall ewes were captured and marked at the Dry Creek and Robertson River mineral licks in Interior Alaska from 1967 to 1984 (Erickson 1970, Heimer et al. 1980, Heimer and Watson 1986). Returns of marked ewes were documented using various schedules of observation which were dependent on project objectives and funding. The return percentage for ewes known to be alive each year (either by sighting that year, or in subsequent years) was calculated. Observations were terminate after 1985 in the Robertson River and 1986 in Dry Creek, so both final year return frequencies are possible maximums. Percent sightings for each year were then regressed as functions of winter snow accumulation, spring precipitation up to the typical onset of peak mineral lick use and combined water equivalent (assuming 0.3 inches of water per inch of snow in April). Correlation coefficients were calculated and probability values determined using standard statistical tables.

RESULTS

In the data from Dry Creek, there was some suggestion that mineral lick use, as reflected by observed return of marked ewes, decreases with precipitation (as the hypothesis predicts) between the last week of May and the first week in June ($\underline{n}$ = 7 years, average ewe return = 81%, $\underline{r}$ = 0.731, $\underline{P} < 0.10$, Table 1), but the correlation was not significant at $\underline{P} > 0.05$. There was no suggestion of correlation between percentage ewe return and winter snow accumulation or total water equivalent.

In the Robertson River, sheep mineral lick-use trends suggested that mineral lick use may decrease with increasing total water equivalent ($\underline{n}$ =

5 years, average ewe return = 95%, r = -0.8186, $\underline{P}$ < 0.10, Table 2). The correlation was not significant at $\underline{P}$ > 0.05. There was no suggestion of correlation between lick use and winter snow depth or early spring precipitation. The hypothesis did not predict, even qualitatively, in this case.

Table 1. Percent of living ewes returning to the Dry Creek lick, spring precipitation, winter snow depth, and combined precipitation, Alaska Range, Alaska, 1973-86.

Year	% return observed	Spring precipitation (inches)	Winter snow depth (inches)	Combined water equivalent (inches)
1973	89	0.65	24.3	8.20
1974	75	0.84	17.3	6.03
1982	75	0.10	22.5	6.85
1983	79	1.00	18.3	6.49
1984	88	1.20	12.5	4.95
1985	93	1.20	22.7	8.01
1986	70	0.25	16.3	5.14
		r = 0.7031	r = -0.1277	r = 0.1228
		$\underline{P}$ < 0.10		

Table 2. Percent of living ewes returning to the Robertson River mineral lick, spring precipitation, winter snow depth, and combined water equivalent, Alaska Range, Alaska, 1981-85.

Year	% return observed	Spring precipitation (inches)	Winter snow depth (inches)	Combined water equivalent (inches)
1981	100	2.1	8.8	4.74
1982	96	0.1	22.5	6.85
1983	93	1.0	18.3	6.49
1984	95	1.2	12.5	4.95
1985	89	1.2	22.7	8.01
		r = 0.3166	r = -0.7273	r = -0.8186
			$\underline{P}$ > 0.10	$\underline{P}$ < 0.10

DISCUSSION

The differences in sign of correlation coefficient between Dry Creek and the Robertson River suggest several possibilities. First, measurements of moisture may have been too crude to be relevant to the question.

Second, differences could have been due to human factors. Experienced observers were present at the Robertson River lick throughout June each year while observers kept incomplete or variable schedules at Dry Creek. Had observers been at the Dry Creek lick at all times, as was the case at the Robertson River lick, it is possible that return percentages would have been uniformly higher. Still, years with continuous observer presence in Dry Creek gave differing percentage returns of living ewes, and most sheep visit the lick several times during the month. The suggested relationship may not be spurious.

Third, lick drive may not be equally variable in both populations. Plant species compositions in winter diets of these 2 populations are different (Heimer 1983), and it is possible that the Robertson River ranges chronically supply less magnesium with respect to potassium than the Dry Creek ranges.

Finally, it is possible that the hypothesis has no relevance to measurable mineral lick use. It is also possible that sheep visit mineral licks for reasons other than physiological prophylaxis.

It should also be noted that the final years of observation, 1985 for the Robertson River and 1986 in Dry Creek, are maximum estimates of return because continuous observations were discontinued after those years. Hence, living ewes who "skipped" those years could not have been resighted subsequently. Whatever the case, mineral lick observations still appear to offer considerable promise for population monitoring. Better testing of the predictions of the magnesium hypothesis should include careful, on-site measurement of soil moisture, plant calcium plus magnesium to potassium ratios, serum magnesium values from sheep, and mineral lick use. I think return of marked animals to the mineral lick each year is the best present indicator of mineral lick use.

I realize that evaluation of the predications of the magnesium hypothesis is not an immediate management concern. However, the prospect of mitigating loss of mineral licks is. I think the magnesium hypothesis is a sufficiently satisfactory model from physiological and nutritional perspectives that sheep populations will be better served by recommending nutritionally balanced supplements in addition to sodium. Tankersley (1987) recommends establishment of replacement licks with substrate and ionic composition as similar as possible to the original lick.

LITERATURE CITED

Cowan, I. McT., and V. C. Brink. 1949. Natural game licks in the Rocky Mountain National Parks of Canada. J. Mammal. 30:370-387.

Curby, C. H. 1981. Habitat selection and activity patterns of Dall sheep ewe groups in the Sheenjek River drainage, Northeast Alaska. M. S. Thesis. Univ. Alaska, Fairbanks. 84 pp.

Epstein, E. 1972. Mineral nutrition of plants: principles and perspectives. John Wiley and Sons, Inc., New York. 412 pp.

Erickson, J. A. 1970. Use of drop net and collars in study of Dall sheep. Trans. North. Wild Sheep Counc. 1:20-21.

Forbes, G. B. 1962. Sodium. Pages 1-72 in C. L. Comar and F. Bronner, eds. Mineral metabolism. Vol. 2, Part B. Academic Press, New York.

Fraser, D., and E. Reardon. 1980. Attraction of wild ungulates to mineral-rich springs in central Canada. Holarctic Ecology 3:36-40.

French, M. H. 1945. Geophagia in animals. East Afr. Med. J. 22:103-110.

Hebert, D., and I. McT. Cowan. 1971. Natural salt licks as a part of the ecology of the mountain goat. Can. J. Zool. 49:605-610.

________, and W. G. Turnbull. 1977. A description of southern interior and coastal mountain goat ecotypes in British Columbia. Pp. 126-246 in W. Samuel and W. Macgregor (Eds.). Proc. First Intl. Mountain Goat Symp., B.C. Wildl. Branch, Victoria.

Heimer, W. E. 1973. Dall sheep movements and mineral lick use. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Final Rep. Proj. W-17-2 through W-17-5. Job 6.1R. Juneau. 67 pp.

________. 1974. The importance of mineral licks to Dall sheep in interior Alaska and its signficance to sheep management. Pp. 49-64 in K. J. Constan and J. L. Mitchell (Eds.). Proc. Bienn. Symp. North. Wild Sheep Counc. Montana Dep. Fish, Wildlife, and Parks, Missoula.

________. 1983. Interior sheep studies. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Final Rep. Proj. W-17-8 through W-21-1. Job 6.12R. Juneau. 52 pp.

________, and S. M. Watson. 1986a. Time and area specific variations in Dall sheep lamb production: an explanatory hypothesis. Bienn. Symp. North. Wild Sheep and Goat Counc. 5:78-105.

________, and ________. 1986b. Comparative dynamics of dissimilar Dall sheep populations. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Final Rep. Proj. W-22-1 through W-22-5. Job 6.9R. Juneau. 101 pp.

________, S. D. DuBois, and D. G. Kelleyhouse. 1980. The usefulness of rocket nets for Dall sheep cature compared with other capture methods. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:601-604.

Jakle, J. A. 1969. Salt on the Ohio Valley Frontier, 1770-1820. Ann. Assoc. Am. Geogr. 59:687-709.

Jones, R. L., and H. C. Hanson. 1985. Mineral licks, geophagy, and biogeochemistry of North American ungulates. Iowa State Univ. Press, Ames. 301 pp.

Levin, R. J. 1976. The adrenal cortex and the alimentary tract. Pp. 207-291 in I. C. Jones and I. W. Henderson (Eds.). General, comparative, and clinical endocrinology of the adrenal cortex. Vol. 1. Acad. Press, NY.

Murie, O. 1951. The elk of North America. Harrisburg, PA, Stackpole.

Ruch, T. C., and H. D. Patton. 1965. Physiology and biophysics. W. B. Saunders Co., Philadelphia and London. 1,242 pp.

Spindler, M. A. 1983. Dall sheep mineral lick use and age and sex composition in selected river drainages of the Arctic National Wildlife Refuge, 1979-82. U.S. Fish and Wildl. Serv., Fairbanks, AK. Mimeo.

Spraker, T. 1976. Capture myopathy in bighorn sheep. Pp. 113-116 in T. Thorne (Ed.). Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. Wyoming Game and Fish Dep., Laramie.

Stockstad, D. S., M. S. Morris, and E. C. Lory. 1953. Chemical characteristics of natural licks used by big game animals in western Montana. Trans. North Am. Wildl. Conf. 18:247-258.

Tankersley, N. G. 1984. Mineral lick use by Dall sheep in the Watana Creek Hills, Alaska. Fourth Bienn. Symp. North. Wild Sheep and Goat Counc., Yukon Wildlife Branch, Whitehorse. 4:211-230.

________. 1987. Importance of natural mineral licks to ungulates. Alaska Dep. Fish and Game, Anchorage, Alaska. 13 pp. Mimeo.

Thomas, G. W., and B. W. Hipp. 1968. Soil factors affecting potassium availability. Pp. 269-291 in V. J. Kilmer, D. E. Younts, and N. C. Brady (Eds.). The role of potassium in agriculture. Am. Soc. Agron., Crops Sci. Soc. Am., and Soil Sci. Soc. Am., Madison, WI.

Thompson, R. W. 1982. Mountain goat sodium dynamics in the Eagles Nest Wilderness, Colorado. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:202-231.

Weeks, H. P., Jr. 1974. Physiological, morphological, and behavioral adapations of wild herbivorous mammals to a sodium-deficient environment. Ph.D. Thesis, Purdue Univ., Lafayette, IN.

________, and C. M. Kirkpatrick. 1978. Salt preferences and sodium drive phenology in fox squirrels and woodchucks. J. Mammal. 59:531-542.

Wicklander, L. 1964. Cation and anion exchange phenomena. Pp. 163-205 in F. E. Bear, ed. Chemistry of the soil, 2nd ed. Am. Chem. Soc. Monogr. Ser., Reinhold Publ., New York.

Wilcox, G. W., and J. E. Hoff. 1974. Grass tetancy: An hypothesis concerning its relationship with ammonium nitrition of spring grasses. J. Dairy Sci. 57:1085-1089.

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APPLICATION OF REMOTE SENSING AND TERRAIN MODELLING TO THE ANALYSIS AND MAPPING OF DALL'S SHEEP WINTER HABITAT IN THE YUKON TERRITORY.

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Abstract: The objective of this research was to develop a digital analysis and mapping tool to assist sheep habitat managers in their assessment and management of Dall's sheep winter habitat. Remote sensing and terrain modelling techniques were employed to quantitatively characterize the four major components of Dall's sheep winter habitat: slope magnitude, slope direction, snow-free areas, and proximity to escape terrain. Sheep winter habitat areas, identified by Yukon biologists during a March 1987 aerial survey, were digitized to produce a binary (sheep/no sheep) digital mask. A March LANDSAT image was digitally classified to delineate snow-free areas, while derivative products from a digital elevation model supplied the topographic information. The resultant classified LANDSAT image and the derived topographic datasets were integrated and the spatial characteristics of Dall's sheep winter habitat were determined for the masked sheep areas using overlay techniques and then described quantitatively using linear and circular statistics.

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MEASURING SEASONAL MOVEMENTS OF A MALE DALL SHEEP BY SATELLITE TELEMETRY

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Abstract: We used satellite radio telemetry to measure the seasonal movements of an adult male Dall sheep from October 1986 to October 1987. The transmitter package, weighing approximately 2 kg, provided three locations per day for one year. Average error of the locations was approximately 2 km. The sheep exhibited distinct summer and winter ranges that were approximately 40 km apart. Spring migration occurred in early June, and winter migration occurred in November. Additional information from a mercury-switch activity sensor in the transmitter may be useful for monitoring intensity of local movements.

Winter and Predation Impact

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SNOW DEPTH AS A LIKELY FACTOR CONTRIBUTING TO THE DECLINE OF A SHEEP POPULATION IN THE CENTRAL YUKON

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Abstract: A thinhorn sheep population was counted and classified in the Glenlyon Range of the Pelly Mountains in response to a decline in the average age of the sheep kill, and the outfitter's concerns that sheep had severely declined in the area. The population was found to have declined by about 40% of the estimated 1976 population, with the virtual absence of one-half-curl rams and large full-curl rams.

The winter of 1982-83 was a particularly severe one with deeper than average snow conditions during all but one month ($p<0.5$). The loss of the 1982 cohort and older-aged animals during this winter, compounded by the reproductive failure of the 1983 lamb crop, adequately explains the decline of the population and the average age of the kill. Relatively poor lamb production in 1981 and 1982 possibly contributed to the decline.

The concentrated distribution of sheep during the winter of 1976-77, in what was possibly an average winter, in comparison to the wide distribution observed in the relatively snow-free winter of 1986-87, further suggests that winter snow conditions may play a key role in the dynamics of sheep in the area.

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THE IMPACT OF COYOTE PREDATION ON LAMB MORTALITY PATTERNS AT THE JUNCTION WILDLIFE MANAGEMENT AREA

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Abstract: Lamb/ewe ratios at the Junction Wildlife Management area in central British Columbia, have been declining since the late 1970's. Although the pregnancy rate reaches 95%, lamb/ewe ratios declined to 25-30/100 ewes in August and 12-18/100 ewes the following March. Preliminary examination of range condition, nutrition, stress, parasites and disease and climate indicated that these factors were probably not the cause in the decline of the lamb/ewe ratios. The year following extensive coyote control, lamb/ewe ratios increased 2-3 times in August and March.

The Junction Wildlife Management Area (W.M.A.) contains the largest, northernmost population of California bighorn sheep (*Ovis canadensis californiana*) in North America (Fig 1.). This sheep population is non-migratory, remaining on the banks of the Fraser and Chilcotin rivers year round. It is composed of the Deer Park herd of approximately 150 sheep and the Junction herd of approximately 400-450 sheep. These bands are separated by 7-10 km. and, although the ewes and lambs intermingle infrequently, the ram population (approximately 150) moves freely between the two areas. The area is provincially renowned for its high quality ram hunting (1000 limited entry hunt applications for 5-9 permits) and for its accessibility to nonconsumptive users (up to 3000 user days/year). In addition, its international reputation is based on a 34 year history of transplants to 6 western states in the U.S.A. Approximately 250 sheep have been transplanted during this period, resulting in a present day population in those states of 2500-3000 animals (Hebert unpub., Thorne 1986).

Since the late 1970's, lamb/ewe ratios and recruitment levels declined drastically as did the size and availability of legal rams in the harvest. It was apparent that these conditions could curtail or reduce both the transplant and ram harvest programs. Programs were designed to determine the influence of climate, range condition, nutritional status, health of the herd and reproductive status on lamb production and recruitment. Poaching was suggested as the primary cause of the decline in ram horn size and ram population numbers. Preliminary analysis of data

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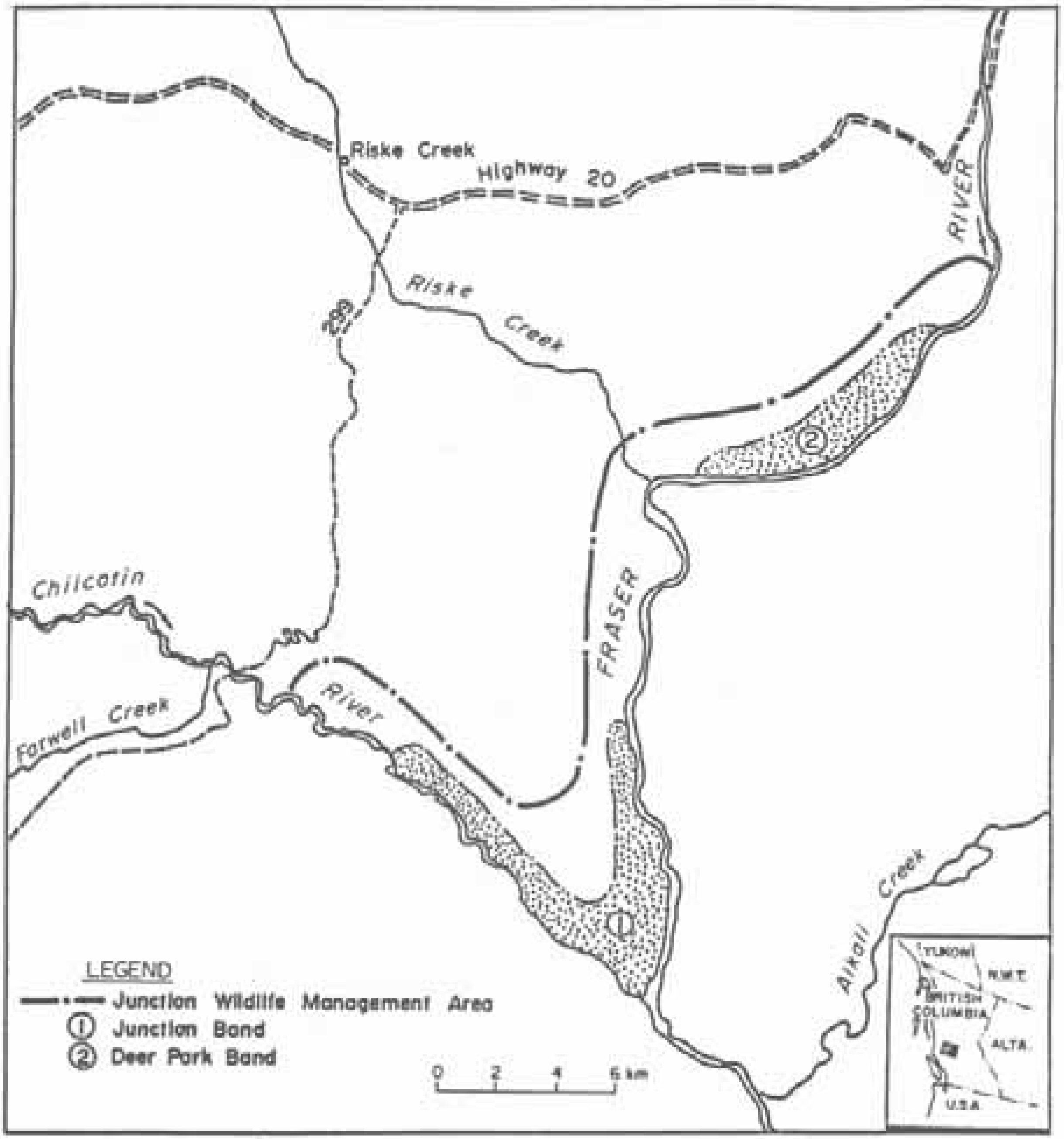

Figure 1. The Junction Wildlife Management Area indicating the Junction and Deer Park bands of sheep.

from these programs suggested that these variables had a minimal influence on either lamb survival or ram availability.

During the study period, information on predator sightings and approximate numbers on observed predation (Harrison and Hebert 1988) suggested that it might play a role in the growth and structure of the Junction sheep population.

Predator populations have never been monitored closely. However, cougar, coyote and wolf populations were severely reduced during the period 1940-1975, due to poison programs, trapping and intense hunting.

This paper examines the relationship between coyote predation and lamb production and survival on the Junction sheep range from the mid-1970's to the present.

STUDY AREA

The Junction W.M.A. is comprised of approximately 6,000 hectares at the confluence of the Fraser and Chilcotin Rivers. It is composed of grassland covered benchlands, interspersed with patches of Douglas fir on north slopes and wetter seepage sites. The study area is larger than the W.M.A. and contains approximately 225 km^2 (Fig. 1).

METHODS

Helicopter surveys were conducted on the two sheep bands between 1968-1988 to determine lamb/ewe ratios at various periods throughout the year and to approximate population numbers. Minimum counts were used in most years, however, in some years replicated counts and marked-unmarked ratios were also used. Ground surveys were often used to supplement aerial surveys to support or adjust composition data.

