NORTHERN WILD SHEEP AND GOAT COUNCIL

Proceedings of the Fifth Biennial Symposium

APRIL 14-17, 1986

Missoula, Montana

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Edited by Gayle Joslin

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Special thanks are extended to those Session Chairmen who took the time to review manuscripts; to Jonas Brothers Taxidermy for providing the Jonas Bighorn Trophy; to the Montana Wildlife Federation for advertising the Conference; to Fay Moore who helped with meeting arrangements, registrations, and in assembling the proceedings; to Gwynn Gamrandt who helped with registration; to Pam Hyatt who retyped several papers; to Jim Truex for contributing artwork for the abstract brochure; to Vince Yannone for an entertaining banquet presentation; to Earl Sherron of Earl's Distributing who provided libations; to Chris Marchion, Jim Magnus and their families for an excellent lunch on the field trip and evening barbecue; and, to Jim Ford for transporting beverages and setting up the trophy display room.

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Kerry Constan	Population Dynamics
Harvey Nyberg, Registration	Habitat and Nutrition
Glenn Erickson, Administration/ Question and Answer Recording	

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FOREWORD

The fifth biennial symposium of the Northern Wild Sheep and Goat Council was attended by some 120 individuals representing Italy, Japan, Canada and the United States. A paper from the USSR is also included. Several informative displays and presentations were provided at the evening poster session which was held in conjunction with a display of bighorn trophies provided by owners from around Montana.

Chairmen were responsible for circulating each manuscript to two reviewers within his session before submitting the session package to the general editor. Final versions of the papers were left to the discretion of individual authors.

The question and answer session following each presentation was tape recorded to the best of technical limitations, however, poor electrical connections at times pre-empted recording. Our apologies to those authors whose questions and answer sessions were not recorded.

Proc. Fifth Bienn. Symp. North.
Wild Sheep and Goat Council 1986

Keynote Address

VALUES, THREATS AND CHALLENGES TO NORTHERN WILD SHEEP, GOATS AND BIOLOGISTS

Arnold Olsen, Wildlife Division Administrator
Montana Department of Fish, Wildlife and Parks

I would like to take this opportunity to welcome all of you to Montana. I hope your stay here in Missoula will be enjoyable and will lead to a better understanding of northern wild sheep and goat management or research in your state, province, or country. I also want to take this opportunity to thank the members of my staff who have worked hard putting this fifth symposium of its kind together. Please take advantage of this meeting to make this as much a workshop as it is a symposium to help resolve key concerns common to all.

I would like to talk briefly about some new programs that we have been involved with in Montana related to our sheep and goat management. Afterward I will discuss some values, threats and challenges facing us now and in the future. We recently transplanted a sheep herd in the Tendoy Mountains in southwest Montana which makes our twenty-seventh sheep herd in the state. We have about 5,000 sheep in Montana with about 230 permits issued last year. We also still maintain seven unique districts as unlimited areas under a quota system. Our sheep committee is developing standardized guidelines for sheep transplants within the state which will also lay out priorities and eventually long range objectives. Recent wildlife transplant legislation now requires thorough public review and a written plan prior to any transplant action. For those attendees who have such guidelines in place in your home state or province we would like to share your ideas on this topic at this meeting.

We have about as many goats in Montana as sheep if not a few more. This includes 12 native herds and 21 introduced herds. We hunt 41 herd segments out of a total of 59 and harvest about 215 goats per year with 320 permits. We have developed a brochure which aids in field identification using both behavioral and physical characteristics. These are available if anyone is interested.

Perhaps the most newsworthy recent event related to sheep management in Montana was the legislation authorized by the 1985 session which allowed for the auctioning of one sheep license valid anywhere in the state to the highest bidder, similar to what a few other western states have done. In February of this year the Foundation for North American Wild Sheep conducted the auction at their annual meeting in Hawaii. The highest bidder was Arthur Dubs, an Oregon film producer who paid $79,000, the highest price paid for a sheep license anywhere in the United States to date. The motivation apparently was related to the desire to put together the largest grand slam ever assembled, since Montana apparently harvests more 180 and 190 point plus, Boone and Crockett Rocky Mountain bighorn sheep than any other state annually. This auction about doubled the dollars to be spent on sheep in Montana since 90 percent of the dollars are earmarked for Montana sheep projects including transplants, habitat easements and acquisition and other efforts which will contribute to sheep conservation.

What causes people to want to pay this much for the chance for a big sheep? It is unlikely that anything close could be raised for a goat, moose or any other big game license in North America. Leopold stated that "the trophy...is a certificate. It attests that its owner has been somewhere and done something...that he has exercised skill, persistence or discrimination in the age-old feat of overcoming, outwitting or reducing-to-possession. These connotations which attach to the trophy usually far exceed its physical value." Ralston, a philosopher from Colorado, has suggested we appreciate wildlife and it has aesthetic value to us because it is "spontaneous motion wild and on the loose in the field, a wild autonomy. The experience of wildlife comes by surprise. We must catch it while we can, see it now or miss it forever. We admire the sense of struggle of the big trophy ram which represents knowledge and experience that the small ones don't have." We seem to selectively appreciate nature. The old weather beaten animal at the end of a long tough winter seldom graces the cover of our wildlife magazines and some consider it ugly, but as Ralston relates, "it is not ugly unless endurance is ugly."

Large rams have a high social status. A "macho" animal among its type. Men or women who shoot these sheep apparently also belong to a certain social class in that most would rather not shoot a sheep at all than shoot a "small one" and be excluded from the group. This apparently happened last year with the Nevada License Auction for a desert bighorn sheep that went for $67,500 in that a sheep was not taken. The high price paid may be related to the continual struggle for self-worth or gaining something no one else can have.

We need to work more on defining values related to wildlife management decisions including our actions with wild sheep and goats. Economists have been described as those that "know the cost of everything but the value of nothing." Yet economic considerations cannot be ignored in defining the value of wildlife. The economists define "total value" as the amount of money it would take to pay someone to totally give up something they value. I would hazard to guess that someone would have had to pay Mr. Dubs a lot more than $79,000 to get him to give up forever his opportunity to hunt wild sheep.

The interesting and yet baffling attribute of wildlife is the fact that many place high values, and their experience is enhanced, in just the chance or perception that the animal is present, even if it isn't. A perfect example for this is the whale-watchers at the Cabrillo Monument on Point Loma near San Diego, California. Thousands every year spend hours gazing off toward the horizon until almost blinded by the sun reflecting off the ocean, just for a possible glimpse of a spout eminating from a whale, satisfied in perhaps not even seeing the whale itself.

Should we spend more on a decision regarding sheep or goat management than what is at stake to be won or lost? Most economists would say no, but these intrinsic values make the biologist not so sure. Another way to develop decision criteria is to ask "would society be better off if an action, such as increasing a sheep herd, occurred?" The "Pareto-Criterion" in socio-economics states that society is better off if at least one person is better off and no one is worse off in regards to an action; or society is better off if the gainers can compensate the losers. (I wonder what the reaction would be if the losers were hunters in an anti-hunter case and the hunter sought compensation for their loss of opportunity).

The question of value differences between sheep and goats is curious to me and may relate to some of the factors I have already mentioned. Even with this symposium, out of about 40 papers, only 5 are on goats. Loomis and others recently reported that the net economic value of goat hunting in Idaho exceeded sheep hunting, but I doubt the same trend would hold up for Montana. Perhaps the low prices we charge for resident licenses (only recently changed from $25 to $50) contribute to its perceived worth. This trend of perceived values does not hold up for non-consumptive users, however, based on a recent study by Nelson in Wyoming indicating higher non-consumptive values for both sheep and goats than consumptive values. This factor makes sheep and goats somewhat unique among other big game species and has probably contributed to their preservation. Non-consumptive users speak out strongly against loss of these species or their habitat, so the hunter usually does not carry the total weight of conservation responsibility as much as he might for deer or elk.