Pregnancy testing was done during several trapping operations using serum progestin (Ramsay and Sadlier 1979). Lamb mortality patterns using lamb/ewe ratios, were determined from consecutive searches of the lambing grounds between April and September 1984 (Caldwell unpub.). Nutritional levels and seasonal food habits were undertaken between 1981 and 1986 (Hebert et al. 1984, Hebert 1986). Stress level in the population was examined using serum cortisol (Hebert and Spraker unpub.) and population health was examined through necropsy (Spraker unpub.). General range condition was examined (Demarchi unpub.) and is improving, although several critical winter ranges used during severe winters have remained stable but in poor condition. Climatic data for the area has shown that winters have been light to moderate for 5 of the last 6 years.

The coyote population in the Deer Park area was controlled by ranch hands (shooting) during the mid-1970's through to 1988. At the Junction, coyotes were controlled by trapping and shooting during the winter of 1986-87 and 1987-88.

RESULTS

Examination of range, climatic, nutritional, health and reproductive status suggested that these variables were insignificant in the regulation of lamb production and survival.

Aerial survey data collected between 1968 and 1980 (Table 1) indicated that lamb survival was at least moderate in most years.

Table 1. Lamb/100 ewe ratios for the Junction-Deer Park bands of California bighorn sheep during late summer and midwinter.

Date	August	Nov. - Feb.
1968	38 (302)[b]	22 (203)
1969	44 (174)	45 (185)
1970[a]	29 (161)	
1971	39 (209)	
1974	41 (124)	
1975		37 (109)
1979		45 (331)
1980		20 (284)

[a] September
[b] ( ) = sample size

The data combines information from both the Deer Park and Junction herds. During this time, ranchers at the Deer Park herd were undertaking some coyote control that could increase the lamb survival figures by an unknown amount. Since the largest proportion (80 percent) of the population occurred at the Junction, where no coyote control was undertaken, the lamb/ewe ratio of the combined data was only partially influenced.

Throughout the period 1982-1985 (Fig. 2), approximately 95% of the ewes tested during trapping and transplant operations were pregnant. During the lambing period, April 10 - June, the highest lamb/ewe ratio observed was 70 (Fig. 1). Lamb/ewe ratios at the Junction declined each summer (1984-86) to 25-30 lambs/100 ewes in August (Fig. 2, 3, 4). Simultaneously, lamb/ewe ratios at Deer Park were maintained at 40-45 lambs/100 ewes for the same month. Between August and the following March (1984-86) lamb/ewe ratios at the Junction continued to decline to 12-18/100, while those at Deer Park were maintained at 30-40/100 (Fig. 2, 3 4).

During the early and mid-1980's, ranch hands at Deer Park were removing 30-50 coyotes/year during the winter trapping season, preceeding the lambing period. During the winter of 1986-87, ranch hands removed 59 coyotes at Deer Park while trappers and hunters removed a minimum of 26 at the Junction. Although 85 coyotes were known to be removed, it is more likely that 95-100 were actually removed. During the latter stages of

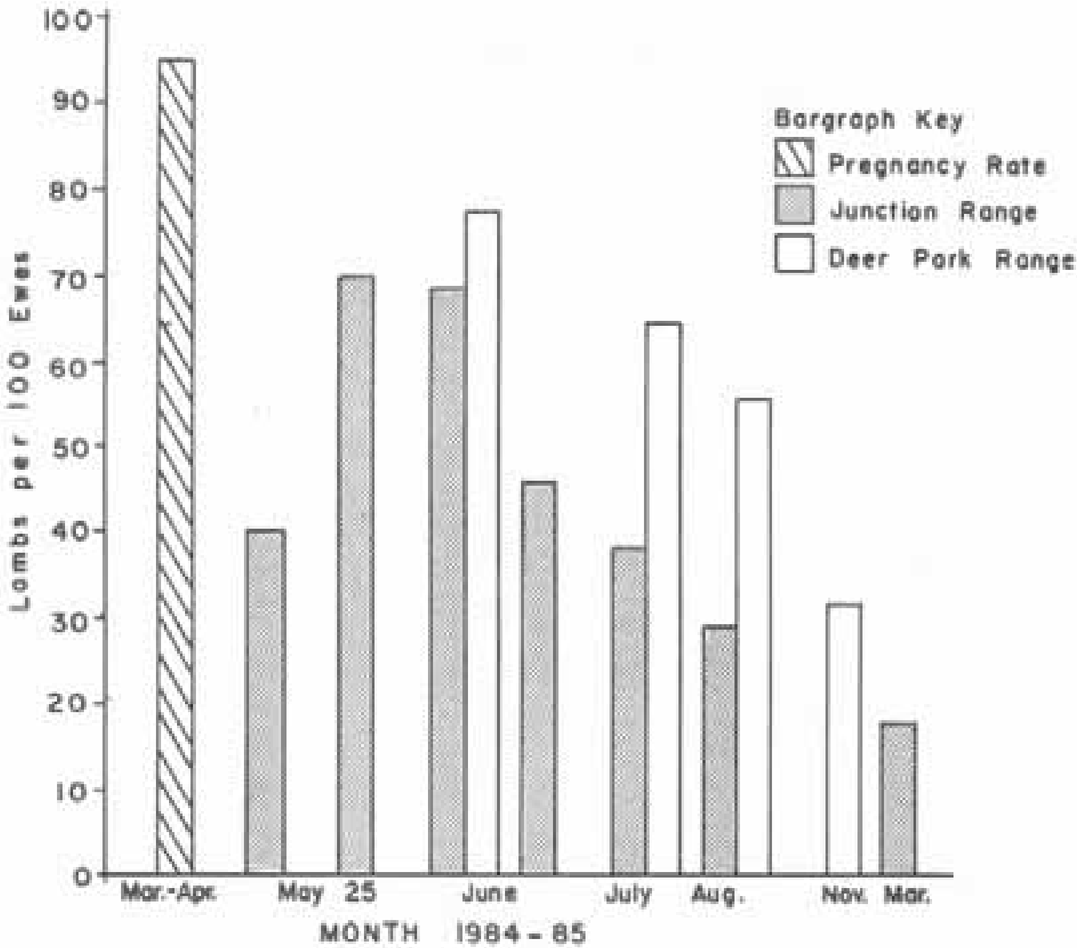

Figure 2. The ratio of lambs per 100 ewes on the Junction Wildlife Management Area prior to coyote control.

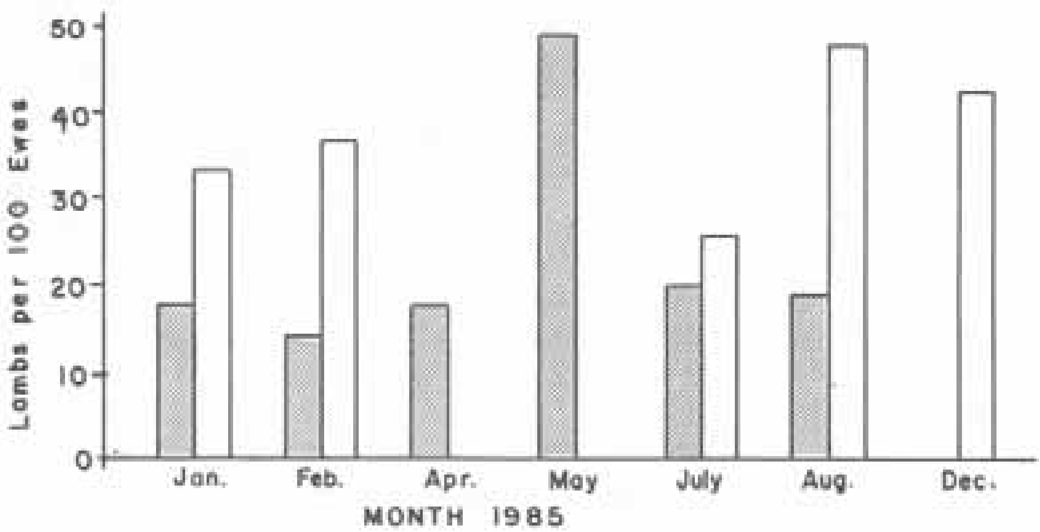

Figure 3. The ratio of lambs per 100 ewes on the Junction Wildlife Management Area prior to coyote control.

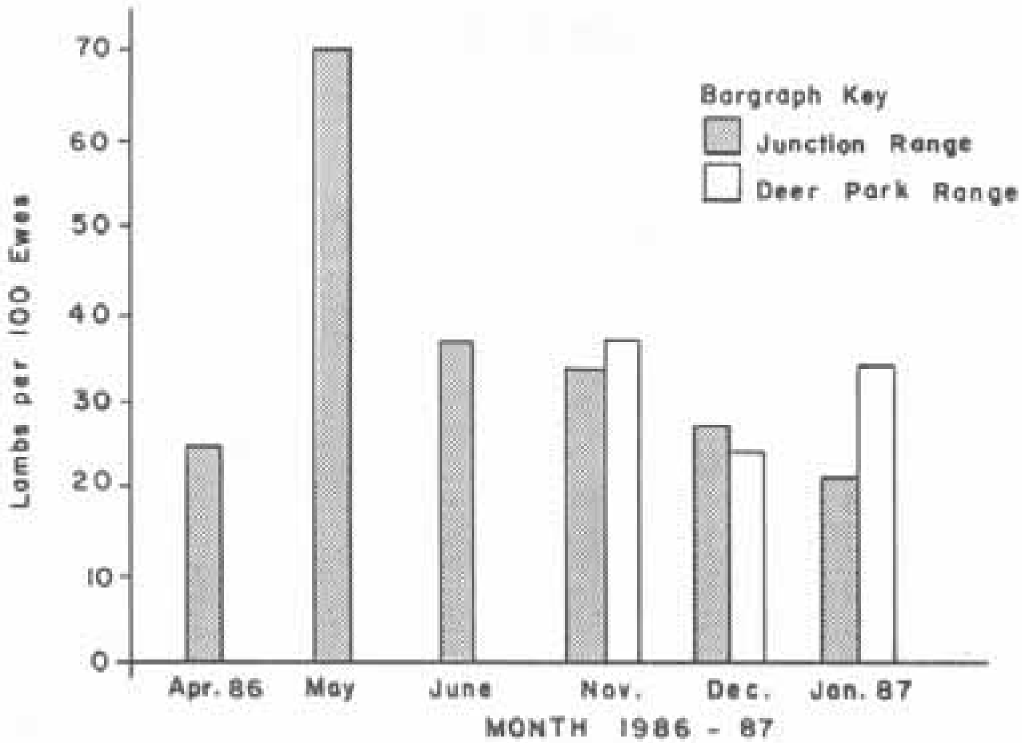

Figure 4. The ratio of lambs per 100 ewes on the Junction Wildlife Management Area following coyote control.

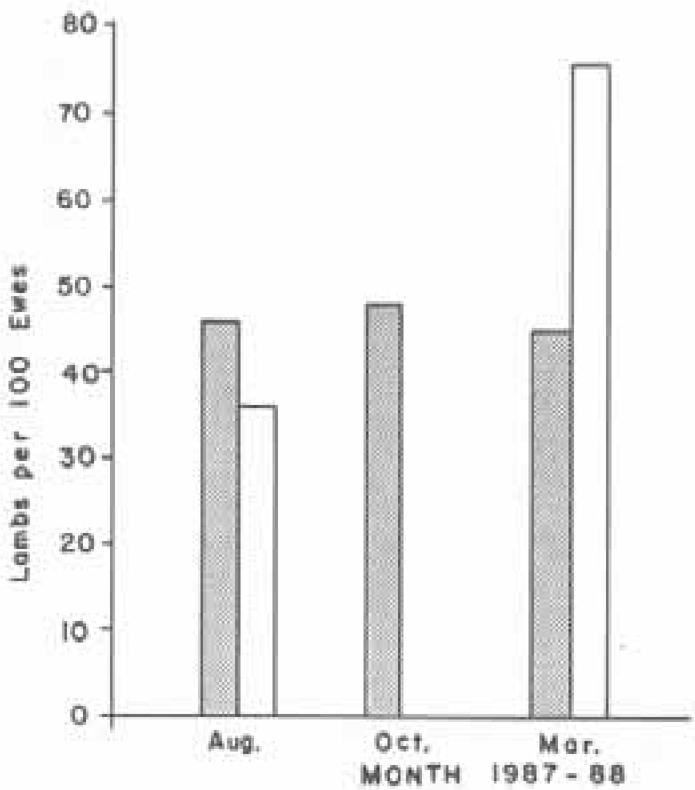

Figure 5. The ratio of lambs per 100 ewes on the Junction Wildlife Management Area following coyote control.

coyote removal it was estimated (tracks after fresh snowfalls) that at least 25-30 coyotes still remained in the study area. As well, preliminary radio tracking data indicated that coyotes moved between the Junction and Deer Park.

Sheep surveys undertaken in August 1987 following coyote control, produced a lamb/ewe ratio of 56/100 at the Junction and 46/100 at Deer Park (Fig. 5). The post control lamb/ewe ratio at the Junction was approximately 2 to 2.5 times higher than during the previous three years. Subsequently, surveys in October 1987 and March 1988 indicated that the lamb/ewe ratio was not declining. The October survey at the Junction produced a lamb/ewe ratio of 58/100. Subsequent surveys in March 1988 produced lamb/ewe ratios of 45 and 76/100 for the Junction and Deer Park, respectively. The post-control, August - March decline at the Junction was only 19.6% as compared to the pre-control decline of approximately 44%. The increase in the Deer Park ratio from 46/100 to 76/100 during the August - October period was likely the result of survey bias due to trapping and the distribution of small ewe groups without lambs. During the October survey, the sample size was reduced and groups were undisturbed and in larger visible groups as they prepared for the rut. Baiting and trapping in late February attracted a disproportionate number of ewes with lambs (20 lambs, 22 ewes) which were added to the surveyed sample. During the March survey, small ewe groups without lambs were less visible due to the disturbance, reduced population size and the complete lack of snow on the winter range. The actual lamb/ewe ratio is somewhere between 46 and 76:100 ewes.

During the fall and winter of 1987-88, 8 coyotes were removed at the Junction and 35 were removed from Deer Park. Intensive field inspections indicated a significant decline in coyote sightings, sign and tracks throughout the entire study area.

DISCUSSION

Biologists throughout the range of bighorn sheep in North America have traditionally examined the role of range condition, nutrition and animal health in relation to population status of bighorns. There are several instances where this approach has not explained the level of lamb survival (Bodie and Hickey 1980, Harper 1984). Several studies indicate moderate to high lamb production and recruitment (Coggins 1980, Whitfield and Keller 1984, Schuerholz 1984) while others note low to moderate ratios (Hass and Decker 1980, Harper 1984) with no apparent reason for the loss.

At the Junction W.M.A., golden eagles, black bear, coyote, cougar and humans all prey on bighorn lambs. Without intensive study, the role of each predator species in lamb mortality is difficult if not impossible to assess. Predation is impossible to assess through normal observational procedures and as a result is almost always underestimated. Peek (1986) suggests that "it should be clearly understood that it is difficult to determine the magnitude of effect predation has in field studies". A few instances of predator activity (coyotes chasing sheep or cougar predation on sheep) usually indicate an underlying predator problem. Evidence of the presence of predators with no evidence of predation does not indicate a lack of significant predation. This study indicated that significant predator control at Deer Park (approximately 10 years) was responsible for maintaining favorable lamb/ewe ratios. Similarly, predator reduction at the Junction, produced a dramatic increase in the lamb/ewe ratio. Stout (1982) determined that fawn production increased by 154% following coyote control. Horejsi (1976) suggested that coyotes are present in the Sheep River area of Alberta and they do hunt sheep. Fairaizl (1980) indicated that coyote predation was the major cause of lamb mortality following population transplants in North Dakota. Festa-Bianchet (1987) noted that several lamb carcasses were consumed by coyotes and coyotes were observed pursuing sheep on about two dozen occasions.

Without continuous radio-collar monitoring and an understanding of predator population dynamics, the impact of specific individuals or the general predator population is difficult to identify or separate. It may be that only certain individuals, at a variety of predator densities, have learned to prey successfully on bighorn sheep. Alternatively, predator population density may be the ultimate cause of increased coyote predation on bighorn sheep.

Removal programs do not allow these aspects of predator population dynamics or behaviour to be examined. However, removal programs can confirm the impacts of predators and can produce dramatic improvements in survival and population growth, especially where one predator species predominates. Combined impacts of predators are even more difficult to determine.

Coyote control has produced a population surplus which the critical winter ranges could not sustain in a severe winter. Consequently, California bighorn sheep transplants will continue until most or all of the native sheep range in the U.S.A. is repopulated.

LITERATURE CITED

Bodie, W. L., and W. O. Hickey. 1980. Response of wintering bighorn sheep to a rest-rotation grazing system in Central Idaho. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:60-69.

Coggins, V. L. 1980. Present status of Rocky Mountain bighorn sheep in northeast Oregon. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:90-105.

Fairaizl, S. D. 1980. Population characteristics of transplanted California Bighorn Sheep in western North Dakota. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:70-89.

Festa-Bianchet, M. 1987. Survival of Bighorn Rams in South West Alberta: Why do some rams die young? Can. J. Zool. 1987. In press.

Harrison, S. W. and D. M. Hebert. 1988. Selective predation cougar on the Junction Wildlife Management Area. Bienn. Symp. North. Wild Sheep and Goat Counc. 6:In press.

Hass, W. L. and E. Decker. 1980. A study of a recently introduced bighorn sheep herd. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:143-167.

Hebert, D. M., J. Hebert and M. Caskey. 1984. Fecal nitrogen as a determinant of animal condition in bighorn sheep. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:317-340.

________ and J. Hebert. 1986. Animal condition - a comparison of fecal nitrogen and diaminopimelic acid. Bienn. Symp. North. Wild Sheep and Goat Counc. 5:386-393.

Horeijsi, B. 1976. Some thoughts and observations on harassment and bighorn sheep. Pp. 149-155 in E. T. Thorne (Ed.), Proc. Bienn. Symp. North. Wild Sheep Counc. Wyoming Game and Fish Dept., Cheyenne, Wyoming. 165 pp.

Ramsay, M. A. and Sadleir, R.M.F.S. 1979. Detection of pregnancy in living bighorn sheep by progestin determination. J. Wildl. Manage. 43:970-973.

Schuerholz, G. 1984. Annual ecological cylces of Rocky Mountain bighorn sheep populations with high elevation winter ranges in the East Kootenays. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:192-210.

Stout, G. G. 1982. Effects of coyote reduction on white-tailed deer productivity on Fort Sill, Oklahoma. Wildl. Soc. Bull. 10:329-332.

Thorne, E. T., W. O. Hickey and S. T. Stewart. 1985. Status of California and Rocky Mountain Sheep in the United States. Pp. 56-81 in M. Hoefs (Ed.), Wild Sheep, distribution, abundance, management and conservation of the sheep of the world and closely related mountain ungulates. Spec. Rpt., North. Wild Sheep and Goat Counc., Yukon Wildl. Branch, Whitehorse. 218 pp.

Whitfield, M. B., and Keller, B. L. 1984. Bighorn sheep of the Teton Range, Wyoming: Ecology of a remnants population. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:120-136.

Bienn. Symp. North. Wild Sheep
and Goat Council 6: 292 - 306

SELECTIVE PREDATION BY COUGAR WITHIN THE JUNCTION WILDLIFE MANAGEMENT AREA

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Abstract: Cougar (*Felis concolor*) on the Junction Wildlife Management Area (W.M.A.) were fitted with radio collars and located by ground and aerial telemetry. General site reconnaissance and telemetry relocation work from 1986 to 1988 revealed 116 prey species remains on which 40 were confirmed as recent cougar kills. Bighorn rams (*Ovis canadensis californiana*) comprised 55.2% and 40.0% of the respective totals. Analysis indicated that cougars were selecting rams in greater proportion than would be expected based on their availability. Selection of rams appeared to be seasonal and linked to poor ram condition following the rigors of the rut.

The Junction W.M.A. of central British Columbia has supported a large population of approximately 150 California bighorn rams for the past two decades (Ministry of Environment [MOE] unpubl.). Population censuses and compulsory inspection harvest data from the early 1980's, however, indicated that the demographics of the ram component had shifted from the age structure seen during the previous decade. Older, full curl rams were less prevalent and comprised a lower proportion of the population (MOE unpubl.). Annual harvest was restricted with only 2-4 rams harvested through 5 limited entry permits from 1976-1982 and 4-6 rams harvested under 9 permits from 1983-1988. The discovery of 19 ram heads during a summer of general site reconnaissance disputed the notion that illegal harvest was solely responsible for the observed age structure of rams. Further reconnaissance revealed that a number of cougars were utilizing the Junction W.M.A.

Cougars have long been recognized as predators of bighorn sheep (Beuchner 1960, Sugden 1960, Kelly 1980), yet documentation of the occurrence and extent of this predation has been anecdotal at best. Lack of information on cougar/bighorn relationships does not reflect the potential importance of this predation for wild sheep populations but reflects the difficulties of monitoring and documenting the impact of this highly cryptic predator.

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Intensive studies of cougars have usually concentrated on home ranges and intraspecific population dynamics (Hornocker 1970, Seidensticker et al. 1973). Prey species composition has generally been gathered from hunter- killed cougar stomach samples or from incidental discovery of cougar kills during trapping efforts (Robinette et al. 1959, Spalding and Lesowski 1971, Toweill and Meslow 1977, Alberta Fish and Game Division unpubl.).

The Junction Cougar Study was undertaken to investigate the predator/prey dynamics of this system. Cougar density, distribution, and movement within the W.M.A. were assessed, and the hypothesis that selective predation by cougars was occurring on the ram component was tested. Data presented here were collected during initial field work conducted from April 1986 to January 1988.

A number of individuals have contributed to many facets of the Junction Cougar Study. In particular, M. Evans, J. Hirsch, D. Lay, T. Smith, R. Wright, E. (Slim) Shrek, T. Ardunini, and Mike, Tody, Jack, and Joe have provided valuable assistance. Financial support was provided by the B.C. Ministry of Environment Wildlife Branch (Williams Lake), Foundation for North American Big Game, Guide Outfitters Association of B.C., Foundation for North American Wild Sheep, The Williams Lake Sportsmen's Association, B.C. Conservation Foundation, and Lake City Ford in Williams Lake. Without the involvement of such individuals and organizations, quality field data from a study of this nature are difficult to obtain.

STUDY AREA

The Junction bighorn sheep range lies 35 km southwest of Williams Lake in the Chilcotin region of central British Columbia. The area is characterized by rolling plains and undulating grasslands that drop sharply from the 1070 m elevation of the Fraser Plateau to the 370 m river level. Douglas fir (Pseudotsuga menziesii) predominate 30-40% of the slopes leading to the Fraser River while bluebunch wheatgrass (Agropyron spicatum) and sagebrush (Artemisia tridentata) cover the sidehills and hogbacks dropping to the Chilcotin River.

The study area, which was larger than the W.M.A., was bounded by Highway 20 to the north, the Chilcotin River to the south, the Fraser River to the east, and the Wineglass Ranch road to the west (Figure 1). This bounded area represented 425 km^2, but consideration of the areas utilized by cougar, sheep, and mule deer (Odocoileus hemionus hemionus), resulted in a functional study area of approximately 150 km^2. An area of 6,300 km^2 was closed to the harvest of cougars. This closed area included the 425 km^2 bounded area and a 5,875 km^2 surrounding buffer zone.

METHODS

Collaring and Relocation with Radio Telemetry

All cougars utilizing the Junction W.M.A. were fitted with radio collars as outlined in Harrison (1987). General collaring procedures involved treeing the cougars with trained hounds, immobolizing animals

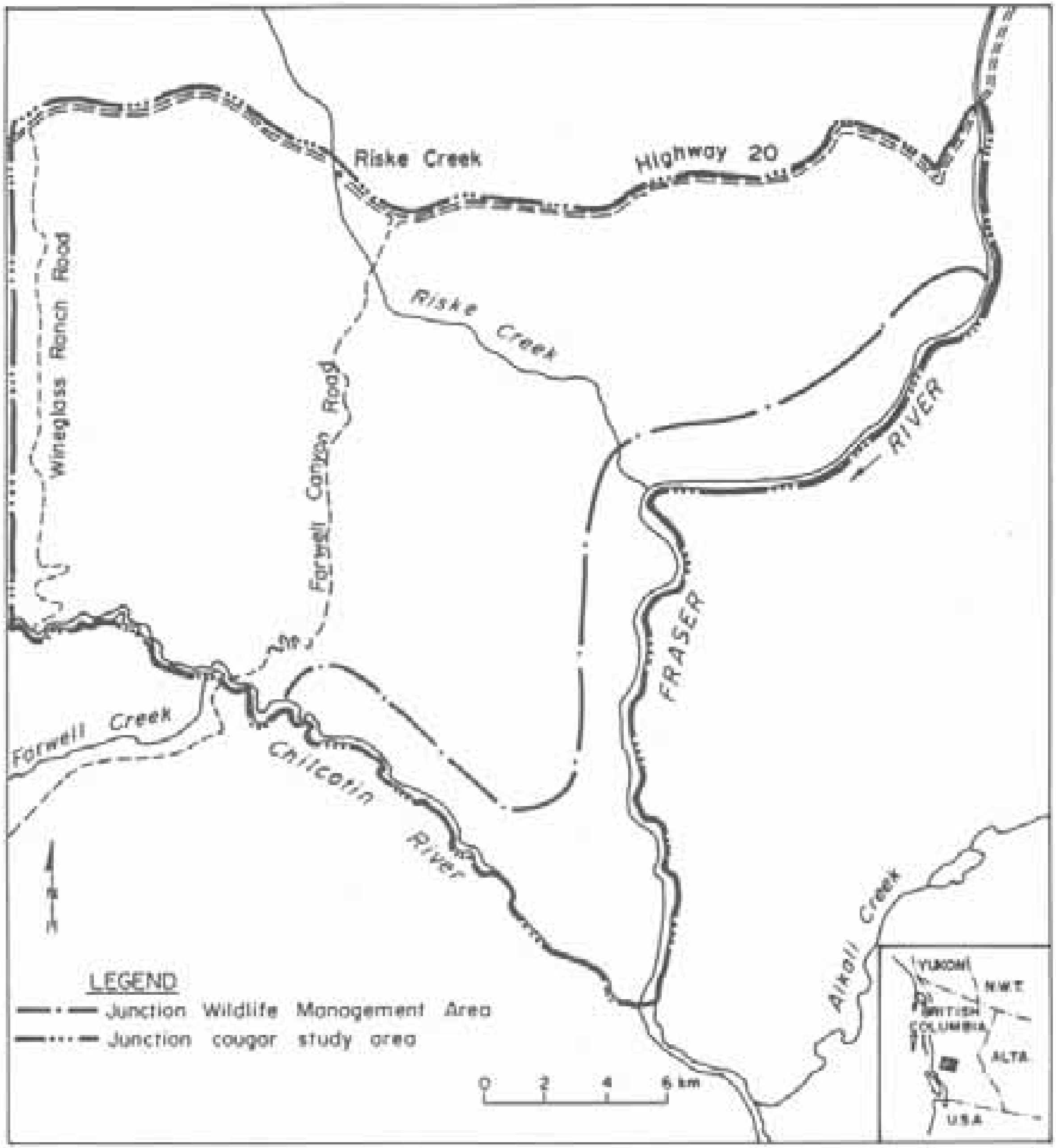

Figure I. Junction Wildlife Management Area and Junction cougar study area in central British Columbia. All cougars entering the study area were radio collared and monitored daily while in the study area. Biweekly telemetry flights were undertaken to find cougars that moved out of the study area.

with a mixture of ketamine hydrochloride and xylazine hydrochloride (4:1 ratio) and lowering drugged cougars by rope. The first cougars were collared in November 1986 with radio relocated occuring daily during intensive field work (December-September) and a minimum of 4 times/week the rest of the year. Ground telemetry work was conducted with a single hand-held H- antenna. Initial radio relocations were made from a series of high elevation points that enabled scanning of the entire study area. Triangulation was used to pinpoint the signal to a single draw or gulley. The ground work was periodically supplemented with aerial telemetry locations to locate animals, particularly males, that had undertaken long movements beyond the study area boundaries. Telemetry relocations were utilized under 2 sampling regimes:

Direct sampling.--When cougars were relocated in the same area for 2 consecutive days or were suspected to have made a kill, the area was subject to a ground sweep. The canyon nature of the Junction made it possible to search the individual draws for kill remains. In terrain types where such sweeps were ineffective, the cougar was approached prior to departure. Approaching cougars at kill sites was of concern, not only for safety considerations but for fear of "bumping" cougars from their kills whereby they would leave and not return. This was not a problem and occured at only 1 of the 40 site examinations.

Inference.--Bighorn sheep and mule deer both inhabit the study area; however, they are segregated through differential habitat use. Moreover, rams and ewes utilize different parts of the sheep range throughout most of the year (Ashcroft 1986). Relocating cougars in certain habitat types allowed inference about prey selection based on that areas' prey availability. Data collected under this second sampling regime are not dealt with in this paper.

Confirmation of Cougar Kills

Cougar kills were readily identified by a number of criteria: dragging the kill to cover, burying the carcass, intact removal and separate burying of the rumen, and the presence of buried scat mounds in close proximity to the kill. Tracks and sightings at kill sites also confirmed cougar involvement. It was assumed that cougars made- rather than scavenged- any kills indicating cougar involvement because cougars prefer freshly killed meat (Robinette et al. 1959), and there are no other predators on the Junction W.M.A. that prey consistently on adult ungulates.

Data Analysis

The total mortality sample included all carcasses and identifiable bones found on the Junction whether a confirmed cougar kill or not. Mortalities for which no head could be found were classified as unidentified. All unidentified mortalities were sheep rather than deer based on hair colour and likely, most were rams based on their location on ram range.

Tests for differences between the prey composition of the total mortality and confirmed kill samples were conducted using the G-test of independence at a significance level of P<0.05 (Sokal and Rolf 1981). For this analysis, confirmed kills and the unidentified sheep were removed from the total mortality sample.

For analysis of the confirmed kill data, the single lamb and fawn samples were added to their respective adult species and sex categories to avoid inadequate sample sizes. The coyote sample was dropped from the analysis because the coyote trapping effort (Hebert and Harrison 1988) was not constant throughout the cougar study thereby disrupting normal coyote population dynamics and complicating the estimation of coyote availability as a potential prey species.

Prey availability calculations varied for the two ungulate species. The Junction bighorn sheep are non-migratory and remain on the W.M.A. year-round. Sheep numbers were taken from triannual helicopter and ground counts. The majority of the deer population, however, is migratory and utilizes the Junction as a winter range. Deer availability was estimated from the regional deer density of 14 deer/km^2 calculated independently by the Habitat section (MOE unpubl.) and the Ministry of Forests Research section following a deer study (Ministry of Forests [MOF] unpubl.). Fourteen deer/km^2 represented the value for important wintering areas along migration corridors and may have been a high estimation for the Junction W.M.A. To correct for this, deer numbers calculated for the Junction with this density were adjusted by comparison with spotlighting indices (this study). Seasonal conversions of spotlighting indicies to population numbers followed McCullough (1982). A buck:doe ratio of 0.45 calculated from regional deer data (MOE unpubl.) was used for the analysis.

Determination of the extent of predation on bighorn sheep was made by varying deer availability as follows:

a) high deer numbers (1,700 deer)
b) moderate deer numbers (1,000 deer)
c) low deer numbers (102 deer)

Making the ram component of the prey population proportionately larger by conservatively estimating deer numbers yielded results which truely tested the notion of prey selection by cougars. This occurred under scenarios (b) and (c). Utilization-availability statistics using the Bonferroni z statistic to calculate 95% confidence limits were employed to test for prey selection by cougars (Neu et al. 1974).

Only the ram and deer components were plotted in the monthly distribution of confirmed kills to show trends specifically related to these 2 prey types. The exact month in which 3 rams and 1 deer were killed could not be determined and they were excluded from the analysis.

RESULTS

A total of 116 prey mortalities were discovered from April 1986 to January 1988 (Figure 2). Of this total, 40 were confirmed as recent cougar kills (Figure 3). The confirmed sample represents kill data collected from 2 adult females each with 2 kittens. The number of

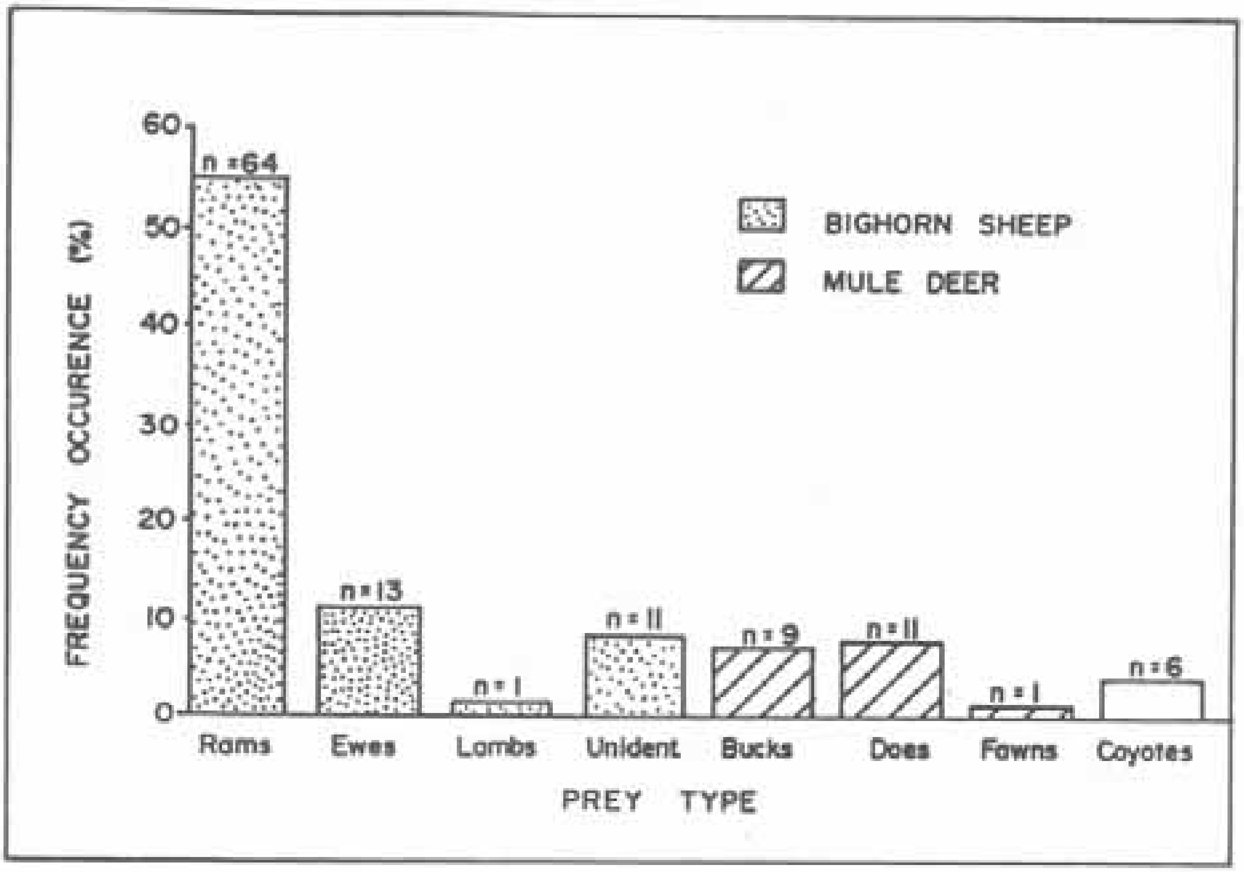

Figure 2. Total mortalities found in the Junction Wildlife Management Area, British Columbia. (April 1986 - January 1988)

confirmed kills represents a conservative figure since the majority of the total mortality sample was found prior to collaring and intensive monitoring of cougars. Moreover, many of the mortalities were discovered in areas indicative of cougar kills such as covered gullies or beneath trees in more open areas.

Tests for sample differences between the total mortality and confirmed kill samples indicated that proportions were not similar ($G = 13.53; P<0.01$). The prey species composition of both samples, however, reflected the general proportion of prey species occurrence and the predominance of rams.

Analysis of the confirmed kill data revealed that prey species were not utilized equally for either moderate ($X^2 = 48.17; P<0.001$) or low ($X^2 = 35.26; P<0.001$) estimations of prey numbers. Utilization-availability statistics showed that cougars were preying on bighorn rams in greater proportion than would be expected based on their availability in the potential prey population (Tables 1 and 2).

Categorizing the confirmed kills the confirmed kills by month revealed that the majority of rams were taken during the late fall and

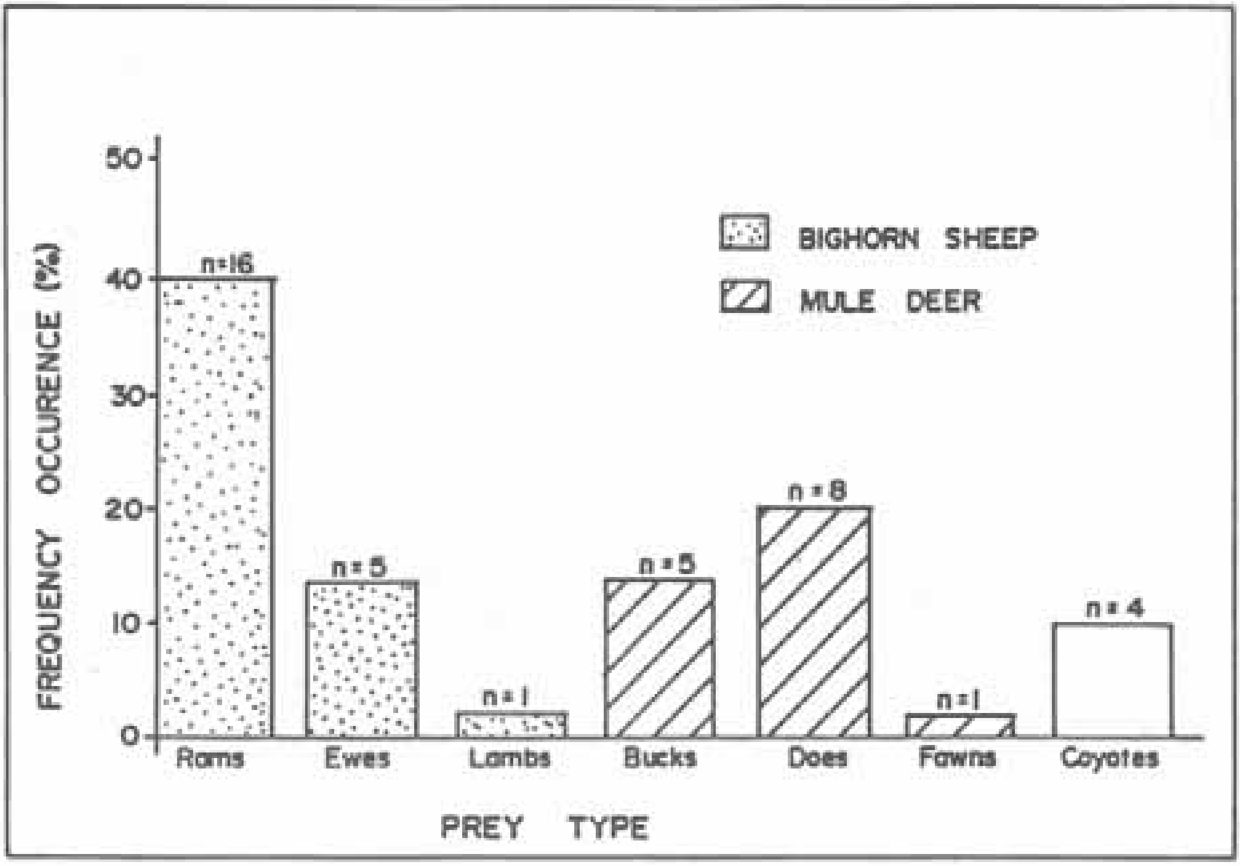

Figure 3. Confirmed kills from 2 radio-collared female cougars in the Junction Wildlife Management Area, British Columbia. (December 1986 - January 1988)

early winter months ($X^2 = 30.48$; $\underline{P} < 0.01$) while deer were selected during the midwinter and spring months ($X^2 = 21.21$; $\underline{P} < 0.05$) (Figure 4). The lack of samples recorded during August and September reflected a decreased efficiency finding kills due to changes in cougar movements and distribution resulting from intraspecific interactions in May 1987. These changes affected the discovery of summer sheep and deer mortalities equally.