Even though sheep and goats enjoy a somewhat broader constituency, the need to broaden that constituency is certain, and we as biologists must seek to accomplish this task. Leopold recognized this same need in his Sand County Almanac. "The same dilution and damage (that mass-use tends to give to trophies), is not so apparent in the yield of indirect trophies such as photographs. Broadly speaking, a piece of scenery snapped by a dozen tourist cameras daily is not physically impaired thereby, nor does any other resource suffer when the rate increases to a hundred."

I would like to turn my attention now away from values and direct it toward what I feel are real threats to wild sheep and goat management as we know it today. Jack Berryman, the executive vice-president of the International Association of Fish and Wildlife Agencies in a recent address to The Wildlife Society, stated that, based on his extensive career on the front lines of wildlife resource issues, he felt there are two ominous threats to wildlife management. They are, number one: loss of habitat and number two: the animal rights movement, and I couldn't agree more. (By the way during Berryman's talk and throughout the TWS Conference there were animal rights demonstrations on the steps of the Hotel Syracuse right outside the meeting). I also believe these threats are directly applicable to northern wild sheep and goats. Expounding on the virtues of habitat protection to this group would be somewhat of a wasted effort, because I'm sure all of you are fully aware of the importance of habitat and fully dedicated to its improvement and preservation. Therefore, I will focus my comments on the second threat; the Animal Rights Movement. I feel that we, in the Northern Rockies, have been somewhat isolated from this movement to the point of complacency. It has only been within the last few months in Montana that we have experienced such groups as Cleveland Amory and the Fund for Animals regarding our bison hunt north of Yellowstone National Park. The recent book written by Ron Baker entitled "The American Hunting Myth" exemplifies my point. The jacket reads "How hunter-dominated state and federal agencies are systematically destroying America's wildlife and natural lands and what you can do to help restructure these agencies and insure a responsible stewardship over America's wildlife." Baker is the vice president of a New York based Committee To Abolish Sport Hunting. It has 2,000 members and is growing. How many in this room ever heard of the news magazine called "Agenda"? It is the news magazine of the Animal Rights Network that each of us should follow. The philosophy behind Animal Liberation is simply that pleasure is good, therefore it should be maximized and pain is bad, therefore it should be minimized. Peter Singer promotes "the welfare of the individual animal over the welfare of the population" which is directly opposite to our training and traditional beliefs. Anti-hunters have a humanistic and moralistic base and therefore ecological arguments in support of hunting, that we typically promote, won't convince them. It is like being on different channels of the same television set.

Sheep and goat hunting is perhaps trophy hunting at its finest in North America and elsewhere, and yet that is the very factor that relates to the problem.

In a recent national survey out of the five most important reasons why people were opposed to hunting, trophy hunting was number one and worrying about endangered wildlife was number two. In another survey, Jim Peek found that in ranking reasons people give for hunting, survey respondants found the reason "to obtain meat" the most acceptable and the reason "to obtain a trophy" the least acceptable out of six categories. A third survey entitled "Youth and Wildlife" conducted with fifth and sixth graders by the U.S. Fish and Wildlife Service and O.P.M. through the "Weekly Reader", is perhaps the most sobering. The survey portrayed a widespread prevalence of humanistic sentiment and concern over sport hunting by young people. Conclusions stated that "young people clearly distinguished between hunting for food and hunting for sport and whereas opinions about food hunting may become more positive as they mature, their negative attitudes about sport hunting are established before they reach their teens."

The trophy-recreationist has peculiarities that contribute in subtle ways to his undoing. To enjoy, he must possess, invade and appropriate. This makes it imperative that we seek to improve and promote a higher degree of ethics in trophy hunting perhaps even more than for other types of hunting. Again going to Leopold, "A peculiar virtue in wildlife ethics is that the hunter ordinarily has no gallery to applaud or disapprove of his conduct. Whatever his acts, they are dictated by his own conscience, rather than by a mob of on lookers. It is difficult to exaggerate the importance of this fact. Voluntary adherence to an ethical code elevates the self respect of the sportsman but it should not be forgotten that voluntary disregard of the code degenerates and depraves him." What have you done in your career (and I ask myself the same question) or what will you do this next year to promote the ethical restraints we collectively call sportsmanship?

I would like to now shift focus to management and research needs and challenges. "Game management is the art of making land produce sustained annual crops of wild game for recreational use" (Game Management - 1933). How often have we heard this definition but how often do we forget it? The statement that game management is an art, I feel, implies an inexactness and a sense of change and progression over time. For example the backwoods biologist in some areas is now almost extinct. We have become more people managers than species or habitat managers. All biologists are beginning to realize, as funds get tighter, isolation from the joys of budget management is no longer possible or expedient. There are more organized special interest groups now than ever before. We used to deal primarily with sportsmen groups alone. The public is demanding more specifically a certain quality of experience. Now instead of just resource allocation, we deal with license allocation by group. No group seems satisfied unless other groups are exactly equal (i.e. residents vs. nonresidents; outfitters vs. non-outfitters; landowners vs. non-landowners). The issue of more access to federal lands has changed to a desire for less access and less roads and more access to private lands. Failing agriculture shifts survivors to using all the products of the land for profit, including wildlife.

Within this framework of the changing art of wildlife management, we have learned a few things from our mistakes, for example goats cannot be managed like deer and can easily be over harvested resulting in the necessity to close seasons. When the season closes, the interest and support from our constituency also wanes which may somewhat explain the lower than desired perceived value for goats today compared to sheep in Montana. The most important effort we could now make is a better survey of what we now know, using and applying what we have. We must effectively and carefully prioritize our future activities. We may know now more than we can apply in some areas. We can no longer afford to reach for the last decimal in every case but must resolve some of our management problems now before they are resolved for us by an entity other than our own agency. We need to be less afraid to establish experimental or showcase management actions or seasons, in a systematic way, using the now popular procedures of "adaptive management." An example that needs further testing may be Geist's theory that with our 3/4 curl restrictions are we maybe in fact focusing pressure on the very segment of the population we want to protect, thus over time, producing something contrary to our original goal? We have overlooked answering some of the most basic questions in management, at least in some areas, such as where can we put sheep and goats, where do we want sheep and goats and how many do we want? Is our goal to maximize large males in the harvest or to maximize general recreation? How do we reduce the harvest of nanny's and improve field identification? We know how to manage biologically for each option perhaps, but we aren't as good at making the decision of where along the continuum of options our objectives should be for a specific area, especially considering socio-economic and socio-political constraints.

I think we have done a fairly good job in the area of research, particularly with sheep. In preparing for this address I reviewed the research recommendations from the 1974 Boone and Crockett proceedings of the workshop on the Management Biology of North American Wild Sheep also held here in Missoula. I also briefly reviewed the Whitehouse Yukon Northern Wild Sheep and Goat Council proceedings available last night. Many of the papers at this conference 12 years later, reflect responsiveness to the challenges presented at the 1974 meeting particularly in the areas of habitat, nutrition, development impacts, parasites and disease and harvest impacts. We are also beginning to tackle issues like defining and understanding our sheep, and goat hunters and quantifying values. Other research areas that haven't enjoyed as much attention are behavior and genetics perhaps due to the difficulty in getting funds for these topics; and more applied research such as improving inventory techniques especially for sheep, and learning more about trapping and transplanting to enhance success. Needs expressed at the 1974 meeting for sheep trapping and transplanting (also applicable to goats) were:

1. The need for better literature research to document ancestral ranges.

2. The need for behavior studies to determine what sex, age, and family composition of captured animals are needed to provide optimum opportunity for success on releases.

3. The need to determine optimum numbers of animals to be released to assure establishment.

4. The need for better monitoring of releases to determine movements and permanent herd establishment.

Having discussed some threats and challenges to our profession, the question ultimately boils down to a personal and individual reflection. What is my responsibility as an individual biologist? Won't someone else at a higher level or in another agency take care of these concerns? Can't I be left alone with my animals?