DISCUSSION

The high proportion of rams found in the total mortality sample indicated that rams were dying of natural causes, and although some illegal harvest probably did occur, it was not the major cause of the decline in the number of large rams at the Junction. The 11 unidentified sheep carcasses represented animals that may have been poached; however, legal harvest would have accounted for some of this sample because hunters are required to remove only 1 hindquarter under B.C. hunting regulations for bighorn sheep. Other unidentified sheep would have died due to natural causes, including predation, with the heads being removed by hikers or previous researchers.

Table 1. Proportion of prey species in confirmed cougar kill sample found on the Junction Wildlife Management Area (December 1986 - January 1988) calculated for moderate deer numbers.

Prey species	Total prey numbers	Proportion of total prey population (availability)	Confirmed # of cougar kills	Expected # of cougar kills	Proportion of confirmed kills (p_i) (utilization)	Confidence Intervals (95%)
Rams	150	0.097	17	4	0.472	$0.230 < p_1 < 0.714$
Ewes	400	0.258	5	9	0.139	$(-0.028) < p_2 < 0.306$
Bucks	310	0.200	6	7	0.167	$(-0.013) < p_3 < 0.347$
Does	690	0.445	8	16	0.222	$0.021 < p_4 < 0.423$
Totals	1550	1.000	36	36	1.000	

$X^2 = 48.17$; $P < 0.001$

Table 2. Proportion of prey species in confirmed cougar kill sample found on the Junction Wildlife Management Area (December 1986 - January 1988) calculated for low deer numbers.

Prey species	Total prey numbers	Proportion of total prey population (availability)	Confirmed # of cougar kills	Expected # of cougar kills	Proportion of confirmed kills (p_i) (utilization)	Confidence Intervals (95%)
Rams	150	0.230	17	8	0.472	$0.230 < p_1 < 0.714$
Ewes	400	0.614	5	22	0.139	$(-0.028) < p_2 < 0.306$
Bucks	32	0.049	6	2	0.167	$(-0.013) < p_3 < 0.347$
Does	70	0.107	8	4	0.222	$0.021 < p_4 < 0.423$
Totals	652	1.000	36	36	1.000	

$X^2 = 35.26$; $P < 0.001$

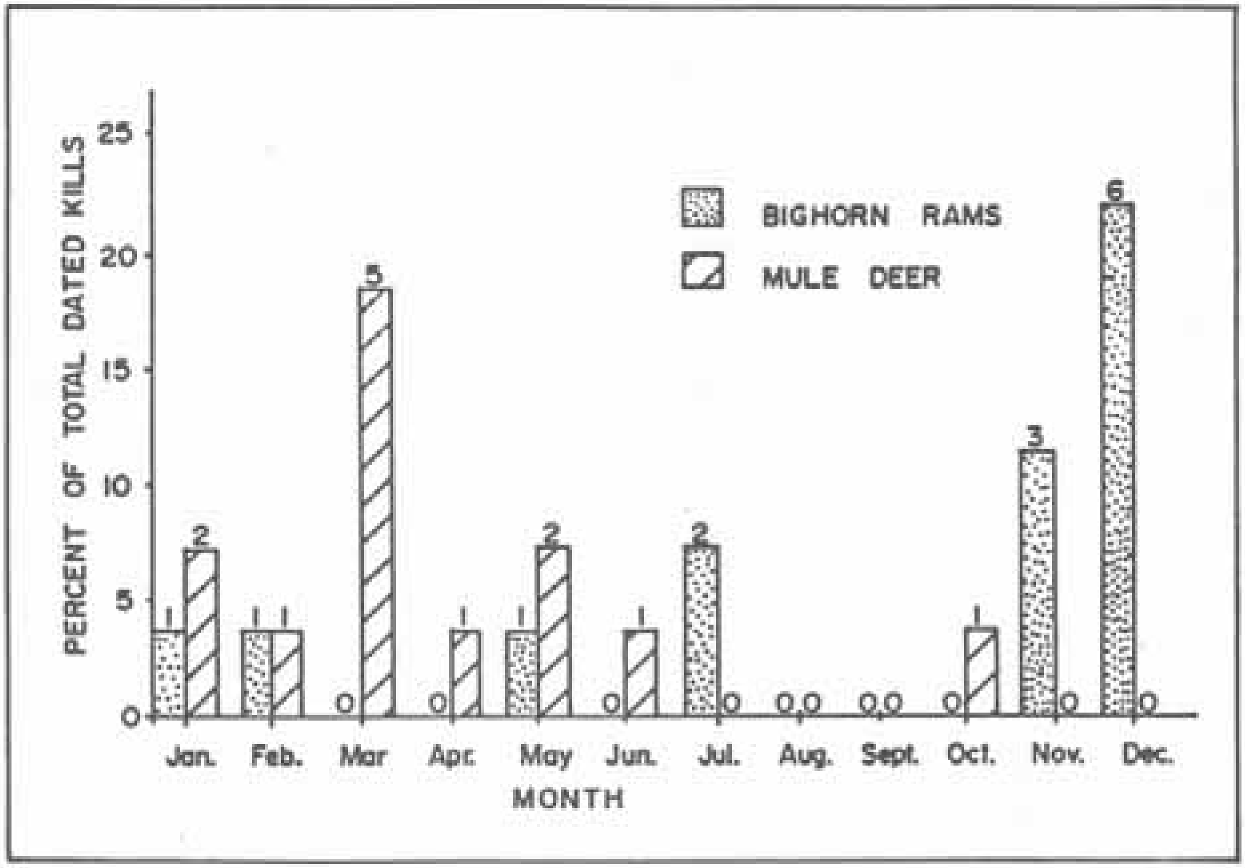

Figure 4. Monthly distribustion of bighorn rams and mule deer killed by radio-collared cougars in the Junction Wildlife Management Area, British Columbia.(December 1986-January 1988). Sample sizes shown above.

The differences between the total mortality and confirmed kill samples were the result of the higher proportion of rams in the total sample which, to some degree, reflected differential species and sex skull perishability of the ungulate species involved (Murphy and Whitten 1976). The confirmed kill data, however, were the result of the intensive radio relocation and sampling regime and not reflective of the perishability differences.

The direct sampling method was particularly effective for locating kills of females with young, collared kittens. The kittens would remain at the kill site while the female moved off to hunt. As the kittens became older, however, the rate at which kills were located declined despite the fact that the utilization rate and likely the kill rate were increasing. An increase in mobility around kills made it more difficult to rely solely on the kittens' location to mark the site. The central area of kitten activity could be approached using ravens (Corvus corax), bald eagles (Haliaeetus leucocephalus), and golden eagles (Aquila chrysaetos) as distant markers (100-200 m radius) and magpies (Pica pica) as more exacting markers (5-10 m radius) of the kill site.

The difficulty finding summer kills resulted from a series of intraspecific interactions among the cougars of the area. In May 1987, tracks of an uncollared cougar were found in the vicinity of both collared family groups (two adult females each with 2 kittens). Within 1 week, the 2 kittens of 1 family had been killed by a cougar (Provincial Vet Lab necropsy rep.) and the other family had vacated the study area by crossing the Chilcotin River despite full freshet conditions and a river width of 15 m. The result was a single collared female in the area for most of the summer although the other family group did return.

Evidence of Selective Predation

Documentation of a predator's prey species composition is useful for addressing a number of aspects of predator/prey interactions especially the selection of specific prey types. Selection of mule deer bucks by cougars has been reported in a number of studies (Robinette et al. 1959, Hornocker 1970, Shaw 1975, Russell 1978); however, after analyzing prey species composition of 6 such cougar studies, Anderson (1983) concluded "the assertion of puma selectively killing certain sex and age classes of mule deer remains an untested hypothesis".

Inherent in the examination of prey selectivity is the need for an understanding of prey availability. Difficulties in determining the availability and the population structure of the prey base has precluded definitive statements on cougar prey selection. This is particularly true when examining the intraspecific selection of deer. Deer availability and population structure are difficult to document particularly in forested habitats. Although a number of deer censusing techniques have been developed (Lewis and Farrar 1968, Floyd et al. 1979, McCullough 1982), they are often prohibitively expensive or ineffective in the terrain types of most cougar study sites. Indices of relative deer abundance, however, are readily obtained through seasonal spotlight counts and can provide valuable information in the examination of cougar prey selection under two conditions:

1) inter rather than intraspecific prey selection is being examined, and

2) good population composition data are available for the alternative prey species.

In this study, bighorns represented the alternative prey for which population data were available (Ashcroft 1986, MOE unpubl.). Relative abundance of deer became important only in determining the extent of selective predation by cougars on sheep with respect to deer.

Moderate prey numbers (Table 1) represented the conservative estimation of the prey base wintering on the study site from late October to April. Under this scenario, rams were clearly utilized by a significantly greater proportion (47.2%) than they were available (9.7%) in the total prey population.

To further examine the extent of cougar prey selectivity, the estimated deer population was reduced to a level where the proportional availability of rams equalled the lower limit of the 95% ram utilization confidence limit (Table 2); that is, the deer numbers were lowered to the point where selection of rams was, statistically, no longer occurring given a significant level of $P<0.05$. To achieve this, the deer population had to be reduced to 102 animals: an unrealistic winter figure given that 131 deer have been counted in a single 5 km^2 field during fall spotlight counts (this study).

The breakdown of the confirmed kills by month (Figure 3) revealed that utilization of both deer and rams peeked during the fall to spring period suggesting that wintering deer numbers (Table 1) were more appropriate for the analysis. This revealed that strong selection of rams by cougars was occurring on the Junction W.M.A.

Reasons for Selective Predation

Cougars are capable of killing a wide range of prey species (Anderson 1983) under a wide range of conditions. Reports of a 43 kg female cougar killing 6-point bull elk (Hornocker 1976) and observations of cougars stalking and killing prey on open grasslands (this study) attest to the cougar's predatory abilities. Despite this prowess as a top predator, cougars must still acquire prey within the constraints of predator/prey dynamics. The functional responses of predators to varying prey densities have been demonstrated in foraging experiments (Holling 1965). Prey palatability was an important component determining the predator's prey selection in the systems studied; however, Holling also recognized that behavioural and physiological characteristics of the prey may be important in determining prey choice in other systems.

The solitary nature of male mule deer combined with their preference for rugged, dense habitat have been cited as behavioural factors that increase buck vulnerability to the stalking attack of cougar (Robinette et al. 1959, Hornocker 1970, Spalding and Lesowski 1971). Work done on sexual segregation and group size in the Junction bighorn herd, however, showed that ram group size and habitat use were stable year-round outside of the October rut (Ashcroft 1986). Moreover, the annual concentration of cougar-killed rams suggested that while both prey group size and habitat selection were undoubtedly important parameters in determining prey vulnerability and cougar hunting success, these factors alone did not adequately explain the observed pattern of cougar predation observed at the Junction. The selection of rams occurred during November and December when poor condition following the October rut would have been an important factor underlying ram vulnerability to predation.

The rut represents a time of high energy demands for rams. Despite the long, intense battles throughout the rut, rams do little or no foraging (Geist 1971) resulting in extremely poor body condition. The inattentiveness of rams resulting from poor post-rut condition likely predisposed them to the observed cougar predation. It has been suggested that bucks' pre-occupation with the activity of the rut increases their vulnerability to cougar predation (Robinette et al. 1959). This was not the case observed here as no cougar-killed rams were found during the rut.

Another series of factors potentially important in determining cougar selection of rams relate to horn size. Social dominance in bighorn sheep is related to horn size with the larger, dominant rams involved in most of the active rutting (Geist 1971). Large rams likely enter the post-rut period in particularly poor condition although, as Festa-Bianchet (1987) pointed out, this remains an untested bypothesis as younger rams may expend energy attempting to gain access to estrous ewes (Hogg 1984). Even if all rams enter the post-rut period in equally poor condition however, the larger horned rams would be more vulnerable to cougar predation due to the nature of the attack. Cougars stalk prey to within some critical distance (Hornocker 1970) and then pounce on the back of the prey and biting at the base of the neck (Robinette et al. 1959). Large, full curl rams would be particularly vulnerable to this form of attack because of inhabited rear and peripheral vision.

Horn structure may have also been responsible for the low cougar utilization of ewes. The short, relatively straight horns of the ewes may represent greater injury potential for a cougar biting at the base of the neck. By throwing her head back, even if an uncontrolled response, a ewe's horns are more likely to strike the cougar.

Implications of Selective Predation

Cougars were found to be selecting rams at the Junction W.M.A. following the rut as cougars keyed on the exhausted and less wary rams. The relationship demonstrated here between reproductive effort--the rut, and the associated costs--an increased vulnerability to predation, have implications for the ecological fitness of rams. If this pattern of predation is a regular component of the Junction predator/prey system, it may pay rams to expend less energy during any one rut. The cost of such a strategy would be a decrease in short-term breeding success while the benefit would be increased survival resulting in long term breeding success and overall fitness.

Cougar predation may, conversely, be a relatively new component of the Junction system as provincial cougar numbers recover from the combination of predator control and disease epidemics that are believed to have reduced cougar numbers significantly during the 1950's and 1960's (MOE 1980). If the observed pattern of cougar predation has only recently become a part of the Junction system, the resulting trends in the sheep population may serve as a natural test of a hypothesis linking lower production in sheep populations to breeding by immature rams (Heimer and Watson 1986).

Another implication of this study relates to predator/prey systems and the perception of predation in a more general sense. Wild sheep biology involves the examination of the factors affecting sheep population dynamics. Discussions of escape terrain and predator avoidance behaviour are common place in this examination (Buechner 1960, Sugden 1961, Demarchi and Mitchell 1973, Gionfriddo and Krausman 1986, Festa-Bianchet 1988); yet, actual predation on sheep is rarely documented. This often lead to the conclusion that predation is a minor or nonexistent component of even the most intensively studied sheep populations.

Predators, particularly the act of predation, are extremly difficult to observe, quantify, and document. To accomplish this requires a different approach to field work. Dead sheep are found in markedly different places than live ones. The discovery of these mortalities requires reconnaissance of the thickets and gulley bottoms: places sheep biologists rarely venture. Regular, systematic searches of this sort are required to find mortalities within the 1 or 2 days of death that enables a realistic assessment of the cause of death. The time and physical constraints of such searches are obviously high; however, without them little can or should be concluded about the extent of predation on wild sheep popupations.

LITERATURE CITED

Anderson, A. E. 1983. A critical review of literature on Puma (*Felis concolor*). Colorado Division of Wildlife Research Section. Special Report Number 54.

Ashcroft, G. E. W. 1986. Sexual segragation and group sizes of California bighorn sheep. M. Sc. Thesis. University of British Columbia, Vancouver B.C. 55 pp.

Buechner, H. K. 1960. The bighorn sheep in the United States. Its past, present, and future. Wildl. Monogr. 4. 174 pp.

Demarchi, D. A. and H. B. Mitchell. 1973. The Chilcotin River bighorn population. Can. Field-Nat. 87:433-454.

Festa-Bianchet, M. 1987. Survival of bighorn rams in southwestern Alberta: why do some rams die young? Can. J. Zool. (in press).

________. 1988. Seasonal range selection in bighorn sheep: conflicts between forage quality, forage quantity, and predator avoidance. Oecologia. (in press).

Floyd, T. J., L. D. Mech and M. E. Nelson. 1979. An improved method of censusing deer in deciduous-coniferous forests. J. Wildl. Manage. 43:258-261.

Geist, V. 1971. Mountain sheep: a study in behaviour and evolution. University of Chicago Press, Chicago. 300 pp.

Gionfriddo, J. P. and P. R. Krausman. 1986. Summer habitat use by mountain sheep. J. Wildl. Manage. 50:331-336.

Harrison, S. W. 1987. The Junction cougar study: preliminary progress report. Ministry of Environment, Wildlife Branch. Queen's Printer Victoria, British Columbia. 7 pp.

Hebert, D. M. and S. W. Harrison. 1988. The impact of coyote predation on lamb survival at the Junction Wildlife Management Area. Bienn. Symp. North. Wild Sheep and Goat Counc. (this issue).

Heimer, W. E. and S. M. Watson. 1986. Harvest strategy panel: maximizing ram harvests. Bienn. Symp. North. Wild Sheep and Goat Counc. 5:24-33.

Hogg, J. T. 1984. Mating in bighorn sheep: multiple creative male strategies. Science 225:526-529.

Holling, C. S. 1965. The functional response of predators to prey density and its role in mimicry and population regulation. Memoirs of the Entomological Society of Canada. No. 45. 60 pp.

Hornocker, M. G. 1970. An analysis of mountain lion predation upon mule deer and elk in the Idaho Primitive Area. Wildl. Mongr. 21. 39 pp.

_______. 1976. Comments. Page 45 in G. C. Christensen and R. J. Fischer, co-chairmen. Trans. Mountain Lion Workshop. U.S. Fish and Wildl. Serv., Portland, Oregon and Nevada Fish and Game Dept., Reno. 213 pp.

Kelly, W. E. 1980. Predator relationships. Pp 187-195 in G. Monson and L. Sumner (Eds.), the desert bighorn, its life history, ecology and management. Univ. Arizona Press. Tucson, Arizona. 370 pp.

Lewis, J. C. and J. W. Farrar. 1968. An attempt to use the Leslie census method on deer. J. Wildl. Manage. 32:760-764.

McCullough, D. R. 1982. Evaluation of night spotlighting as a deer study technique. J. Wildl. Manage. 46:963-973.

Murphy, E. C. and K. R. Whitten. 1976. Dall sheep demography in McKinley Park and a reevaluation of Murie's data. J. Wildl. Manage. 40:597-609.

Ministry of Environment. 1980. Preliminary cougar management plan for British Columbia. Queen's Printer, Victoria, B.C. 23 pp.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38:541-545.

Robinette, W. L., J. S. Gashwiler, and O. W. Morris. 1959. Food habbits of the cougar in Utah and Nevada. J. Wildl. Manage. 23:261-273.

Russell, K. R. 1978. Mountain lion. Pp 207-225 in J. L. Schmidt and D. L. Gilbert (Eds.), Big game of North America: ecology and management. Stackpole Books, Harrisburg, PA. 494 pp.

Seidensticker, J. C., M. G. Hornocker, W. V. Wiles, and J. P. Messick. 1973. Mountain lion social organization in the Idaho Primitive Area. Wildl. Monogr. 35. 60 pp.

Shaw, H. G. 1975. Impact of mountain lion on mule deer and cattle in northwestern Arizona. Pp 17-32 in R. L. Philips and C. Jonkel (Eds.), Proc. of 1975 Predator Symp. Univ. Montana, Missula. 268 pp.

Sokal, R. R. and F. J. Rohlf. 1981. Biometry. 2nd ed. Freeman and Co. San Francisco, Calif.

Spalding, D. J. and J. Lesowski. 1971. Winter food of the cougar in south-central British Columbia. J. Wildl. Manage. 35:378-381.

Sugden, L. S. 1961. The California bighorn in British Columbia with particular reference to the Churn Creek herd. British Columbia Department of Recreation and Conservation, Queen's Printer, Victoria, B.C. 58 pp.

Toweill, D. E. and E. C. Meslow. 1977. Food habits of cougars in Oregon. J. Wildl. Manage. 41:577-578.

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THE EFFECT OF WOLF REDUCTION ON DALL SHEEP DEMOGRAPHY IN THE SOUTHWEST YUKON.

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Abstract: Wolf density in an 11,200 sq. km area in the southwest Yukon was reduced in 1984 from an estimated 1.2 ± 0.2 wolves per 100 sq. km., providing the impetus to examine its effect on Dall sheep demography. Two areas were surveyed for sheep in July, from 1980 to 1986, one within the wolf removal area, another isolated from the area of systematic wolf reductions. Sheep population size, composition and mid-summer productivity were determined.