Wildlife biology is more than just a job, it is a vocation. We must become actively involved in effecting and influencing the changes. Jack Ward Thomas expressed it well in his recent address at the North American Wildlife and Natural Resource Conference in Reno, Nevada. "The university degree is the beginning not the end, otherwise you become a functionary, not a professional. (We must continue to learn and be curious.) The last thing we wanted to be while in school was a negotiator or salesman, but thats what we are and must be." We do a lot of talking to each other but not enough to the public and to interest groups in language they can understand. Out of all of the universities offering a wildlife curriculum, someone recently commented that only 2 or 3 require public relations courses and less require popular journalism. This has added to the communications gap. The expansion of our constituency beyond hunters is essential to our long term survival and the protection of the resources we now enjoy. In 1980 4 billion dollars were spent on non-consumptive uses of wildlife. How much have we influenced this? We must develop skills to solve tomorrows problems not just current ones. If 15 years is taken to resolve a problem, the problem will long since be dealt with without our input. We have become too used to, and attached to, our gadgets and the services available to us, like the homeowner unable to add up the checkbook without a calculator. The advances of telemetry and professional training available to us have enhanced our profession greatly, but we must not lose the skills of good old fashioned field observation. A field notebook, pencil and binoculars don't cost much and lack of funds should only change how we collect data and the type of data we collect, and not force us to the confines of the office. If dollars for travel or training aren't there, we should increase our reading and thereby become enriched.

Finally, I think we have an obligation concerning what we leave behind for our youth. The number of battles we fight can not be more important to us than the results we obtain and ultimately what we leave behind. But just leaving something behind isn't enough, either. We must prepare youth to deal with resource issues they will face in the future. The Weekly Reader "Youth and Wildlife" survey I previously discussed indicated that "children demonstrated limited knowledge about the physical and behavioral characteristics of wild animals." The survey also indicated that participation by youth in specific wildlife oriented activities such as animal observation in the wild, belonging to an animal club, and hunting, had a much more positive influence on their wildlife attitudes than other forms of non-participatory wildlife related encounters. It is one of our responsibilities to see that youth have opportunities to participate in wildlife activities through our voluntary efforts in such programs as Project Wild, 4-H, and Hunter Education.

Yes, times are definitely changing. This came home to me recently as I read my young son a bedtime story from his newly acquired book. "Once upon a time there was a Papa Bear, a Mama Bear and a Baby Bear from a Previous Marriage." Setting the course of the future so that the future won't have to repeat the same process is an admirable goal but one difficult to achieve. I hesitate to mention this, because I have as many concerns about some of the Forest Plans currently under review as a biologist and someone might hold me to it but.... Perhaps it would be a healthy exercise for us to prepare 50 year wildlife plans like the 50 year Forest Plans. How well would our wildlife plans hold up to intensive scrutiny? A Michigan DNR planner recently projected that by the year 2000 in the United States, we will have 3 million more hunters, primarily focused in the west and southwest, 20 million more non-consumptive users, a decrease in population growth and a decrease in the percent of people that hunt. How will we accommodate these changes? The economic growth we are now experiencing will likely cause a reduction in participation and concern for natural resources with a low point in 1995 before this trend begins to reverse, (according to the Michigan report). This means it will take until at least the end of the careers of most of the people in this room before a major trend shift is realized, if this prediction holds true. This was proposed based on what has happened historically. Periods of economic growth and exploitation are almost always followed and preceded by periods of environmental protection and concern. (For example the "Roaring Twenties" were followed by the birth of wildlife management and the influence of Aldo Leopold; the post war boom was followed by the environmental movement of the 1960s and the current and future baby boom and yuppie surge may result in a renewed environmental revolution peaking by the year 2035 if the cycle continues). The economic status of the country during adolescence tends to influence subsequent attitudes toward environmental concerns. Adult value systems are difficult to influence.

Another theory espoused by Berryman is that we have gone through four phases of conservation evolution from legislative to biological to economic to the present social phase. If this is true, what will be the next phase?

This kind of creative evaluation and projection into the future, even though its speculative, should be a part of our wildlife planning for the future. Our contribution to our profession today, must have the optimum possible influence on resource allocation tomorrow and beyond.

As a wise old philosopher once said, "We in our country are so rich that we can afford to keep wildlife, but not so rich that we can afford to lose them."

Mountain Sheep Harvest Strategies

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BIGHORN SHEEP HARVEST STRATEGIES IN WYOMING

John M. Emmerich, Wyoming Game and Fish Department, Lander WY

Abstract: Wyoming has employed a limited permit, three-quarter curl or larger ram harvest strategy almost exclusively since 1937, with seasons open primarily from September 1 to October 31. The state's bighorn sheep (*Ovis canadensis*) population has increased substantially over the past 50 years with this harvest strategy. Hunter success statewide has fluctuated from 32 to 64 percent during this time period and has averaged 56 percent since 1980. During the last six years an average 364 permits were issued and an average of 194 bighorn sheep were harvested each year. At the present time ewes and lambs are controlled in only one herd and this is accomplished exclusively by trapping and transplanting.

From 1937 to 1985 bighorn sheep harvest in Wyoming has been regulated by a limited permit system. Harvest has also been restricted most years to rams with at least three-quarter curl horns. During this period hunting seasons have opened as early as August 15 and closed as late as November 20. September 1 is now the opening date for all areas and closing dates occur between September 30 and November 16. Most areas close October 31.

Exceptions to the three-quarter curl ram restrictions occurred in 1965 through 1969 and 1976 through 1978. The Jakey's Fork/Green River area south of Dubois, Wyoming had an either sex hunting season for the entire hunt area in 1965 and for a restricted portion of the area in 1966. Also, during this two year period rams with at least a half-curl horn were legal in the Dinwoody-Sheep Mountain area south of Dubois. This same restriction replaced the either sex season in a portion of the Jakey's Fork/Green River area in 1966 and in the entire area in 1967 and 1968. During the four year period from 1965 through 1968, rams with at least a half-curl horn were legal in the Temple Peak area near Lander, Wyoming, and the same half-curl regulation applied to the Jackson area near Jackson, Wyoming from 1965 through 1969. There were nine hunt areas open for hunting through 1961 and from nine to twelve areas from 1961 to

1969. Any ram was legal in the Temple Peak area from 1976 to 1978.

From 1970 to 1985 the number of hunt areas increased to 25 of which 17 are presently being hunted. Three of these new areas are the result of splitting existing hunt areas and thirteen are the result of sheep reintroductions. Due to an aggressive trapping and transplanting program since the mid 1960's and increasing sheep numbers in many of the state's original, established herds the statewide sheep population has slowly increased during the last 50 years. The current post-hunt population estimate is 6,100. Harvest statistics since 1949 clearly demonstrate this trend in the statewide sheep population. The average annual ram harvest was 26 during the 1940's, 50 during the 1950's, 117 during the 1960's, 142 during the 1970's, and 194 during the first six years of the 1980's.

In response to the observed or perceived increase in sheep numbers over the past 50 years permit numbers have been increased substantially. An average of 71 permits were issued each year during the 1940's, 107 during the 1950's, and 327 during the 1960's, an increase of over 250 percent. The big increase during the 1960's occurred at a time when the concept of maximum sustainable sheep harvest was being promoted and there was sentiment within the Game Division that harvest strategies for elk and deer were also appropriate for bighorn sheep. As a result Wyoming not only increased permit numbers in many areas but half-curl ram and either sex sheep seasons were tried during this decade. The 50 percent average annual hunter success during the 1950's was probably an additional factor influencing the increase in permit numbers during the 1960's. Since good population estimates were not available and hunter success remained relatively high through the 1950's, permit numbers were probably inceased each year during the 1960's in an attempt to find out what ram harvest the existing population could support. With the increased number of permits average hunter success for the 1960's dropped to 41 percent despite increased hunter success in those areas with half-curl or either sex regulations. Either sex seasons only lasted two years because of the public protest against the harvest of ewes. The half-curl seasons lasted a few more years but met the same fate as the either sex season due to public pressure to go back to a three-quarter curl restriction probably due to the public's fear that large mature rams would become scarce and therefore much less available for harvest.

Insight into some effects of half-curl ram seasons can be obtained by reviewing the harvest results from two hunt areas where half-curl or larger ram seasons were implemented. The half-curl ram regulation was maintained for the longest period of time in the Jackson hunt area. The total number of permits for the area remained at 40 from 1960 to 1974 a time period that includes the five years that half-curl rams were legal. Harvest doubled during the second, third, and fourth year of the half-curl season then dropped back to the pre-half-curl regulation harvest level the last year. In the Jakey's Fork/Green River area, ram harvest also doubled during the three years when half-curl rams were legal. The average age of rams harvested during the five year period (1969-1973) immediately following the three years of half-curl or larger harvest in the Jakey's Fork/Green River area was 5.3 (sample size 72). The average age increased during the next five year period (1974-1978) to 6.7 (sample size 68) after five years of the three-quarter curl or larger ram harvest. The number of permits were essentially the same during this time period. These results do suggest that large mature rams will become less abundant when rams as young as half-curl are harvested with no adjustment in permit numbers to compensate for the increased harvest that occurs with a half-curl harvest restriction compared to a three-quarter curl harvest restriction.

Despite a drop in hunter success in the 1960's permit numbers continued to increase through 1973 peaking at 408. Twelve areas were open to hunting at that time. During this 1967 to 1973 period when permit numbers were at their peak hunter success reached an all time low averaging 35 percent for the seven year period. Probably in response to the lower hunter success permit numbers were reduced to 356 in 1974 and have remained between 352 and 389 up until the present time. There were an average of 364 permits issued per year from 1980 to 1985 and hunter success averaged 56 percent.

Through a combination of trial and error over the last 50 years and recently more intensive data collection efforts and population modeling on certain herds it appears that with the present harvest strategy Wyoming can issue approximately 375 to 390 permits annually, harvest about 200 rams three-quarter curl or larger, and maintain a hunter success of 45 to 50 percent with the current sheep population.

Hunter success between 30 and 60 percent has recently been established as an acceptable range for bighorn sheep hunting in Wyoming. This success range has been determined to be a suitable compromise for providing adequate hunter opportunity and maintaining an acceptable number of class III and IV rams in the harvest and post-hunt population. An analysis of harvest statistics from the two hunt areas that make up the Whiskey Basin Sheep Herd, the largest and most intensively managed herd in Wyoming, indicates that if permit numbers are kept low enough, in relation to the number of legal rams available, that average hunter success will be maintained at 40 percent or greater, the average age of harvested rams will remain near six, the post-season ram/ewe ratio will run between 40 to 50/100, and the post season class III and IV rams/ewe ratio will run near 8/100. This herd's annual yearling recruitment has averaged 13 percent (13 yearlings per 100 sheep) from 1981 to 1985. A sheep herds accessibility during the hunting season and of course different recruitment rates would effect these relationships.

There has been a moderate yet steady increase in state-wide sheep harvest and hunter success during the past six years, even though permit numbers have remained about the same. These trends suggest that the state's population is still increasing gradually under the current limited permit, three-quarter curl ram harvest strategy. All the net increase in the Whiskey Basin Herd is removed annually through ram hunting and annual trapping of ewes, lambs, and a few young rams. Since 1980 this herd has been decreased about 10 percent and is now stabilized at approximately 950 to 1,000 sheep, the carrying capacity of the herd's crucial winter range. An averge of 105 sheep (59 rams, 32 ewes, 14 lambs) have been removed each year since 1980. This intensive herd management in conjunction with some range improvement, and redistribution work has increased the herd's lamb/ewe ratio and lowered the age at which rams are reaching three-quarter curl status. Despite an average 20 percent fewer permits and a stable post-season ram/ewe ratio, the age of rams harvested from this herd has decreased from 6.2 (sample size 160) to 5.6 (sample size 185) in the 1980's relative to the 1970's. A large number of rams are now growing three-quarter curl horns at four-and-a-half years of age and even a few at three-and-a-half. In other herds within the state where the sheep winter above timber line on wind swept plateaus and ridges periodic severe winters appear to keep the populations relatively stable. In some of the reintroduced herds population levels are still increasing but have not reached carrying capacity yet, in others recruitment is so low that the populations are not increasing. A few of the older established sheep herds in the Cody country have experienced obvious population increases over the last twenty years and are probably approaching their winter range carrying capacity.

A limited permit three-quarter curl ram harvest strategy has served the state well during the past fifty years providing a quality hunting experience and allowing sheep numbers to rebound from the extremely low levels that occurred in the state around the turn of this century. Currently in the one sheep herd known to be near its winter range carrying capacity an agressive trapping/transplanting program has been an effective tool for maintaining the herd in a thrifty condition as well as re-establishing many historical sheep herds. However, with the current high sheep populations in a few areas still with three-quarter curl ram only harvest Wyoming may in the near future need to look at additional trapping/transplanting programs or ewe/lamb harvest as methods for stabilizing these populations.

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BIGHORN HARVEST STRATEGY IN ALBERTA

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The bighorn population in Alberta outside of the National Parks is about 6000. Since bighorn ram production is dependent on the health and productivity of the nursery herds, the bighorn harvest strategy in Alberta during the past 20 years has been directed towards maintaining the nursery herds at or near optimum production. Limited entry permits for ewes and lambs (non-trophy sheep) are allotted for most of the mountain wildlife management units. Permit numbers are calculated to remove about 15 percent of the total accessible herds based on winter counts. The non-trophy season is during September and October with the opening date one week following the opening date for trophy rams. During the past few years about 300 non-trophy sheep have been harvested by approximately 1000 permittees annually. Hunting success rates of non-trophy sheep hunters average about 30 percent, but range from 10-90 percent depending on the accessibility to nursery herds; permit numbers are adjusted accordingly. Applications for permits outnumber successful applicants about 1.5 to 1. The popularity of the non-trophy sheep permits is due largely to their availability to the unlimited resident trophy ram hunters, i.e., our system allows some bighorn hunters to harvest both a trophy and non-trophy sheep in one hunting season.

Hunters are selective against shooting lambs and yearlings, as well as selective for ewes without lambs. Consequently, there is a disproportionately high harvest of 2-year-old ewes. Approximately 60 percent of the non-trophy sheep harvested are older than 3 years.

The ram harvest is regulated by a 4/5 curl trophy regulation. A 4/5 curl is defined as a male sheep with a horn that can be intercepted at both the front of the horn base and the tip of the horn by a straight line drawn along the front of the eye when viewed in profile. The average age of rams harvested under this regulation is 7 years and the average horn length is 82.5 cm (32.5 inches).

About 80 trophy ram permits are issued to non-Canadian hunters who are required to have guides and outfitters. Hunting success of non-Canadians averages around 50 percent. Non-Canadians who are successful in harvesting a trophy ram are not eligible for a permit for the next 4 calendar years.

There is an unlimited entry for trophy rams for Alberta residents. In recent years, approximately 3000 resident hunters have harvested an average of 200 trophy rams annually, i.e., a harvest success rate of about 6 percent. A successful resident hunter for trophy sheep is not eligible to purchase a trophy licence the following year. All successful trophy sheep hunters are required to have their rams registered and the horns plugged with a permanent marker.

The 4/5 curl regulation was developed partly from a concensus of hunters through questionnaires in the early 70's. In addition, there were some biological considerations for the 4/5 curl size. The 4/5 curl allows rams to reach sufficient size and age to lead younger males to ram ranges that are separate and non competitive with nursery ranges. Bighorn rams begin to break or broom their horns at or about the 4/5 curl stage. There is a continuous natural mortality of rams that increases abruptly at about 8 years of age, i.e., where most rams approach or reach a full curl. A herd of 100 bighorns with a normal production pattern in Alberta will produce about six 4/5 curl rams a year. Generally speaking, the present 4/5 curl regulation is considered an optimum size limit for the management of bighorn rams in Alberta.