Population size varied between years, following a pattern that was consistent between areas. No clear association with wolf density was evident. Nursery sheep numbers in particular closely tracked one another between areas. Ram numbers in the removal area did not enjoy the growth observed in the control area, which appeared to be linked to harvest levels. The sheep harvest in the area within and surrounding the removal area since wolves were reduced occurred at a rate doubling that found in the control area. Nursery sheep numbers appeared to be linked to the rate of lamb production and on an area specific basis, to the previous year's production of lambs. The number of half curl rams across all subzones also varied strongly between years independent of area, and appeared to be linked to previous lamb production, implying that ram numbers are also influenced by gaps and pulses generated by variable lamb production.

Lamb production varied strongly between year, consistently between areas, and appeared to be tied to general weather patterns.

We suggest that general differences in sheep demography between the control and removal areas were associated with sheep density; areas with higher sheep density produced fewer lambs, with slightly less variability between years and appeared to enjoy higher rates of survival, particularly in the lamb year.

Variable densities of wolves, then, in time and across areas produced no predictable response in sheep demography. Rather, demographic trends appeared largely as an expression of lamb production, resulting in cohort gaps and pulses transferred over all sex and age segments.

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and Goat Counc. 6: 308 - 329

FACTORS AFFECTING THE POPULATION DYNAMICS OF MOUNTAIN GOATS IN WEST-CENTRAL ALBERTA.

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Abstract: Populations of mountain goats (*Oreamnos americanus*) in Willmore Wilderness Park of west-central Alberta were inventoried from 1973 to 1987. Hunted populations increased until 1980 - 1983, while harvest rates were held at 4.5 - 9.0%. Most populations began declining following 1980-83 as a result of poor kid production combined with below average survival of kids-to-yearling age. Harvest was reduced or eliminated after that period. The influence of additive harvest mortality on kid production and the possibility of increased predation and weather are implicated in relation to the decline.

Throughout their range, the response of mountain goat populations to regulated harvest has varied between native and introduced herds and between areas. Hunter-caused mortality was considered additive in the decline of native herds in Idaho (Kuck 1977), Montana (Chadwick 1983), and British Columbia (Hebert and Turnbull 1977); however, it was considered compensatory in introduced herds that increased in Montana (Swenson 1985, 1986). Density-dependent responses in mountain goat reproduction, kid survival (Adams and Bailey 1982) initial breeding and litter size (Houston and Stevens 1988) have been observed in introduced herds. Smith (1984) examined trends in native mountain goat populations on coastal mountain ranges in Alaska with limited hunting pressure and found a period of population reduction from 1968 - 1975 followed by a period of population increase (1976 - 1983) equal to or greater than those values reported for introduced herds in Colorado and Idaho (Hayden 1984).

Aerial surveys flown since 1973 in the Willmore Wilderness Park of west-central Alberta were used to monitor mountain goat populations under a relatively constant harvest regime. Based on data collected prior to 1979 (Hall and Bibaud 1978, Youds et al. 1980), a formal harvest strategy of 5% of the observed minimum population estimate from aerial surveys was adopted. The harvest rate was contingent upon minimum recruitment and survival rates of 57 kids:100 females (28.5 kids: 100 adults ≥ 2-years-old), a kid mortality rate of 40%; a yearling mortality rate of 10% and an adult mortality rate of 7%. This approach, a "tracking harvest strategy", was first proposed for ungulates (Caughley 1977:197) and later considered necessary for successful management of mountain goats (Smith 1984). Herds continued to increase under this harvest regime until a period between 1980 and 1983. Since then the populations have decreased despite a reduction in harvest.

The objective of this paper is to explore the cause(s) of the decline in mountain goat populations in west-central Alberta by examining the effects of harvest and weather on recruitment and survival of mountain goat kids and thus the population dynamics of these herds.

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STUDY AREA

The Willmore Wilderness Park (WWP) is located directly north of Jasper National Park and along the British Columbia border in west-central Alberta (Fig. 1). The topography is dominated by several large mountain complexes and the elevation varies from 975 to 3098 m. The weather is characterized by long, cold winters and cool, wet summers with annual precipitation on the eastern edge averaging 540 mm. However, the western portion may receive as much as 1500 mm of precipitation (Alberta Wilderness Association 1973). Vegetation below treeline is dominated by white spruce (*Picea glauca*) and alpine fir (*Abies lasiocarpa*) with lodgepole pine (*Pinus contorta*) on fire-regenerated sites. Above tree line (about 1700 m), the alpine meadows are comprised of grass and sedge species as well as lichens, mosses and a variety of herbaceous species. Further descriptions can be found in Hall (1977), Hall and Bibaud (1978) and Youds et al. (1980).

This paper refers to 11 mountain goat survey areas in or near WWP that were grouped under the category Willmore study area (Fig. 1).

METHODS

Annual helicopter surveys of hunted populations of goats were conducted from 1973 to 1987 by flying mountain complexes above timberline. (Poor weather hampered survey attempts in 1978 and consequently, data are not available for that year). The navigator/principal observer was to the left of the pilot, the second observer was in the left rear seat with the recorder in the right rear seat. Beginning in 1974 mountain goats were classified as kids, yearlings and adults (≥ 2-years-old). Most surveys were conducted in early July after "nursery" herds had congregated. An effort was made to fly between 0600 - 0900 and between 1700 - 2200 when goats were most active. Aerial surveys of non-hunted herds began in 1979. Aerial survey effort was reduced by 80% in 1982 and subsequent flying time allotments resulted in 2/3 of the survey areas being inventoried only on alternate years.

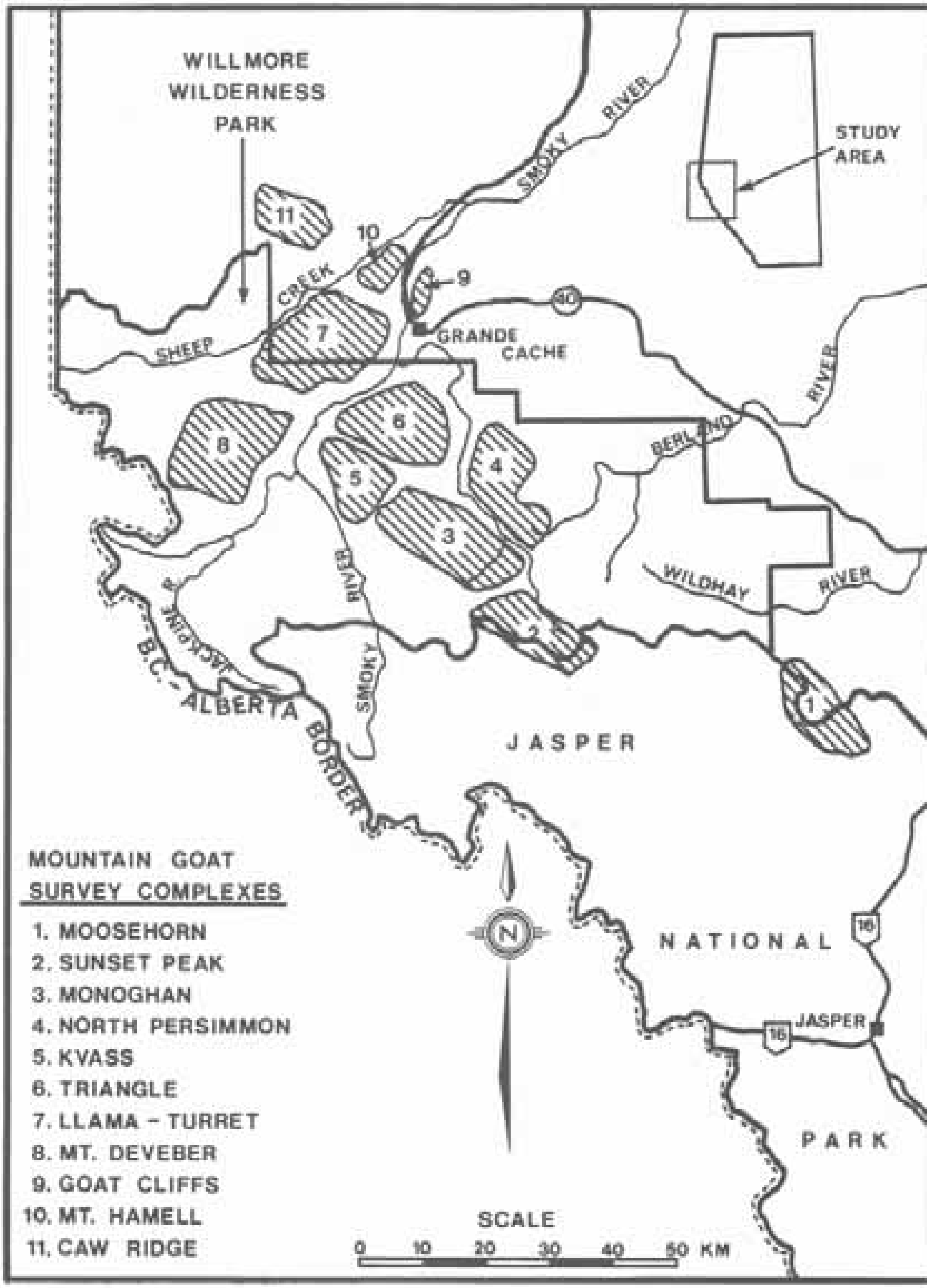

Fig. 1. Distribution of mountain goat survey complexes in the Willmore Wilderness Park study area of west-central Alberta.

Table 1. Calculation of mountain goat kid survival rates to yearling age by 2 techniques.

Year	% Survival - Hunted		% Survival - Non-Hunted	
	Ratio[a]	Observed no.[b]	Ratio	Observed no.
1974	65%	55%		
1975	77%	71%		
1976	35%	31%		
1977	60%	72%		
1978				
1979	66%			
1980	75%	73%	68%	44%
1981				
1982				
1983	41%	50%	55%	64%
1984	53%	51%	34%	49%
1985	49%	50%	10%	9%
1986	25%	28%	53%	67%
1987	36%	35%		

[a]Survival rates calculated by comparing the yearling/adult ratio to the kid/adult ratio from the previous year in each complex.
[b]Survival rates calculated by comparing the actual number of yearlings to the number of kids from the previous year in each complex.

The number of mountain goats observed in each mountain complex was considered the minimum population. In the same mountain complex, kid/adult ratios were compared to the yearling/adult ratio for the following year in order to estimate kid survival to yearling age (13 months). A second method of calculating the kid survival rate was to compare the actual numbers of kids and yearlings observed in the same complex in subsequent years. The two methods resulted in similar survival values (Table 1) and survival rates based on ratios were used because of larger sample sizes. Confidence limits for age ratios were calculated after Bowden et al. (1984).

Annual permit allocations from 1978 - 1987 were determined by taking 5% of the minimum population estimate and dividing it by the mean hunter success rate for previous years in each individual mountain goat hunting area. Harvest data were collected by compulsory hunter registration of each goat harvested. Age was determined by sectioning the first incisor.

Weather data (mean monthly temperature, total monthly precipitation and total monthly snowfall) were obtained from the Alberta Forest Service Ranger Station at Grande Cache, which borders the eastern side of Willmore Wilderness Park at an elevation of 1310m. Regression analyses were conducted using SPSS.PC+ statistical package to investigate relationships between weather variables and the mountain goat recruitment indices. The recruitment indices were kid/adult ratios and survival to 13 months of age based on aerial survey results. Correlation analyses were used to investigate multicollinearity (which could indicate some degree of covariation in the explanatory variables) and to investigate relationships between the number of mountain goats harvested and the % of females in the fall harvest with recruitment and kid survival the following summer. In addition, Durbin-Watson statistics were calculated to investigate autocorrelation in a time-series regression problem such as this study.

Population trends were determined by regression of the natural log of observed numbers on time. The slope of the regression line, $\bar{r}$, represents the mean annual exponential rate of increase or decrease (Caughley 1977:109).

Mean winter temperatures, considering the period October to April inclusive, were computed for each year from 1975-1987, as well as total winter snowfall for the same months. The data for each given year were then compared to the long-term mean value, and the deviation was expressed as a percentage (negative or positive). These two deviations, one for temperature and one for snow, were then combined by addition, and the sum referred to as the "annual winter severity index" (see Burles et al. 1984).

RESULTS

Hunted mountain goat herds on most of the mountain complexes increased during the period 1974 - 1980 (Fig. 2). Between 1980 and 1983, they began declining and continued to do so through 1987. Non-hunted herds increased, or declined only slightly during the same time period (Fig. 3). Mean kid/adult ratios in hunted herds were significantly lower (ANOVA, $F = 28.37$, $P = 0.0003$) during a portion of this decline (1982 - 1986) than were the observed ratios for the period of increase (1974 - 1981) (Fig. 4). Mean kid/adult ratios in non-hunted herds also declined during 1982 - 1986 (Fig. 4), but were significantly higher (ANOVA, $F = 5.79$, $P = 0.03$) than those documented for hunted herds during 1979 to 1986. Mean kid survival estimates to 13 months for hunted herds were lower, though not significantly, (ANOVA, $F = 4.09$, $P = 0.07$) from 1982 to 1986 than the estimates documented previously for the 1974 to 1981 period (Fig. 5). Non-hunted herds had lower kid survival rates after 1980 (Fig. 6), but these were not significantly different from their hunted counterparts during the period 1979 - 1986 (ANOVA, $F = 0.55$, $P = 0.48$).

The mean kid/adult ratios were not significantly correlated with harvest ($P = 0.38$), the % of females in the harvest ($P = 0.40$) or age of harvested goats ($P = 0.62$) at the overall study area level. Nor were mean kid survival rates correlated with any of these independent variables ($P = 0.43$, $P = 0.33$ and $P = 0.76$, respectively).

When the influences of monthly snowfall, monthly precipitation and mean monthly temperature were examined individually, October temperature exhibited a positive correlation ($P = 0.002$) with mean kid/adult ratios in hunted herds (Table 2). April temperature ($P = 0.036$) showed a positive correlation with mean kid/adult ratios in non-hunted herds, and October precipitation was negatively correlated ($P = 0.045$) (Table 2). Individual months of cumulative snowfall were not significantly correlated

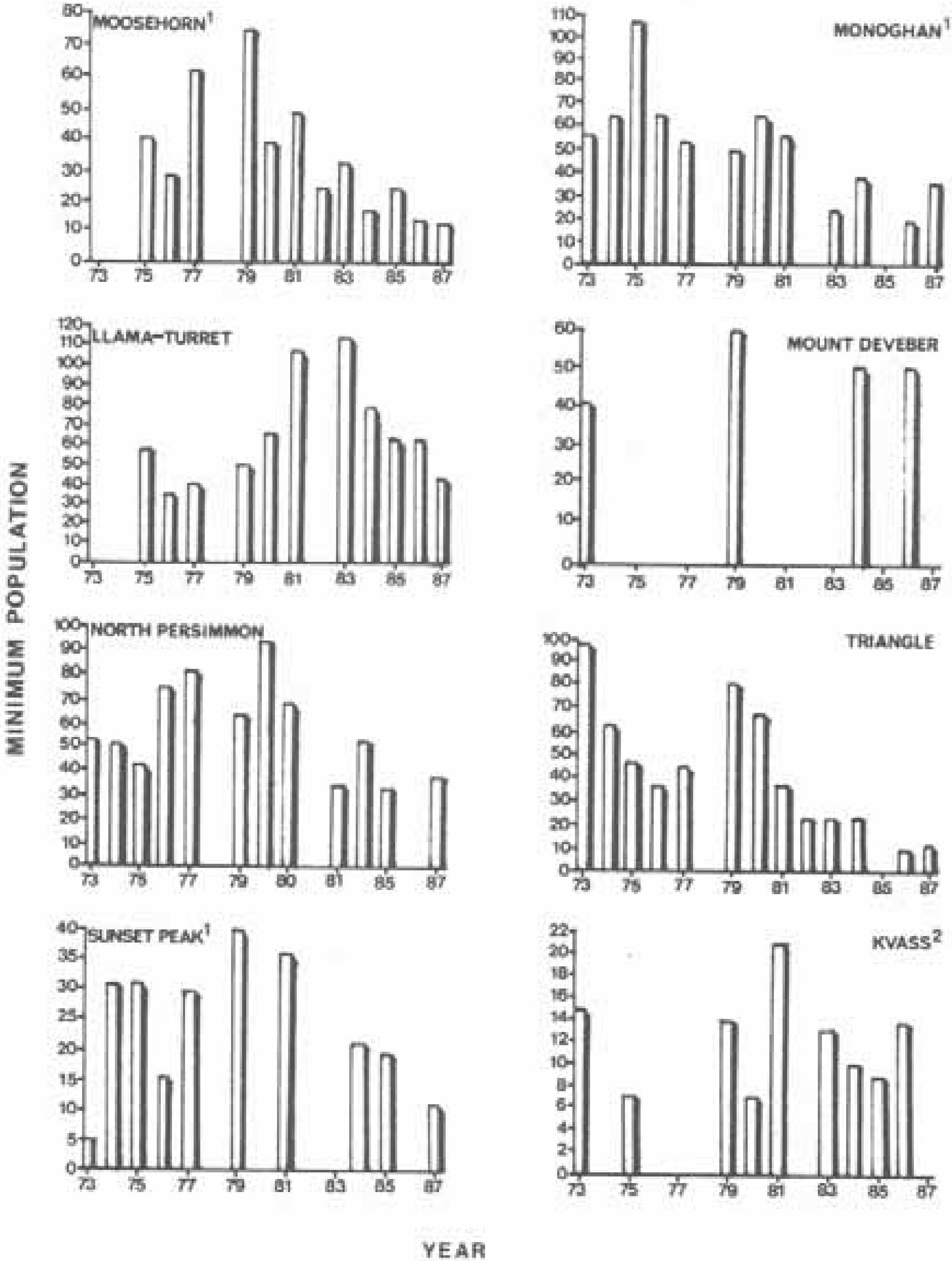

Fig. 2. Minimum mountain goat population estimates for 8 hunted herds in Willmore Wilderness Park based on aerial surveys, 1973-1987. (1=not hunted after 1986, 2=not hunted after 1984)

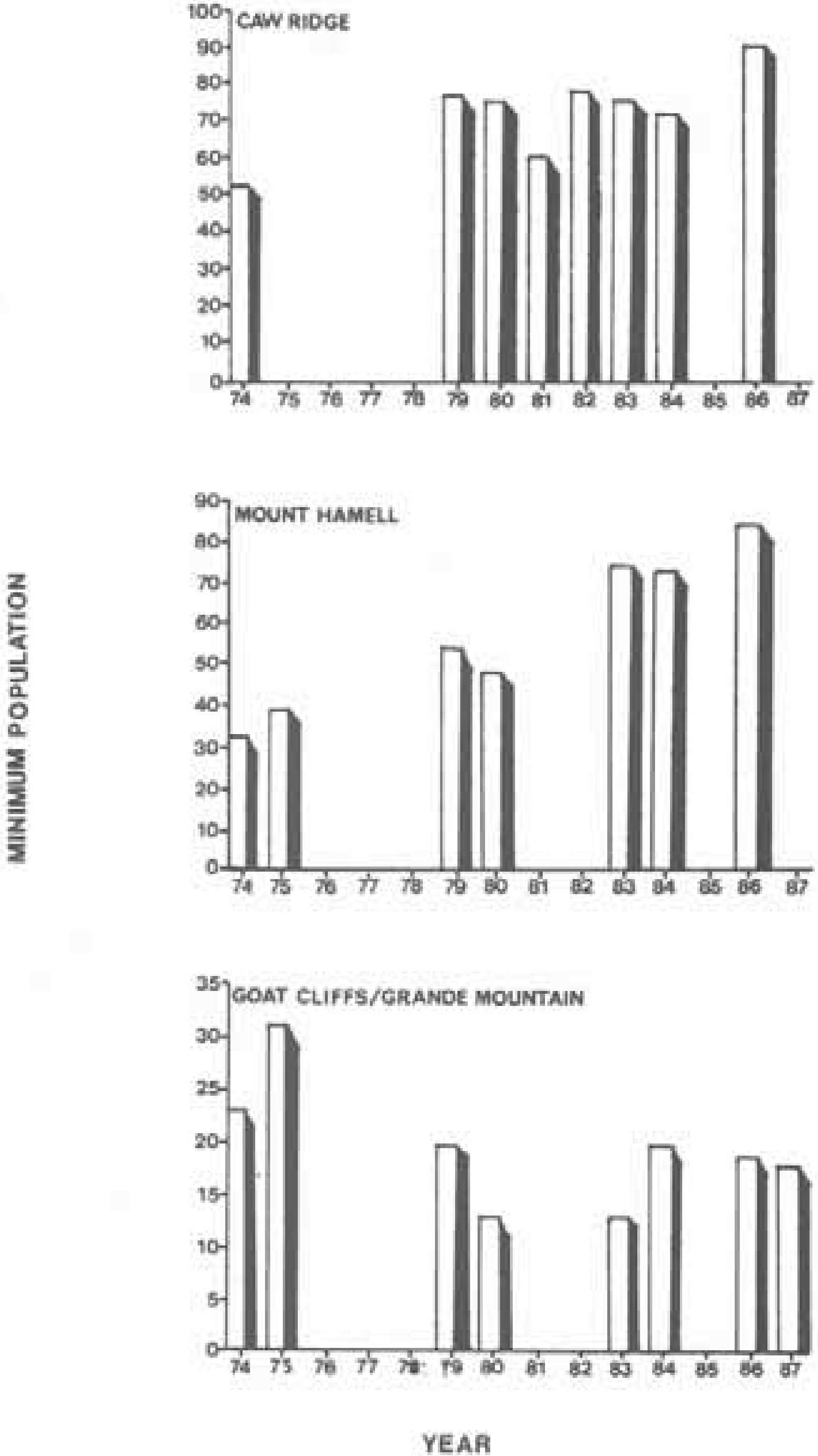

Fig. 3. Minimum mountain goat population estimates for 3 non-hunted herds in Willmore Wilderness Park based on aerial surveys, 1974-1987. Data for 1974 and 1975 are from McFetridge (1977).