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BIGHORN SHEEP SEASONS IN MONTANA, 1872 - 1985

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Abstract: Liberal hunting seasons in Montana from the late 1800's into the early 1900's resulted in the closure of bighorn hunting from 1915 until 1953. With the advent of the Pittmann-Robertson program in 1941 Montana began its research and management programs dealing with bighorns. By 1984 an estimated 4600 sheep were found in the State, and a variety of season types were being used to manage these populations. Season types and their impacts on the hunting opportunities and sheep management are discussed.

Bighorn management in Montana provides a diverse choice of opportunity to hunters who pursue this species either for its trophy value, the aesthetics of the hunt or for the meat. When applying for a sheep permit in the state a hunter can choose between limited entry hunts for areas offering any ram seasons, either sex seasons, ewe seasons, or seasons specifying rams 1/2 curl or less or 3/4 curl or better. If a hunter chooses he may forgo applying for a permit in limited areas and simply buy a permit for areas offering unlimited entry hunting.

I would like to examine some of the circumstances that have brought about this variety of seasons, and some of the implications of these seasons in regards to management and hunter opportunity in the State.

HISTORY OF BIGHORN REGULATIONS AND HARVEST IN MONTANA

Montana, during its early settlement days, went through a series of events similar to those of surrounding states and provinces in regards to the management of bighorns. Extremely liberal seasons were gradually honed down until,in the face of extinction, bighorn hunting was outlawed in an attempt to reestablish dwindling herds.

The first laws regulating the hunting of bighorns was enacted in 1872 by the Territorial Legislature closing the bighorn season from February 1, to August 15 each year. No limit was placed on the numbers any one person could harvest. In 1895 the Legislature limited the number of bighorns that could be harvested to eight per individual, and set the season dates to between September 1, and January 1, each year. In 1910 season dates were reduced to the period of October 1, through December 1, and the bag limit was reduced to one animal. In an attempt to salvage what was left of once abundant bighorn populations all hunting of the species was prohibited in 1915. (Couey and Schallenberger,1971)

Despite the ban on hunting bighorn, numbers continued to decline and by 1930 only small remnant bands existed in the State. By this date bighorns had disappeared from the Missouri Breaks, the Crazy Mountains, The Snowy Mountains, Judith Mountains, Pryors, Little Rockies and the Bear Paws. In 1950 it was estimated 1100 bighorns in 12 different herds, including Glacier Park, were all that remained in the state. (Couey,1950)

With the advent of the Pittmann-Robertson program in 1941 Montana began its research and management programs dealing with bighorns. These programs were aimed at increasing native populations within the State and reestablishing huntable populations in native bighorn habitat. The first bighorn transplant took place in 1942 when 11 sheep were moved from the Sun River Herd to the Gates of the Mountains. By 1974 Montana was occupied by twelve native bighorn herds and 14 transplanted populations. By 1984 ten of the 12 native herds, and 13 of twenty transplanted herds were being hunted. An estimated bighorn population of 4600 head occupied the state.(Janson, 1974; Rognrud, 1983; Thorne et al,1984)

Hunting had begun again in 1953 when a total of 30 permits for 3/4 curl rams was issued in three different areas. Two of these areas, the Spanish Peaks and the Absaroka - Stillwater, were combined and established as unlimited hunting districts in 1956. Permits were first issued for an either-sex hunt in 1967.

Annual bighorn harvests between 1953 and 1958 ranged from 20 to 70 animals. Data derived from questionnaires between 1959 and 1970 indicate harvests varied between 55 and 80 animals for the different years. During this same period hunter success ranged between 59 and 74 percent in the permit areas and 5 to 14 percent in the unlimited areas.

From 1971 through 1980 an average of 116 sheep were taken per year with a range of 79 to 166. A good deal of this increase in numbers was due to the increased numbers of ewe permits issued after 1977. Hunter success in the limited hunting areas averaged over 70 % during this period and hit a high of 92% in 1980. Success in the unlimited areas continued to range between 2 and 5 percent.

In the period from 1981 to 1984 numbers of sheep harvested averaged 262 and ranged from 195 in 1981 to 349 in 1983. Hunter success in the limited areas averaged 93% during this period and also increased in the unlimited areas to an average of over 5% with a high of 7% being recorded in 1984.

Despite the offering of a variety of permits the demand for hunting rams still far exceeds the supply. In 1973, 2619 applications were received for 85 ram permits in limited hunting areas, which gave an applicant one chance in 31 of receiving a license. In 1983, 7679 applications were received for 133 ram permits. This was a 293 percent increase in applications and an increase of 156 percent in the numbers of permits issued, however chances of drawing a license have also increased to one in 58.

In 1985 Montana offered bighorn hunting in 26 districts, eight of which supported unlimited hunter entry on a quota of 19, 3/4 curl rams. A total of 57 any ram permits, and 34 either sex permits were issued in ten and nine districts respectively. Fifteen total permits for rams with less than 1/2 curl of horn growth were valid in two districts and only two district required the taking of 3/4 curl rams using limited entry hunting. Seven permits were issued in these districts. Besides the 132 permits for rams issued statewide 112 ewe permits were also issued.

MANAGEMENT STRATEGIES

Unlimited Areas

Since 1956 bighorn populations in the Hilgards, Spanish Peaks, Beartooth Plateau and Absaroka Range have been open to unlimited entry hunting for 3/4 curl rams. Because the rugged terrain and difficult access of these areas severely limit hunters they have been set aside to provide the maximum hunting opportunity, with the least effect on the bighorn population. Since 1974 the harvest has been regulated by quotas for each of the eight hunting districts making up these areas.

Season dates for these areas are set to coincide with migrational patterns, usually opening and closing earlier than other season in the state. Closing dates occur prior to the time of migration to wintering areas. One exception to this is the area around Red Lodge where seasons are held open until migrations have taken place, which is the only time animals are available to the hunter.

Quotas in these areas are based on the numbers of 3/4 curl rams observed on wintering areas the previous year, and while they have been reached within a few days following the opening of the season they are generally not filled until near the seasons end. Successful hunters must report kills to the Department within 48 hours and any animal taken with under 3/4 curl is counted against the quota. Seasons in seven of the eight districts can be closed on 48 hours notice, and the remaining district may close on 12 hours notice.

Any Ram and Either Sex Seasons

Any ram seasons and either sex seasons allow hunters to take their choice of any ram, or any sheep, within a specified district. They accounted for 73 percent of the permits used to harvest bighorn rams in Montana in 1985. Numbers of permits are based on the number of 3/4 curl rams wintering in the various hunting districts. These type seasons are generally combined with ewe permits in most well established herds in the State.

Some of the management advantages to this type of season are:

1. It's simple, it's easy for the hunter to understand and does away with the pressure of having to meet arbitrary age or curl requirements. In many cases these requirements cannot be justified biologically. They actually serve in the perpetuation of the "Boone and Crockett syndrome" that so many management biologists decry as having done a great disservice to the sport of sheep hunting.

2. It allows for a better distribution of the harvest through the age classes in the ram segment of the population. While most permit holders are still "trophy" hunting, each year a portion of those animals taken fall into the two to three year old category. The literature would indicate that the expected annual natural mortality for bighorn rams between the ages of 2.5 and 7.5 is between 2.5 percent and four percent (Geist, 1971; Cowan and Geist,1971). Under these circumstances harvest of rams in the two to three year old categories can be considered compensatory, as long as the rates of harvest do not exceed expected rates of natural mortality. Stewart has determined mortality among two-year-olds in some areas may exceed 30 percent adding additional leeway to the harvest of 1/2 curl rams (Stewart, 1980).

3. Because permits are based on a percentage of rams that will be in the 3/4 curl or better category during the hunting season, rams that are taken that are just 3/4 curl or less essentially leave an older, larger ram in the population. Assuming nature doesn't get him he will still be in the huntable population as well as the gene pool the next year.

4. This type season does away with the inconsistency with which rams enter curl categories, it also allows for the taking of animals that will never reach a prescribed category no matter how long they live. The combined factors of genetics, habitat and age determine whether or not an animals will become 3/4 curl or better and at what stage in its life this will happen. Herds in Montana seldom have rams over ten years of age. We do however, have males entering the 3/4 curl category any where from 3.5 to 5.5 years of age, and reaching the 7/8ths category by the age of 5.5. Others, because of brooming, genetics or natural mortality never reach this 7/8ths category.

Half Curl Seasons

Seasons permitting the harvest of rams having only 1/2 curl or less were initiated in 1984 as a population control measure in two different hunting districts. Both areas are associated with wintering herds on private lands and require close control of population growth. The theory behind this season is again, younger rams may be removed from a population without affecting the future number of larger animals as long as removal rates are compensatory for, and not additive to, natural mortality. As long as this requirement is met these smaller rams may be taken from a population without reducing either the reproductive base, or the numbers of larger rams available to the hunter. Ewe permits are also incorporated into these seasons in order to maintain population stability.

3/4 Curl Permit Seasons

Regulations requiring the harvesting of rams having 3/4 curl or better have been retained in two hunting districts in the State. In one area adjacent to Yellowstone National Park two permits are issued to harvest rams that are unavailable until they reach winter range. Animals in the area receive a good deal of public attention and it is felt there is better public acceptance of this type season than one allowing the harvest of smaller animals. The other area having only 3/4 curl permits is composed of a small group of native animals in the West Bitter root. Rams in the area do not attain the 3/4 curl category until approximately five years of age. The overall population is being limited by competition with elk and livestock and under the current circumstances this is felt to be the most liberal season that can be maintained in the area.

Ewe Permits

As stated previously ewe permits were first issued in Montana in 1974. By 1983, 288 total permits were being issued in 11 hunting districts. Following recent die-offs in the Sun River and Beartooth herds, and some extensive population control measures in the Thompson Falls area, the numbers of permits were reduced to 112 in 1985. These seasons start with the opening of the general big game season and run through the end of November. The majority of animals are taken during the later portion of the season as animals begin to concentrate on winter ranges. These permits are being used to manage the female segment of populations in well established herds across the state. There seems to be a direct correlation between the accessibility of ewes and the popularity of this permit, and hunter success runs between 60% and 95% depending on the location of the hunting district.

Outlook For the Future

Some possible changes that may occur in future seasons in the State may include the additional use of 1/2 curl permits issued in more areas as population control measures and to provide additional man days of recreation. In order to reduce the high rate of hunter success, which has been estimated at over 90 percent since 1980, and again provide additional man days of recreation, managers are looking at increasing the numbers of permits available for rams and setting up earlier seasons to reduce the ram harvest on winter ranges.

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Table 1. Habitat Use by Bighorn Sheep During Autumn, 1982-1984, Ford Creek, Rocky Mtn. Front, Montana

	1982	1983	1984
No. Relocations	14	17	11
Elevation (Ft.)	7154	7264	7336
Slope (%)	59	64	51
Cover Type (%)			
Rock/Bare	53	72	82
Open Timber	47	22	0
Timber	0	6	0
Grass	0	0	18
Habitat Components (%)			
Ridge	27	28	82
Talus Slope	27	56	9
Cliff	6	10	0
Mtn. Grassland	13	0	9
Sidehill Park	27	0	0
Timber	0	6	0

Correlation Coefficients (r) for cover types and habitat components were all > .90 for comparisons between 1982-1983, 1983-1984 and 1982-1984.

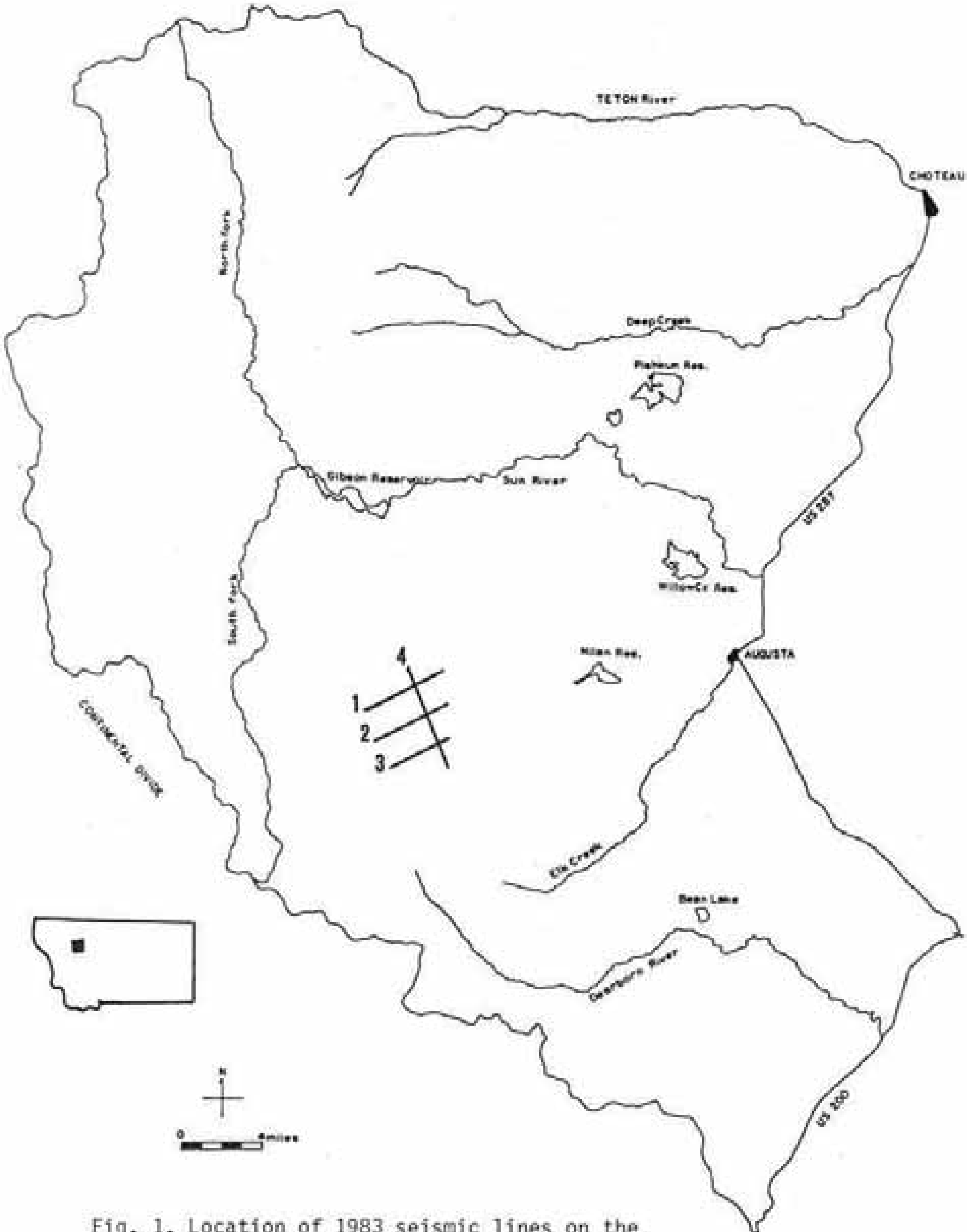

Fig. 1. Location of 1983 seismic lines on the Ford Creek study area, Rocky Mtn. Front, Montana