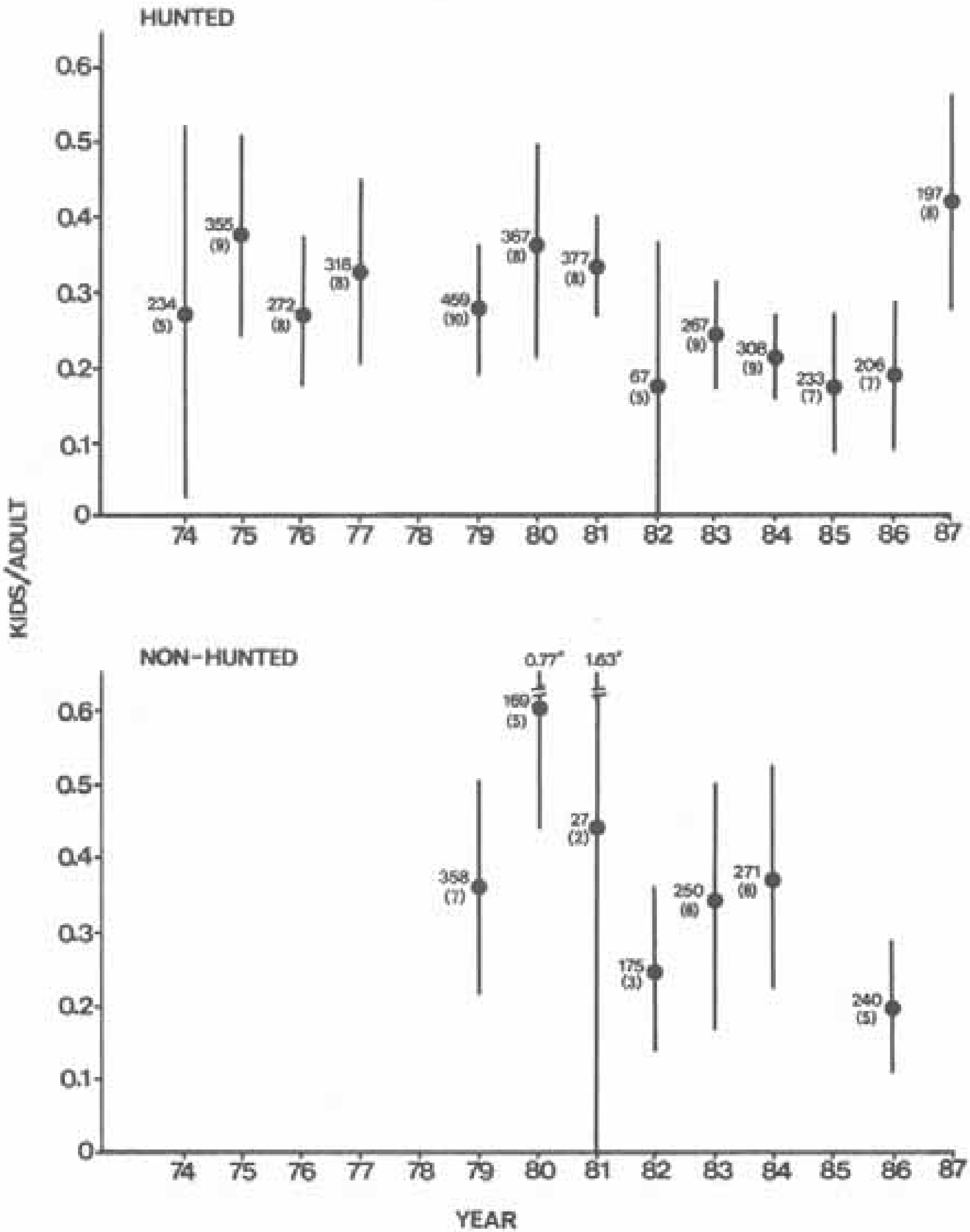

Fig. 4. Mean kid/adult ratios (●) for hunted and non-hunted mountain goat populations in Willmore Wilderness Park, 1974-1987. Vertical lines, numbers and numbers in parentheses represent 95% confidence limits, the sample size of classified animals and the number of survey areas per year, respectively. (*=upper limit of 95% confidence limits).

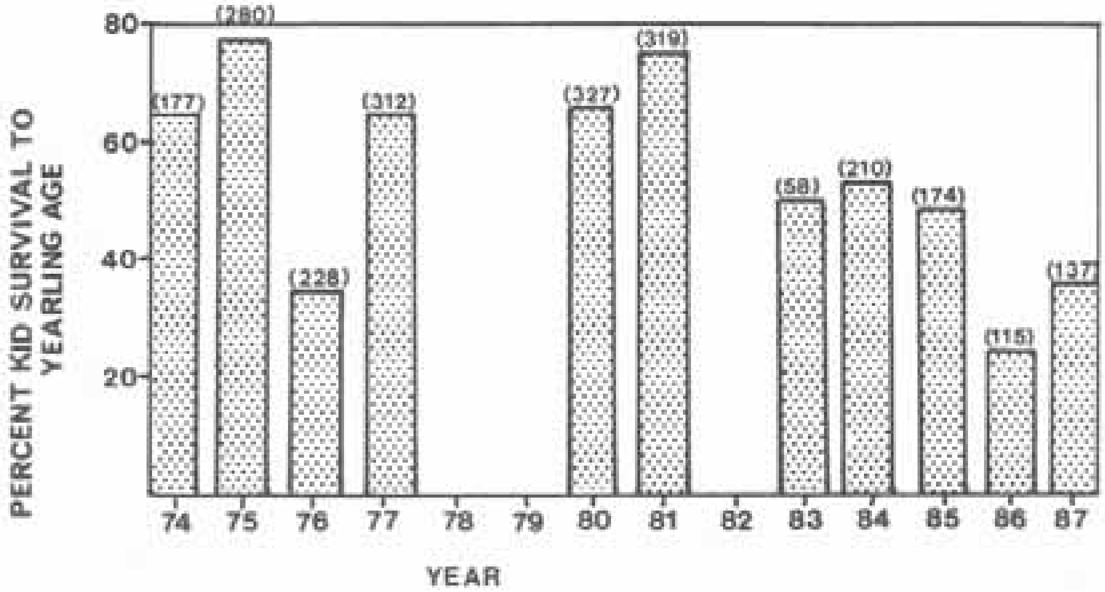

Fig. 5. Mean kid survival to yearling age for hunted mountain goat populations in Willmore Wilderness Park, 1974 - 1987. Numbers in parentheses represent the sample size of classified goats per year.

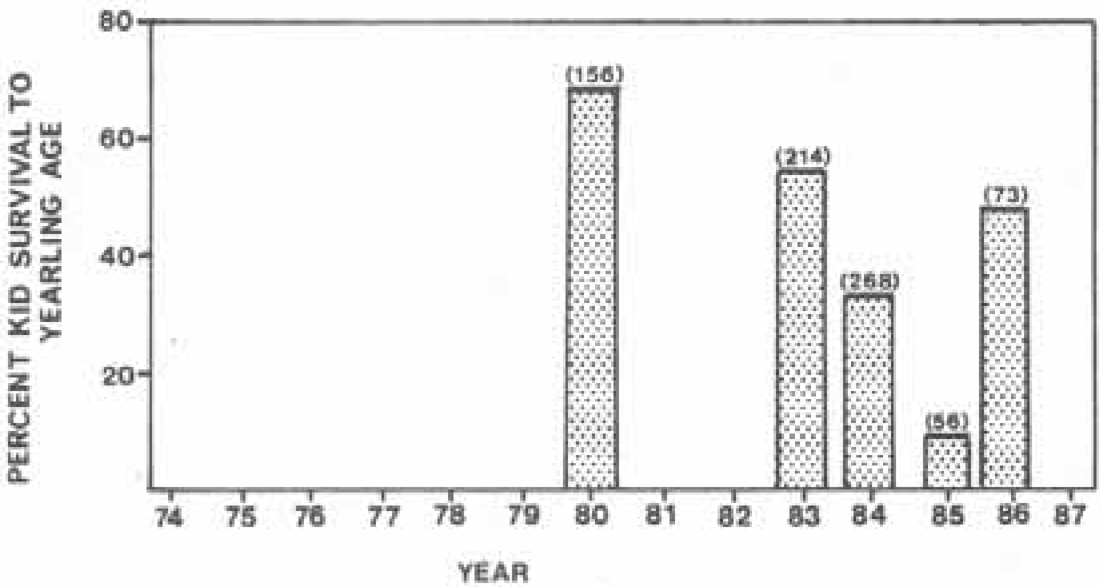

Fig. 6. Mean kid survival to yearling age for non-hunted mountain goat populations in Willmore Wilderness Park, 1980 -1986. Numbers in parentheses represent the sample size of classified goats per year.

Table 2. Significant results ($P<0.10$) of simple regressions of mountain goat recruitment and survival rates on monthly temperature (°C), precipitation (mm) and snowfall (cm), Willmore Wilderness Park, Alberta.

Dependent variable	Independent variable	Month	Regression Slope	R^2	P
Kid/adult ratio 1974-1987 (hunted):	$\bar{x}$ Monthly Temp. (°C)	Oct.	2.45	0.62	0.0002
		Dec.	0.98	0.27	0.084
	Total Precipitation (mm)	Oct.	-0.19	0.23	0.095
	Total Snowfall (cm)	Oct.	-0.33	0.26	0.074
Kid/adult ratio 1979-1986 (non-hunted):	$\bar{x}$ Monthly Temp. (°C)	Oct.	4.49	0.39	0.097
		Apr.	6.91	0.48	0.036
	Total Precipitation (mm)	Oct.	-0.88	0.46	0.045
	Total Snowfall (cm)	Oct.	-1.28	0.34	0.097
Kid survival 1974-1987 (hunted):	$\bar{x}$ Monthly Temp. (°C)	Nov.	1.98	0.39	0.053
Kid survival 1979-1986 (non-hunted):	$\bar{x}$ Monthly Temp. (°C)	Dec.	3.23	0.73	0.065
		Jun.	24.44	0.07	0.078
	Total Snowfall (cm)	Feb.	1.46	0.71	0.077
		Jun.	-213.12	0.71	0.074

with kid recruitment nor were any weather variables for kid survival of hunted or non-hunted herds (Table 2).

DISCUSSION

The initial period of population decline (1980 - 1983) resulted in minor changes in mountain goat management strategies in the WWP study area. One problem symptomatic of goat management in many jurisdictions was the difficulty in distributing harvest pressure equitably over relatively large management zones. Consequently, zones were each divided into 2 or 3 smaller areas by 1985 and in some portions, goat hunting was eliminated. Permit allocation was re-directed into the more inaccessible units in an effort to maintain hunting opportunities, but to reduce the harvest. Permit numbers were reduced yearly (Fig. 7) and, combined with some hunting seasons (which last for 2 weeks) of extremely inclement hunting weather (which reduced harvest success), it was expected that mountain goat herds would begin to increase once more.

With the exception of 1982, winter weather during the period of decline was mild (Fig. 8). Consequently, average or better kid:adult ratios were anticipated in WWP in following years. A negative correlation

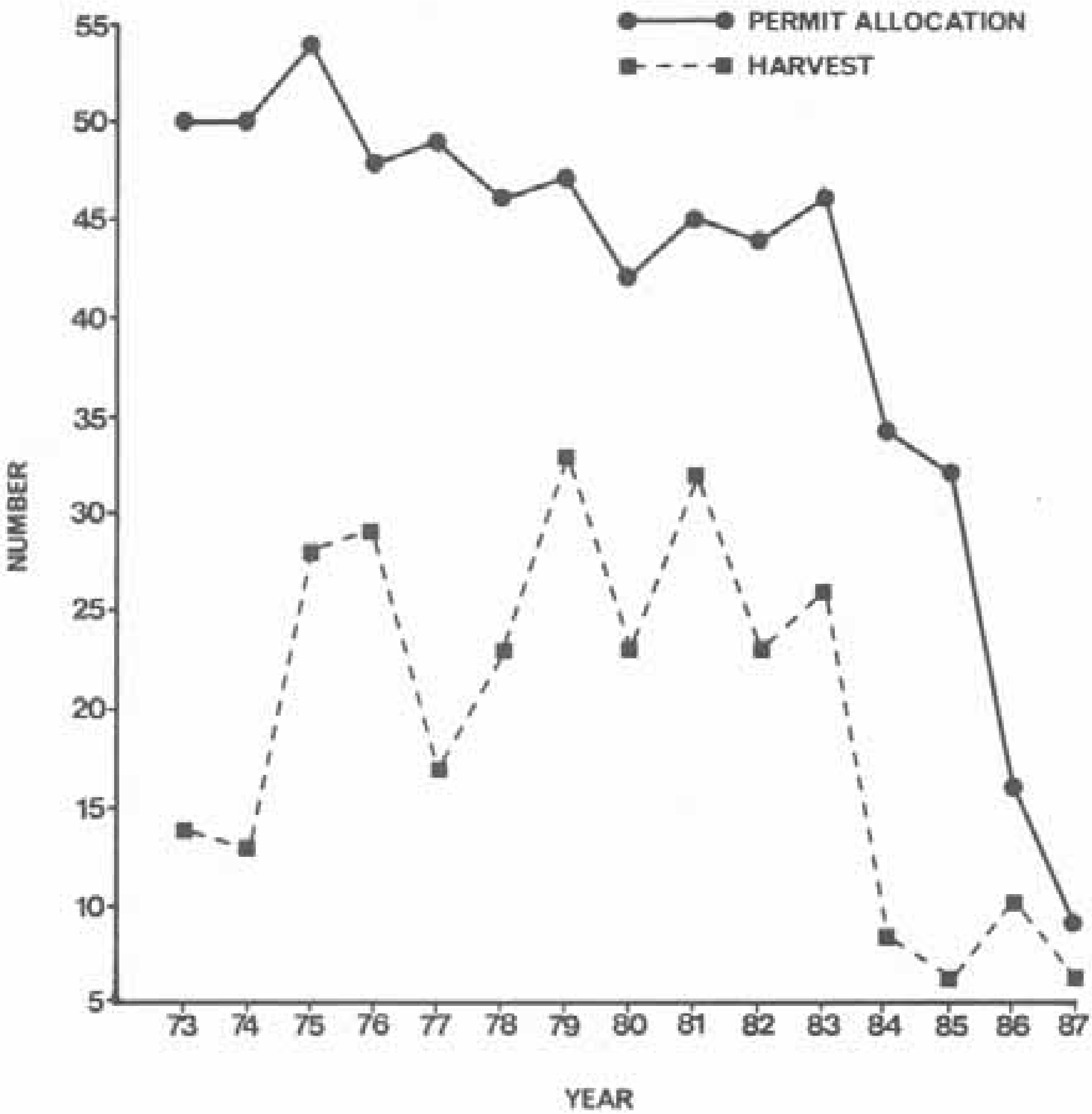

Fig. 7. The number of hunting permits allocated and the number of mountain goats harvested in Willmore Wilderness Park by year, 1973-1987.

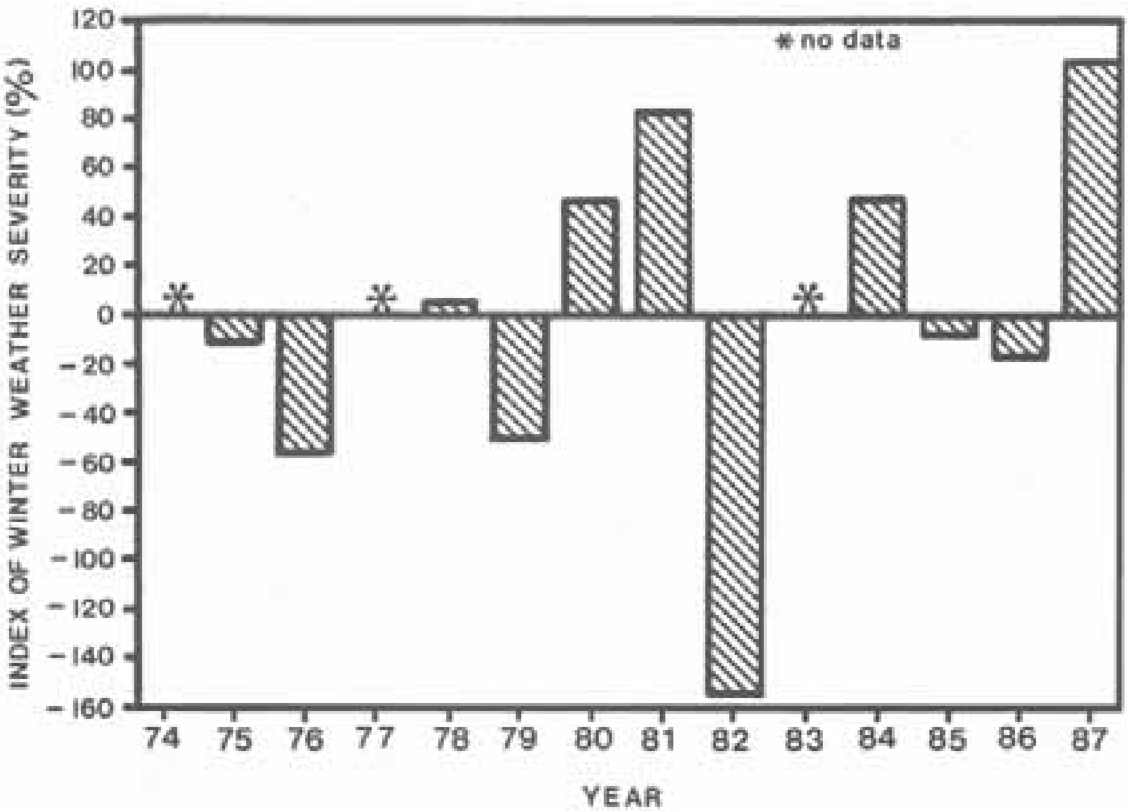

Fig. 8. Winter severity index for Grande Cache, Alberta, 1974-1987. Weather data for 1974,1977 and 1983 was incomplete and therefore not included.

Table 3. Results of multiple regression analysis of mountain goat kid/adult ratios (dependent variable) with weather (independent) variables for the Willmore study area.

	$\bar{R}^2$	b_0	Oct. temp.	Apr. temp	Oct. precip.	F Value
Hunted (1974-1987)	0.65	17.48 (0.0003)[a]	2.46) (0.0028)	-	-	16.66 (0.0028)
	0.82	14.25 (0.0006)	2.35 (0.001)	1.63 (0.028)	-	17.60 (0.0012)
Non-Hunted (1979-1986)	0.57	28.20 (0.0109)	-	7.52 (0.030)	-	7.95 (0.0304)
	0.87	54.55 (0.0016)	-	6.30 (0.011)	-0.72 (0.017)	17.44 (0.0056)

[a]Numbers in parentheses below each estimated value represent the probability associated with the coefficient being = 0(t test).

between 1 May snow depth in Colorado and kid:older animal ratios (Adams and Bailey 1982), a positive correlation with average winter (October - March) temperature in southeastern Alaska and mountain goat population size (Smith 1984), a positive correlation of reproductive rates with the total winter precipitation (November to March) 1.5 years before birth, and a similarly high correlation between reproductive rates and April snow depth 13 months before birth (Stevens 1983, in Chadwick 1983) have been described. Winter weather also has been implicated in overwinter mortality rates of mountain goat kids (Brandborg 1955, Rideout 1974, in Chadwick 1983).

Given the parallel decrease in kid production and survival between hunted and non-hunted herds after 1980, weather was examined in detail as a significant limiting factor. However, other than pointing out the 2 extreme years of weather (Fig. 8), which correlated relatively well with kid/adult ratios (1982 had the lowest winter severity index and the second lowest kid/adult ratio of 0.18; 1987 had the highest winter severity index and the highest kid/adult ratio of 0.42), the winter severity index didn't appear to contribute significantly towards explaining the pattern of recruitment and kid survival that had been observed. Consequently, multiple regression analysis of weather variables on kid production and survival was pursued in an exploratory fashion to test the significance of a grouping of independent variables as possible limiting factors. As pointed out by Wehausen et al. (1987:89), "a lack of significance of an independent variable examined alone in a multivariate system may reflect the confounding effects of additional variables rather than a lack of correlation". Therefore, the weakly significant correlations involving weather variables where $P < 0.10$ were included (Table 3). When October and April temperatures were included together, they explained 82% of the variance in kid/adult ratios in hunted populations. April temperature and October precipitation combined explained 87% of the variance in non-hunted kid/adult ratios. (A log transformation of October temperature reduced the significance of this variable and was an indication that a curvilinear relationship did not exist). However, three factors reduced the probability that these weather variables were biologically significant. I had no a priori hypothesis regarding the significance of temperature alone on kid/adult ratios, but rather had thought that deep snow in combination with cold temperatures should reduce the abilities of nannies to bring a fetus to term. Secondly, if these weather variables were affecting kid/adult ratios, then they should also influence kid survival rates to 13 months, which they did not ($P>0.05$). Finally, a Durbin-Watson test for autocorrelation was inconclusive, indicating that the weather variables could be autocorrelated and thereby making the statistical comparison invalid.

Based on the harvest strategy proposed by Youds et al. (1980), the significant reduction in kid production in hunted herds from a mean of 0.32 kids/adult during 1974 - 1981 to 0.20 kids/adult later on would seriously compromise the ability of mountain goats to sustain the earlier harvest level. Kid production in non-hunted herds was parallel to that of their hunted counterparts (Fig. 4).

It is generally accepted that rates of juvenile mortality are very influential on $\bar{r}$ values of ungulates (Caughley 1977:100). The rate of kid survival to yearling age declined in hunted herds from a mean of 63% (1974 - 1981) to a mean of 44% (1982 - 1986) (Fig. 5). Non-hunted herds also had lower kid survival rates from 1983 - 1986 (Fig. 6). These kid survival rates would have reduced the ability of goat herds to withstand a 5% harvest. Kid/adult ratios inconsistent with $\bar{r}$ values have been reported by others (Hebert and Langin 1982, Smith 1984). However, the mean values calculated annually for the entire study area still appear to correlate with the general population trends (kid/adult ratios were lower during the period of population decline and higher during the period of increase).

As expected, poor recruitment and kid survival after 1981 resulted in lower yearling/adult ratios in subsequent years for both hunted and non-hunted herds (Fig. 9). Although survival rates of yearlings and older goats were not available, there is a distinct possibility that the values necessary to sustain a 5% harvest in WWP were not being achieved during the period of population decline. Smith (1986) provided the first direct estimates of age-specific mortality of mountain goats. One of his most significant findings relative to WWP, is that yearlings suffered an annual mortality rate of 29% ($N = 7$) compared to the 10% used in the harvest strategy model for WWP. Furthermore, during Smith's study, the mountain goat population was increasing. His study also indicates that adult mortality was not constant, but varied from 0 - 9% for goats 2 - 8 years old. Older goats (>8 years) had annual mortality rates of 32%. Youds et al. (1980) predicted that rates of increase are very sensitive

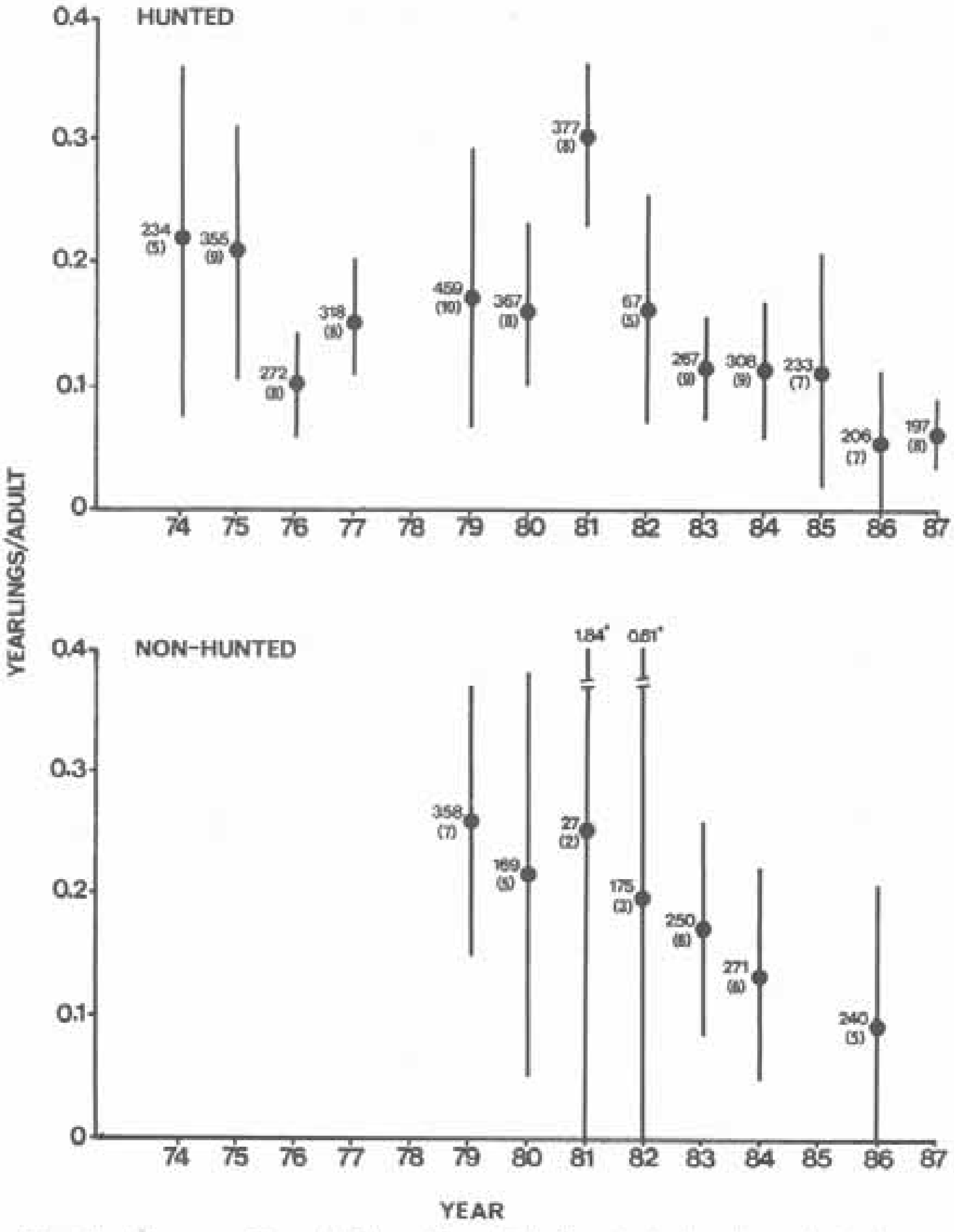

Fig. 9. Mean yearling/adult ratios (●) for hunted and non-hunted mountain goat populations in the Willmore study area, 1974-1987. Vertical lines, numbers and numbers in parentheses represent 95% confidence limits, the sample size of classified mountain goats and the number of survey areas per year, respectively. (* = upper limits of 95% confidence limits)

Table 4. Annual mountain goat harvest results for Willmore Wilderness Park, 1974 - 1986.

Year	Male	Female	Total
1974	7	5	12
1975	10	18	28
1976	17	12	29
1977	5	11	16
1978	12	10	22
1979	28	5	33
1980	7	16	23
1981	21	11	32
1982	14	9	23
1983	15	11	26
1984	5	3	8
1985	6	0	6
Total	153	115	268
(% of harvest)	(57)	(43)	(100)

to changes in adult mortality based on constant mortality values in a population simulation model of WWP; however, Smith (1986) argues that, since adult mortality is not constant, models that use constant death rates for adult goats may produce unrealistic results by prematurely reducing prime-age cohorts.

Because mortality of goats aged 2 - 8 years was almost exclusively due to hunting in Smith's (1986) study, he concluded that this source of mortality is additive in native populations. This fact supports the conclusions of Hebert and Turnbull (1977), Kuck (1977) and Chadwick (1983). Minimum population estimates from aerial surveys of 8 hunted herds (C.V. = 37%) were not significantly more variable (Mann-Whitney U Test, $P < 0.05$) than were estimates for 3 non-hunted herds in WWP (C.V. = 24%). However, these data are consistent with the hyothesis that hunting is impacting herd dynamics in WWP and perhaps the collection of more data will allow statistical significance to be achieved.

Mean kid/adult ratios were significantly lower for hunted herds in WWP when compared to non-hunted herds from 1982 to 1986 ($P < 0.05$). Kuck (1977) found no increase in the kid/adult female ratio as the population size decreased and Hebert and Turnbull (1977) also found significantly lower kid proportions in heavily hunted populations compared to those that were lightly hunted or not hunted. However, kid survival to yearling age in WWP was not significantly different from 1982 to 1986 suggesting that variables other than hunting were relatively consistent in the study area. The mechanism responsible for the difference in kid production may be explained by adult female mortality.

Females made up an average of 43% of the WWP harvest between 1974 and 1986 (Table 4). In addition, the mean age of goats harvested per

Table 5. Mean age of mountain goats harvested in Willmore Wilderness Park year 1977 - 1986.

Year	Male			Female		
	Mean age (years)	Range	n	Mean age	Range	n
1977	6.3	3.5 - 8.5	5	4.6	1.5 - 8.5	8
1978[a]						
1979	4.8	1.5 - 9.5	27	6.3	2.5 - 9.5	5
1980	6.5	3.5 - 12.5	7	5.3	2.5 - 7.5	13
1981	5.1	1.5 - 13.5	19	5.7	1.5 - 10.5	10
1982	4.7	2.5 - 9.5	10	7.0	4.5 - 12.5	6
1983	5.7	1.5 - 13.5	11	5.1	1.5 - 13.5	5
1984	4.0	2.5 - 4.5	4	6.2	3.5 - 9.5	3
1985[a]						
1986	5.5	3.5 - 7.5	4	8.5	8.5	3

[a]No sex specific data.

year was centered in the prime age category for breeders (Table 5). Hunters who were unsuccessful in finding a billy probably took a lead nanny with the largest horns. Among social mammals in general, dominant females often show superior breeding success (Clutton - Brock and Albon 1985, in Houston and Stevens 1988). Consequently, productivity of hunted herds would probably be affected in a negative manner. However, orphaning may not make a significant difference in kid survival (Foster and Rahs 1982).

Observed rates of increase were compared relative to harvest rates during the period of increase and decline in goat populations in WWP (Table 6). Harvest rates were reduced by as much as 58% during the period of decline (Fig. 7), but herds continued to decline. The numbers of goats harvested constituted 0 - 80% of the observed decline in numbers, but the hunter-caused mortality appeared additive nonetheless and contributed significantly to the decline; both directly (through removal of goats) and indirectly (by reducing productivity). Goat populations declined dramatically in Olympic National Park when cropped at levels approaching the production of young (Houston and Stevens 1988). Conversely, non-hunted herds in WWP had positive rates of increase or declined only slightly during the same time period (1974 - 1987).

Unfortunately, predation, which could be significant in affecting mountain goat population dynamics, was not measured in this study. The major predators of mountain goats include mountain lion (*Felis concolor*), golden eagle (*Aquila chrysaetos*), bobcat (*Lynx rufus*), coyote (*Canis latrans*), black bear (*Ursus americanus*) and grizzly bear (*Ursus arctos*) (Rideout 1978). With the exception of bobcat, all are found in WWP. Repeated sightings of a mountain lion harassing mountain goats on Mt. Hammel (Alberta Forest Service, Grande Cache, Alberta) during 1987

Table 6. Observed rate of increase $\bar{r}$ in 9 mountain goat populations in the Willmore study area, 1973-1987.

Complex (Zone)[a]	Period of Increase	$\bar{r}$	Mean Harvest	Period of Decline	$\bar{r}$	Mean Harvest(%)
HUNTED						
Moosehorn (A)	1975-1979	0.20(4)[b]	7.4	1979-1986	-0.20(8)	5.1
Persimmons(B)	1974-1980	0.05(6)	9.0	1980-1984	-0.10(3)	7.5
Monoghan/Sunset/ Rockslide (C)	1974-1980	0.01(6)	6.0	1980-1984	-0.19(5)	5.4
Triangle/Kvass(D)	1974-1979	0.08(5)	4.9	1979-1984	-0.23(6)	5.1
Llama/Turret(E)	1975-1983	0.13(7)	5.4	1983-1987	-0.21(5)	2.3
Mt. Deveber(F)	1973-1979	0.06(2)	4.4	1979-1986	-0.03(2)	3.5
NON-HUNTED						
Caw Ridge	1974-1986	0.04(8)				
Mount Hamell	1974-1986	0.08(7)				
Goat Cliffs				1974-1987	-0.03(8)	

[a]Mountain goat hunting zone designation up to and including 1984.
[b](x) = Number of surveys used to calculate $\bar{r}$.

substantiate this factor. In addition, wolves (Canis lupus) are plentiful in the area and wolf scats collected from Caw Ridge contained mountain goat hair. Wolf predation was the most significant factor limiting the recovery of woodland caribou (Rangifer tarandus) in west-central Alberta (Edmonds 1988). Wolf populations in WWP are considered to have increased since control measures were relaxed in the early 1960's (Edmonds 1988) and other prey species such as woodland caribou and moose (Alces alces), have declined. "Prey switching" by wolves could potentially place more predator pressure on alpine ungulates and increase the chances of mountain goat populations declining while hunting continued. A decline in bighorn sheep (Ovis canadesis) populations for 3 of the mountain complexes where mountain goats were inventoried, paralled that of mountain goats despite a relatively consistent harvest regime throughout the entire period 1975 - 1987 (Fig. 10). Three separate incidences of wolves chasing bighorn sheep were documented in WWP and vicinity during 30 hours of winter helicopter sheep surveys in 1988 compared to none recorded for any of the previous sheep surveys. Increasing wolf predation may be influencing these results. Moreover, Smith (1986) found that of the 13 goats where cause of death could be determined in his study in southeastern Alaska, the mortality was relatively equally distributed among hunting, predation and factors other than hunting. Of the 4 killed by predators, 3 were taken by wolves and 1 by a bear (Ursus spp.).

In summary, populations of mountain goats in WWP appear to have suffered from a combination of factors resulting in a decrease in the mid 1980's. A severe winter in 1982 may have significantly reduced populations in general,

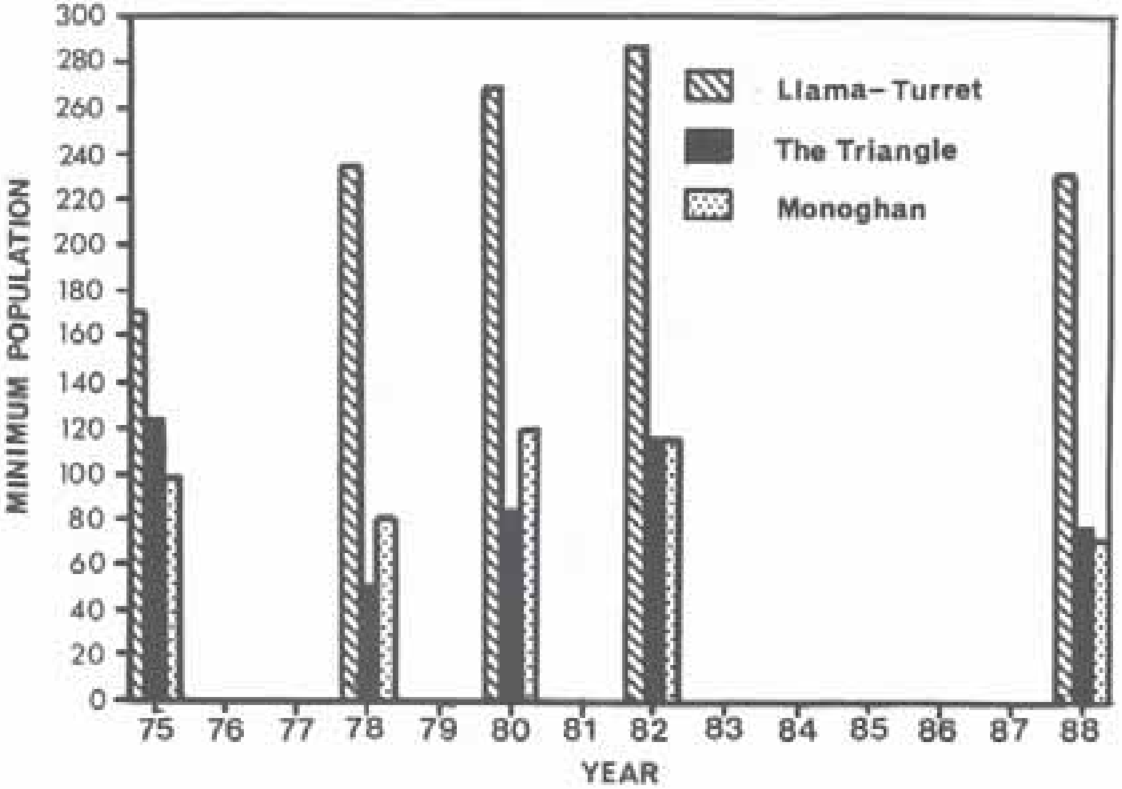

Fig. 10. Minimum mountain sheep population estimates for 3 mountain complexes in Willmore Wilderness Park based on aerial surveys, 1975-1988.

which in turn was not documented sufficiently due to an 80% reduction in helicopter survey time that year. Subsequent inventories resulted in 2/3 of the mountain complexes being inventoried only in alternate years, thereby reducing confidence in predicting trends. Data suggests that hunting mortality was additive and exceeded the rate of increase as kid recruitment and survival continued to decline. The failure of the 1982 year classes continued to affect productivity in subsequent years. Relatively mild winter weather following the severe winter of 1982, resulted in higher expectations for population recovery than were realized. These problems may have been exacerbated by increasing wolf predation, in conjunction with other predators. Non-hunted herds were able to either increase or decrease only slightly during the same time period. Consequently, the mountain goat hunting season in WWP will be closed until populations recover. If population recovery is sufficient to allow hunting, the harvest should remain below 3% (Hebert and Langin 1982) and be restricted to billies only. Annual inventories, with the objective of obtaining total counts, should be required for all hunted populations.

LITERATURE CITED

Adams, L. G., and J. A. Bailey. 1982. Population dynamics of mountain goats in the Sawatch Range, Colorado. J. Wildl. Manage. 46:1003-1009.

Alberta Wilderness Association. 1973. The Willmore Wilderness Park. Unpubl. Rept. The Alberta Wilderness Association. Lynnprint Publishers, Calgary, Alberta. 42 pp.

Bowden, D. C., A. E. Anderson and D. E. Medin. 1984. Sampling plans for mule deer sex and age ratios. J.Wildl. Manage. 48:500-509.

Brandborg, S. M. 1955. Life history and management of the mountain goat in Idaho. Idaho Dep. Fish and Game, Wildl. Bull. 2. 142 pp.