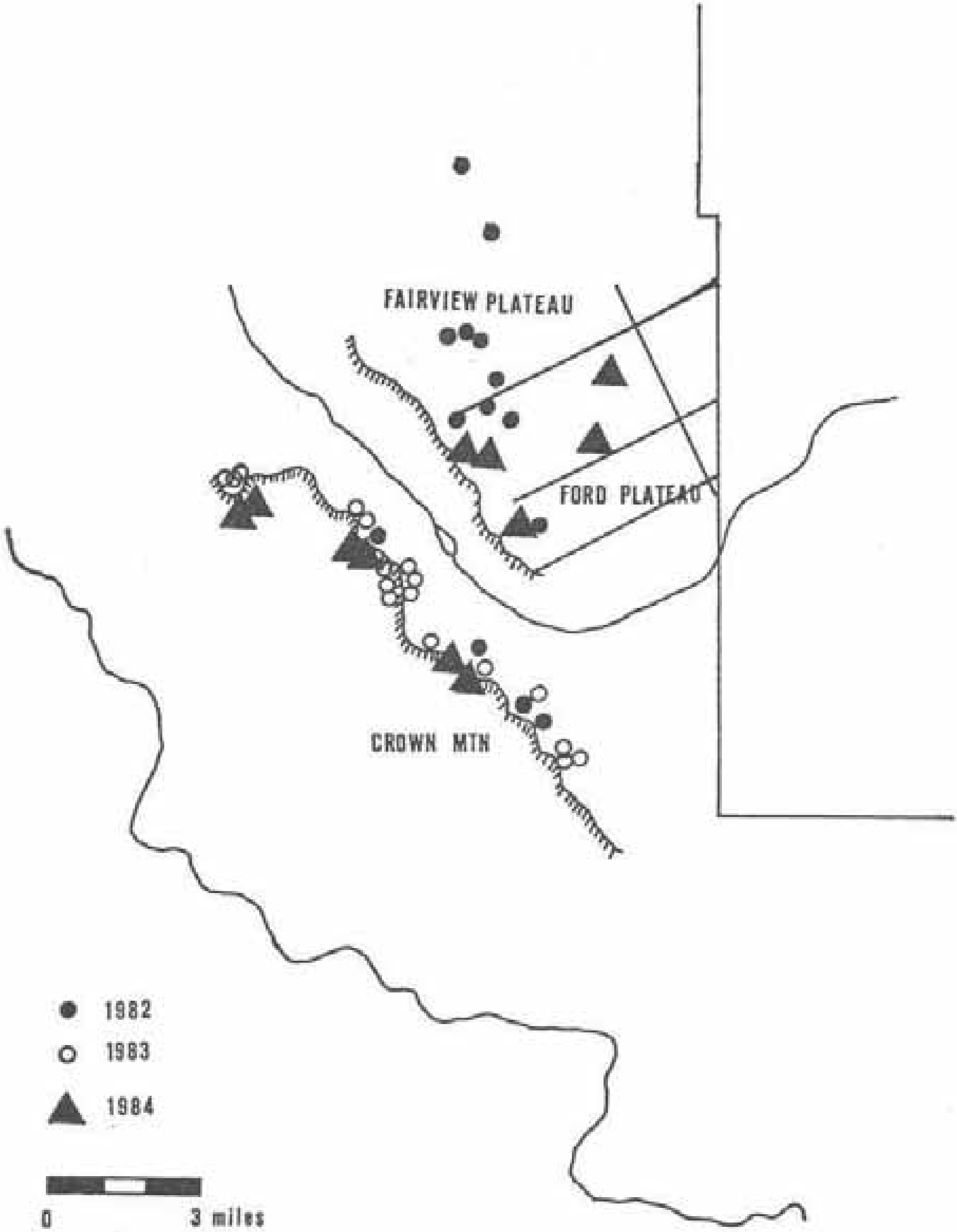

Fig. 2. Relocations of bighorn sheep, autumn 1982-84, Ford Creek study area, Rocky Mtn. Front, Montana

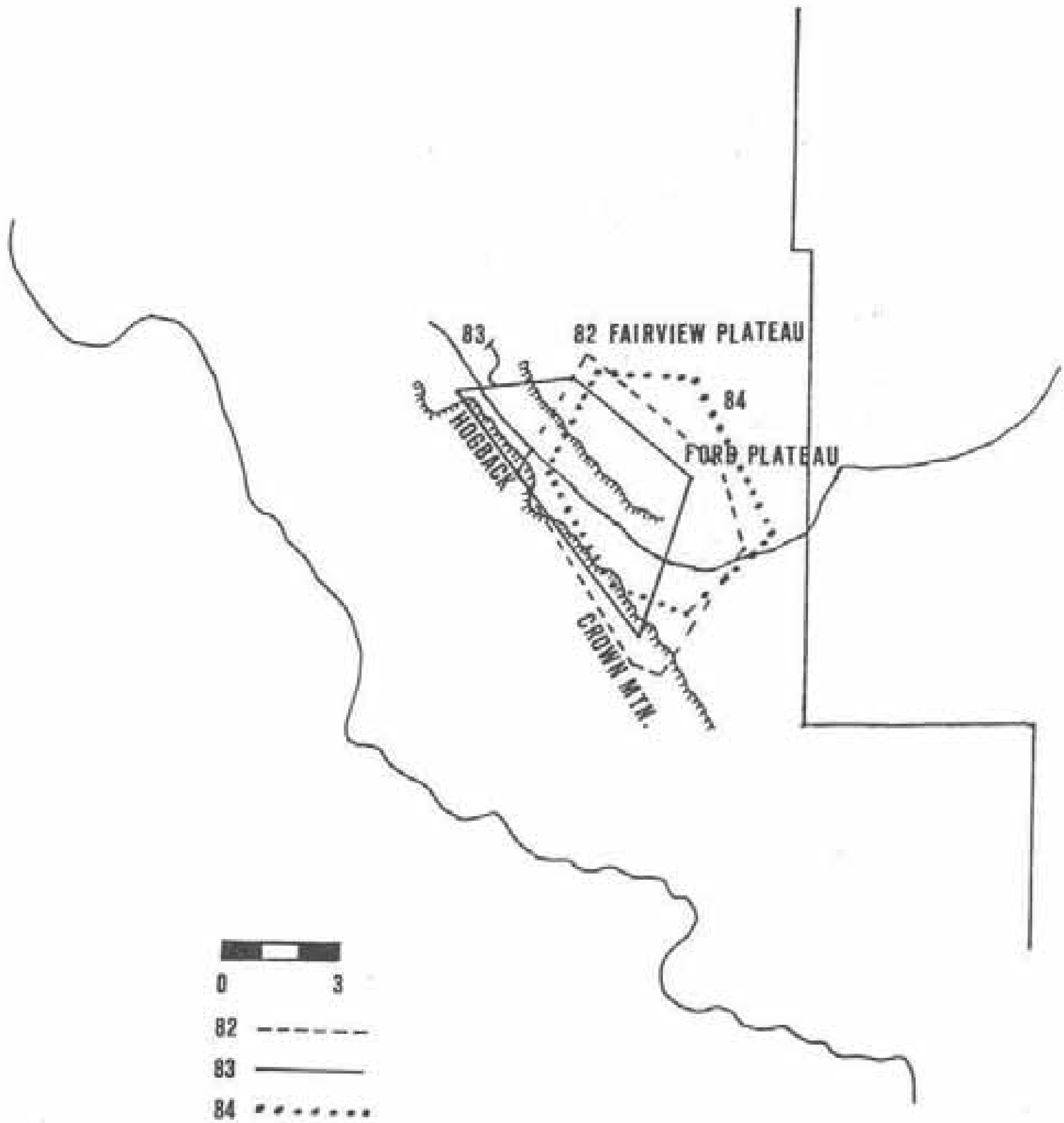

Fig. 3. Sheep 3204 (adult ewe) annual home ranges during 1982-84, Ford Creek study area, Rocky Mtn. Front, Montana

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HARVEST STRATEGY PANEL: MAXIMIZING RAM HARVESTS

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Author's Note: This report is a summary of ideas presented for discussion. It is not intended to represent the position of the Alaska Department of Fish and Game.

Abstract: Discussion of harvest strategy implies a management goal which the strategy is employed to achieve. However, the most common harvest regulation in the western United States, the 3/4-curl law, appears, upon historical review, to exist because of tradition instead of being selected to achieve maximum harvest goals. When maximum sustainable harvest is the management goal, ram mortality patterns, behavior, theoretical energetic considerations, and empirical data gathered in Alaska's Dall sheep (*Ovis dalli dalli*) management experiences indicate greater harvests of rams can be sustained by limiting harvest to Class IV rams. This strategy may not be the most effective if maximum sustained ram harvests are not the primary management goal.