Burles, D., M. Hoefs and N. Barichello. 1984. The influence of winter severity on Dall sheep productivity in southwestern Yukon - a preliminary assessment. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:67-84.

Caughley, G. 1977. Analysis of vertebrate populations. John Wiley and Sons. New York, N.Y. 234 pp.

Chadwick, D. H. 1983. A beast the color of winter. Sierra Club Books. San Francisco, Ca. 208 pp.

Edmonds, E. J. 1988. Population status, distribution and movements of woodland caribou in west-central Alberta. Can. J. Zool. 66:817-826.

Foster, B. R. and E. Y. Rahs. 1982. Implications of maternal separation on overwinter survival of mountain goat kids. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:351-362.

Hall, W. K. 1977. Status and management of the Rocky Mountain goat, (Oreamnos americanus), in the Province of Alberta. Pp. 8-14 in W. M. Samuel and W. G. MacGregor, (Eds.) Proc. First Internat. Mountain Goat Symp., Kalispell, MT. 243 pp.

______ and J. A. Bibaud. 1978. Goats and their management in Alberta. Bienn. Symp. North. Wild Sheep and Goat Counc. 1:142-164.

Hayden, J.A. 1984. Introduced mountain goats in the Snake River Range, Idaho: characteristics of vigorous population growth. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:94-119.

Hebert, D. M. and G. W. Turnbull. 1977. A description of southern interior and coastal mountain goat ecotypes in British Columbia pp. 126 - 146 in W. M. Samuel and W. G. MacGregor (Eds.), Proc. First Internat. Mountain Goat Symp., Kalispell, MT. 243 pp.

______. and H. D. Langin. 1982. Mountain goat inventory and harvest strategies: a re-evaluation. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:339-350.

Houston, D. B. and V. Stevens. 1988. Resource limitation in mountain goats: a test by experimental cropping. Can J. Zool. 66:228-238.

Kuck, L. 1977. The impact of hunting on Idaho's Pahsimeroi mountain goat herd. Pp. 114-125 in W. M. Samuel and W. G. MacGregor (Eds.), Proc. First Internat. Mountain Goat Symp., Kalispell, MT. 243 pp.

McFetridge, R. J. 1977. Strategy of resource use by mountain goats in Alberta. M. S. thesis, Univ. of Alberta, Edmonton, Alberta. 148 pp.

Rideout, C. B. 1978. Mountain goat. Pp. 149-159 in J. L. Schmidt and D. L. Gilbert (Eds.), Big game of North America. Stackpole Books, Harrisburg, PA. 494 pp.

Smith, C. A. 1984. Evaluation and management implication of long-term trend in coastal mountain goat populations in southeast Alaska. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:395-424.

______. 1986. Rates and causes of mortality in mountain goats in southeast Alaska. J. Wildl. Manage. 50:743-746.

Swenson, J. E. 1985. Compensatory reproduction in an introduced mountain goat population in the Absoroka Mountains, Montana. J. Wildl. Manage. 49:837-843.

______. 1986. Reproductive response of the Absoroka mountain goat population to an experimental reduction. Bienn. Symp. North. Wild Sheep and Goat Counc. 5:71-75.

Wehausen, J. D., V. C. Bleich, B. Blong and T. L. Russi. 1987. Recruitment dynamics in a southern California mountain sheep population. J. Wildl. Manage. 51:86-98.

Youds, J. A., D. M. Hebert, W. K. Hall, and R. A. Demarchi. 1980. Preliminary data on mountain goat population growth. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:482-519.

Bienn. Symp. North. Wild Sheep
and Goat Council 6: 330 - 335

SIMPLE METHODS OF COMPARING WINTER SNOW CONDITIONS ON ALPINE AND SUBALPINE RANGES OF DALL'S SHEEP AND MOUNTAIN GOATS IN ALASKA

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Abstract: A simple, inexpensive method was designed whereby 1 person could rapidly estimate winter show depth and relative hardness on accessible Dall's sheep (*Ovis dalli*) winter ranges. The method was repeatable and permitted statistical comparisons between areas and years. It also enabled evaluation of snow conditions relative to sheep's foraging ability. Another method utilizing simple aerial photography was used to estimate percent gross snow cover on winter ranges of both Dall's sheep and mountain goats (*Oreamnos americanus*). Again, statistical comparisons could be made between areas and years. Distribution and density of both species were cor-related with percent snow cover.

In examining winter habitats, it is often useful to be able to compare snow conditions between areas, between winters, or in relation to an animal's ability to obtain food. For example, the relationships between snow cover and caribou (*Rangifer tarandus arcticus*) feeding behavior were studied by Pruitt (1981), and between snow cover and feeding strategies of wild mountain reindeer (*R. tarandus tarandus*) by Skogland (1978), while Lent and Knutson (1971) examined muskox (*Ovibos moschatus*)/snow relationships. The methods used by these investigators, while depicting accurately the variable pro-files of snow layers, were relatively complicated and used expensive instruments such as the ramsonde penetrometer.

During a study comparing 3 herds of Dall's sheep, I needed a simple, economical method by which to compare gross snow conditions between their alpine winter habitats and between years. Also, I wanted to relate snow conditions to the animals' ability to reach forage. The method I developed enabled 1 person to obtain statistically useful data under harsh conditions with relative ease and speed.

In a later study of mountain goats, I needed to compare snow conditions between winter ranges of sub-herds and between winters, but was unable to use the previous method because of difficult topography. I devised another procedure to assess percent snow cover from aerial photographs.

METHODS

Snow Depth and Hardness

This method was described briefly in a previous paper concerned primarily with Dall's sheep management (Nichols 1976). However, I believe it is worth expanding upon in view of its potential usefulness to other biologists.

Snow depth was measured with a 6-joint, tubular avalanche probe (Mountain Safety Research, Inc., 631 S. 96th St., Seattle, WA 98108). Each joint is about 45.7 cm (18 in) in length. The entire probe is 274 cm (108 in) in length; however, it can be used at any length desired in multiples of 45.7 cm (18 in). The point is slightly larger in diameter than the remainder, making it somewhat easier to push through and remove from hard snow than a simple cylindrical rod.

I painted the entire probe with light-colored epoxy paint, then drew on it in black paint a scale with each 2.5 cm (1 in) marked and numbered. Numbers should be clear and easy to read because it is difficult to bend down in heavy winter clothing and on snowshoes. The probe was then waxed to reduce friction with the snow.

In use, snow depth was read directly by pushing the probe vertically to the ground. Some practise was necessary to avoid catching the point in the semi-frozen tundra.

Because Dall's sheep rarely feed in snow deeper than 30 cm (12 in) (Hoefs and Cowan 1979; Nichols pers. obs.), I decided, for practical purposes, to measure relative snow hardness only to a maximum depth of 46 cm (18 in). I used a Chatillon #719-40 "push-pull" scale graduated from 0-40 lb (0-18.2 kg) in 0.5 lb increments. This is a cylindrical spring scale, 2.2 cm (0.88 in) in diameter and 32.3 cm (12.75 in) long with a hook on one end for measuring "pull" and a 0.5 cm (0.19 in) diameter rod extending from the opposite end to measure "push". The scale includes a sliding marker which records the maximum reading. Because the cylindrical scale is made of smooth stainless steel, I wrapped it in several places with rough tape to make it less slippery when used with mittens.

Two pressure probes were used, each a steel rod approximately 122 cm (48 in) in length and 0.64 cm (0.25 in) in diameter. Attached to the bottom of one rod was a circular disk of 1.0 cm^2 area (1.13 cm diam) and to the other a disk of 0.5 cm^2 area (0.80 cm diam). At the top of each rod was attached a short sleeve making a socket approximately 2.5 cm (1 in) deep into which could be inserted the pressure-measuring rod of the scale. Each rod was marked with tape 46 cm (18 in) from the bottom as a quick reference to the maximum snow depth to be measured. This instrument is somewhat similar to the spring penetrometer mentioned by Skogland (1978) but is adapted to penetration and measurement of harder snow.

In use, the 1.0 cm-tipped rod was placed gently on the snow surface, the scale's "push" rod inserted in the socket, the scale's recording indicator set to zero, and the rod pushed slowly and steadily into the snow by pressing with the scale while supporting the snow probe against bending with the other hand. Again, practise was necessary to learn how to avoid faulty readings as the probe broke through snow or ice layers. This combination would record maximum pressures to 18.2 kg/cm^2 (258 lb/in^2). Should the snow or ice layers prove too hard for penetration with the 1 cm-tipped rod, the 0.5 cm-tipped rod was used, recording pressures up to 36.4 kg/cm^2 (516 lb/in^2). Larger tips could be adapted for softer snow if necessary.

Transects were established in sheep winter habitat on relatively flat areas where sheep feeding was known to occur. I used 5 transects on each area, each of which consisted of 10 stations located 10 paces apart. Each line began from a marked point and was run on a compass course. At each station, 1 depth and 4 hardness measurements were taken. It was necessary to take more of the latter because of variation in hardness even in the space of a few centimeters.

Fifty depth and up to 200 hardness measurements were obtained from each 5 transects. Points falling on bare ground were considered as "0" in depth, but were ignored for hardness.

Observations were recorded on a cassette recorder kept inside my parka (batteries rapidly lost power in the cold) with an extension microphone clipped to my collar. Thus, it was possible to conduct the entire survey along on snowshoes and with minimal removal of mittens.

When it appeared that snow was hard enough to cause sheep difficulty in pawing feeding craters, I took a series of depth/hardness measurements around the perimeters of craters where they had been successful in reaching forage, and around a number where they had attempted unsuccessfully to paw through. These measurements were used to estimate those conditions of snow depth and hardness that limited the animals' ability to reach feed.

Percent Snow Cover

Percent of ground covered by snow was estimated from line transects drawn on aerial photographs. Photographs were taken using a 35 mm camera and fine-grained, black and white film from a light aircraft flown approximately 914 - 1219 m (3000 - 4000 ft) higher than the highest point to be examined and distant enough to include the area of interest. This height produced a photograph taken about 90 deg from the plane of the mountain slope. I selected mountain slopes bounded by obvious physiographic features - such as canyons, side valleys, etc. - to make it easier to relocate the sites in future sessions as well as to bound transect lines. Details of each photograph were recorded as taken using a cassette recorder for future reference. Overcast conditions gave a softer light, eliminating harsh shadows that later could be mistaken for bare ground, and a yellow filter enhanced contrast.

After development, photographs were enlarged to 8 x 10 in (20.3 x 25.4 cm) prints using high-contrast paper. Five randomly-selected, horizontal lines were drawn with a fine-point pen on each phototograph within known winter habitat (ususally above tree line). Under magnification, marks were made where each line intersected an interface between snow-covered and bare ground. The portion of each line covered by snow was determined by accumulating lengths of each snow-covered segment using sharp dividers. The total length of the snow-covered portion was divided by the total length of the line to give the percentage of that line covered by snow.

Average percent snow cover and its standard deviation for each area photographed could then be calculated from the 5 transect lines. These, in turn, could be compared with other areas by standard statistical tests.

DISCUSSION

Snow Depth and Hardness

To test the accuracy of the method, 3 simultaneous surveys were done with the stations for each point set at approximately 1 m apart. Analysis of variance showed no difference in either average depth or hardness ($P > 0.25$) between them. I concluded the method was sufficiently accurate to show real differences between areas or survey dates.

On 1 of my study area, I conducted 4 snow surveys throughout a winter (16 Nov., 11 Dec., 31 Jan., and 10 Mar.) to learn what changes occurred over time and to see whether there was any preferable time period in which to do annual surveys. Snow depth and hardness increased significantly ($P < 0.05$) between the first 2 surveys, and hardness increased ($P < 0.01$) between the second and third. There was no difference found ($P > 0.10$) in either parameter between the last 2 surveys despite several heavy snowfalls. I concluded that in this area, snow accumulated on these exposed ridges until it crusted from wind-packing or thawing and refreezing. After a sufficiently hard crust was formed and colder mid-winter temperatures stabilized, further accumulation was removed from the smooth, crusted surface by wind action. Therefore, snow surveys were conducted annually between late January and early March when I assumed conditions would be sufficiently stable to be representative. Using this technique, I was able to compare successfully and relatively easily snow depth and hardness between areas and years.

One weakness in the method was that with the scale used, I was able to measure snow hardness only to a maximum of 36.4 kg/cm^2 (516 lb/in^2). Any ice layers encountered that could not be penetrated with this pressure were recorded as having a hardness of 36.4 kg/cm^2, thus underestimating average snow hardness. This occurred rarely unless the majority of the snow cover was so hard that sheep could not paw through anyway.

Hardness and depth measurements taken in undisturbed snow around sheep feeding craters that were successfully pawed to forage level ($N = 61$) or were attempted but unsuccessful ($N = 15$) were compared. Indices attained by multiplying mean depth by mean hardness were plotted by frequency of occurrence (Fig. 1) and suggested that below an index of 60, all pawing was successful while above an index of 179, no pawing was successful. Thus, average snow conditions as determined by this method could be used to compare or predict winter severity relative to the animals' ability to reach snow-covered forage.

Average winter snow indices over a period of 5 years were compared with lambing success the following spring on 3 herds of Dall's sheep under study (Fig. 2). A significant negative correlation was found between an increasing index (mean depth x mean hardness) and lambing success ($P = 0.02$).

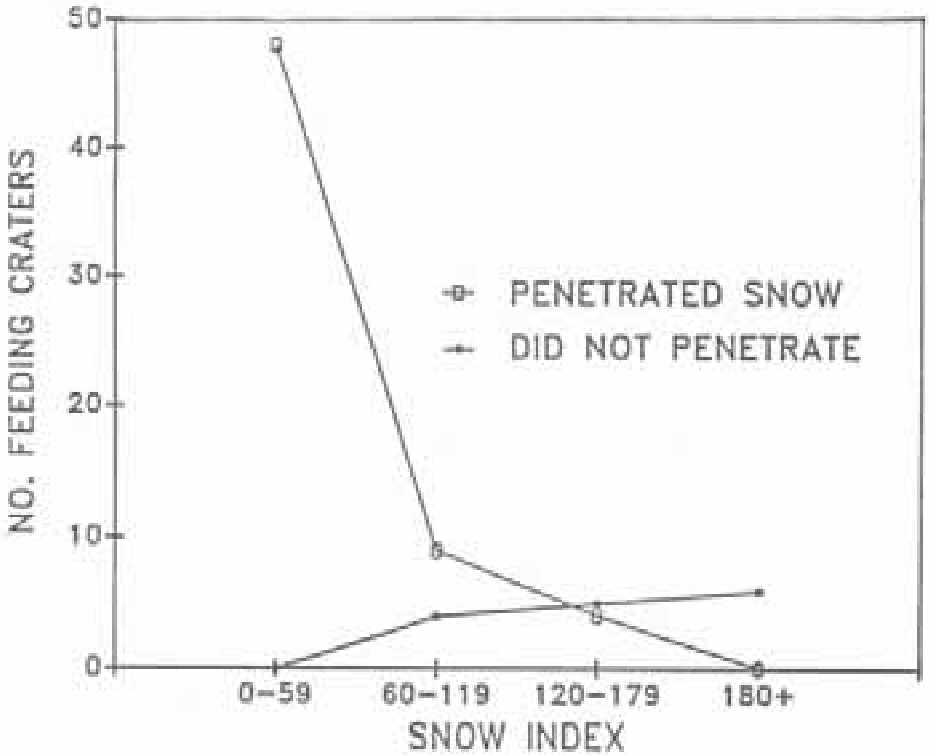

Figure 1. Dall's sheep ability to paw feeding craters through snow as indicated by measurements adjacent to craters. (Snow Index = mean snow depth x mean snow hardness)

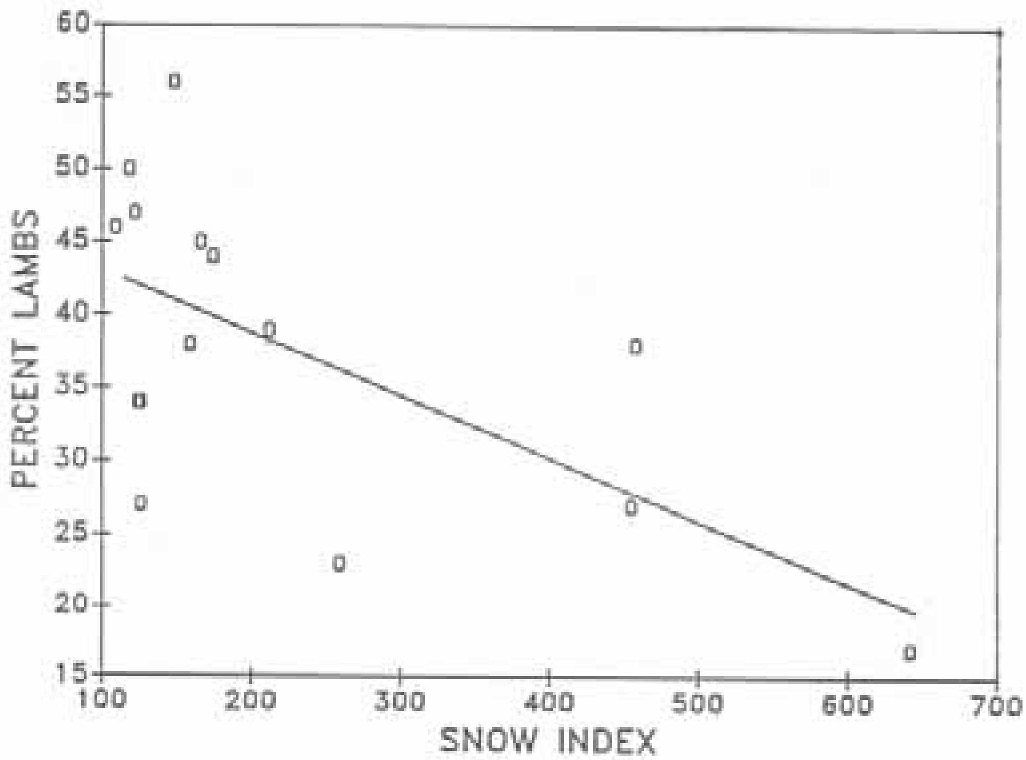

Figure 2. Relationship of snow index (mean snow depth x mean snow hardness) to the ratio of lambs per 100 ewes the following spring. Three Dall's sheep herds over 5 winters (df=13, r=0.6208, P=0.02)

Percent Snow Cover

The 5 transect lines drawn on each photograph proved adequate for estimating percent snow cover on the slope photographed. No improvement in accuracy could be detected by using 10 lines.

Statistical analyses showed that both differences and similarities in snow cover could be demonstrated within and between portions of both sheep and mountain goat winter ranges by this method, and between years. Results appeared to agree closely with observations of winter distribution and abundance and helped explain why most animals used, or did not use certain portions of their habitat.

Average percent snow cover over a 3-year period was examined for the species using each general winter range. Snow cover was higher on ranges used by both sheep and goats than on that used only by sheep ($P < 0.005$), and higher still on ranges used only by goats than on that used by both sheep and goats ($P < 0.001$). Thus, it appears that sheep distribution is limited by average winter snow cover, and that goats can tolerate much higher snow cover than sheep.

Both technique described have been demonstrated to provide useful management and research information about mountain big game in winter. Both are simple to use, fast, and relatively economical; they should be adaptable to other areas and studies.

LITERATURE CITED

Hoefs, M. and I. McT. Cowan. 1979. Ecological investigation of a population of Dall sheep. Syesis 12 (supp. 1):1-81.

Lent, P. C. and D. Knutsen. 1971. Muskox and snow cover on Nunivak Island. Pp. 50-62 in A. D. Haugen, (Ed.), Symposium on snow and ice in relation to wildlife and recreation. Iowa State Univ. Press, Ames. 280 pp.

Nichols, L. 1976. An experiment in Dall sheep management: progress report. Pp. 16-34 in E. Decker, (Ed.), Trans, Second N. Amer. Wild Sheep Conf. Denver, CO. 97 pp.

Pruitt, W. O. 1981. Application of the Varrio Snow Index to overwintering North American Barren-ground Caribou (Rangifer tarandus arcticus). Can. Field-Nat. 95:363-365.

Skogland, T. 1978. Characteristics of the snow cover and its relationship to wild mountain reindeer (Rangifer tarandus tarandus L.) feeding strategies. Arctic and Alpine Res. 10:569-580.