Use of the term harvest strategy indicates the existence of a goal which managers of mountain sheep populations seek to achieve. Presumably, this goal has been defined by a management plan. Presuming even further, this management plan should have as its basis, a sufficient biological understanding of mountain sheep populations that the goal is achievable.

Harvest strategies comprise a spectrum of possibilities which could have goals ranging, at the extremes, from maximal growth to extirpation of any population. The harvest strategy selected should be appropriate for achievement of the management goal.

A brief review of history shows harvest strategy has been inherited more often than selected on the criteria defined above. After the decline of North American mountain sheep which accompanied the settlement of the American west (Buchner 1960), enlightened approaches to management of wild mountain sheep (mostly total protection) eventually brought many populations back to huntable numbers (Trefethen 1975, Hoefs 1985). As sheep populations returned to viability, managers sought a balance between protection and use. This meant allowing for harvest, either by hunting or transplant, within the limits of biological safety and herd growth. The need to assure continued herd recovery and health was easily understood. Likewise, the advantages of maximal use by hunters were well known, though less apparent. These included revenues produced by license and tag fees, the development and maintenance of the guiding and outfitting industries, and a high public interest in the conservation and management which attend hunting.

A review of mountain sheep hunting regulations across North America (Demarchi 1978) shows the most common attempt to balance herd growth (either for recovery or transplant programs) with maximized hunter use was an attempt to limit harvest to surplus males (rams). This same thinking produced "bucks only" seasons for deer at about the same time. Historically, rams which could be removed by hunters without noticeably compromising lamb production were defined as surplus. Sheep survivorship in unhunted populations shows a consistently low mortality between 1 and 7 years of age (Deevy 1947, Bradley and Baker 1967). Still, the conclusion reached by most sheep managers was that harvesting rams at the youngest acceptable age (before natural mortality removed any more of them than necessary from the shootable population) would give the greatest sustainable harvests. This was a data-free assumption. Establishment of the 3/4-curl regulation predated, by almost 15 years, the earliest study of mountain sheep mortality (Murie 1944). Nevertheless, it persists as the dominant rule governing harvest of mountain sheep throughout the western United States. Few dicta have persisted in such a data vacuum justified purely on (seemingly reasonable) assumptions.

Because ram horns grow throughout life and describe a full circle (full curl) at maturity, the legal age of rams for harvest has been defined by the degree of horn growth, portion of a full circle or curl, attained. The age/horn size limit commonly applied in North America was arbitrarily set at 3/4 curl in an effort to provide both biological safety and the maximum number of surplus rams. This defined rams above the ages of 3-5 years (depending on species and population growth rate characteristics) as surplus. This represented a step beyond males-only hunting and appears to have been designed to either assure larger horns or to protect young rams. The first 3/4-curl regulation was instituted in Wyoming in 1930 (Demarchi 1978).

Recently, rams have been shown to reach this horn size well after they develop the capacity to sire offspring, usually at 18 months of age (Nichols 1978). Consequently, some western states have set regulations which define rams above half-curl age/size as legal (i.e., surplus) game. According to Demarchi (1978), Oregon has a half-curl rule and Wyoming and Colorado have had them in the past. Colorado established a half-curl regulation again in 1983.

In this presentation, we shall discuss an alternate management strategy which is more likely to produce maximum numbers of rams for harvest. The rams will also be older and larger.

METHODS

We shall develop this theoretical strategy for maximal ram harvest based on the biology of mountain sheep using several data bases. The first is a review of mortality patterns for Desert (*Ovis canadensis nelsoni*), Rocky Mountain bighorn (*Ovis canadensis canadensis*), and Dall sheep (*Ovis dalli dalli*) by Bradley and Baker (1967). The second is the general behavioral pattern of mountain sheep as described by Geist (1971). The third data base we shall draw upon is our personal interpretation of information obtained from Dall sheep management in Alaska. Graphical analysis for prediction will also be employed.

RESULTS AND DISCUSSION

Natural Mortality Patterns

Murie published the first data relating to his large collection of Dall ram skulls in 1944. Shortly thereafter, Deevey (1947) applied the emerging technology of actuarial statistics to Murie's data, and produced a life table for Dall rams. Twenty years later, Bradley and Baker (1967) wrote a review article in which they produced similar life tables for most other species of North American wild sheep. As the actuarial technology developed, numerous questions arose about these analyses (e.g., Murphy and Whitten 1976). Still, there seems to be little doubt that these life tables, and the survivorship curves they generate, define, generally, the form of the survivorship curves for male mountain sheep and predict with sufficient accuracy to draw general inferences.

Age-specific survival for rams beyond age 1 has been measured for several unhunted populations (Murie 1944, Bradley and Baker 1967, Geist 1971, Murphy and Whitten 1976). The typical pattern from birth to recruitment as yearlings is one of high mortality which ranges 40-60%. The first year is followed by two periods characterized by radically different mortality rates. As Geist (1971:295) said: "It can be seen that there are 2 general phases in the survivalship curve...there is a phase of low mortality between the ages of 2 and 8 years and a phase of accelerated mortality in the higher age categories." Data for Dall rams (taken from Murie 1944) show mean mortality for the low mortality phase averaged about 2.3% per year. The mean rate during the high mortality phase was 17.8% of the 8th-year-and-older rams.

For purposes of analysis and simplicity of comparison, we fitted the least squares straight line to both phases of the survival curve. This analysis confirmed the 7.7-fold increase in mean mortality rate beginning at age 8 in Dall sheep. These mortality rates and the ratios between them are typical for mountain sheep populations (Bradley and Baker 1967). In summary, mountain sheep rams do not face serious mortality risks in unhunted populations until they reach age 8. This age generally corresponds to Geist's Class IV status (Geist 1971). These are the socially dominant rams which do most breeding and maintain social order in ram society.

Hunting Mortality and Management

As a management consideration, development of a strategy for maximizing ram harvests seemingly presumes sufficient harvest effort to take most legal rams, of whatever size, each hunting season. The question then becomes, what are the biological consequences of the 3/4-curl regulation when maximum harvest is allowed?

Observations of several Alaskan Dall sheep populations subjected to this cropping strategy indicated that lamb production continues despite complete removal of Class III and Class IV rams. Formerly, we thought this showed that no negative effects on lamb production attended maximal cropping at 3/4-curl. However, cumulative evidence, which I shall present later in this symposium, indicates this was an optimistic though unwarranted conclusion. Lamb production, it now appears, may be seriously compromised by removal of virtually all rams down to 3/4-curl age/size.

A second question is, "Are we really providing the maximum sustainable harvest by setting the lower legal limit at 3/4-curl age/size?"

Behavior

Consideration of mortality patterns along with studies of the behavior of mountain sheep rams suggest we are not providing the maximum sustainable harvest by setting the lower legal limit at 3/4-curl age/size. Geist (1971:295-296) predicted serious consequences in a population where younger rams actively participate in breeding. Based on energetic considerations, he said:

> "The ages of low mortality in rams coincide with their dominance status and near exclusion from breeding by larger horned, older rams. Conversely, when rams reach near ultimate body and horn size and become dominant breeding rams during the rut, their mortality increases. This relationship between dominance and high mortality appears to be causal for the following reasons: large, dominant rams which breed most ewes virtually do not feed while guarding ewes and they fight extensively and do much running and chasing when following the estrous ewe and discouraging competitors. Unlike small rams, the large breeding males often return exhausted from the rut. They have probably lost most of their fat deposits, whereas subordinate rams probably retain theirs. In the severe winter months following the rut, the rams that have lost their energy reserves probably succumb (see Heptner et al. 1961 for other ruminants). Two predictions, as yet unverified, are that large rams should lose more weight during the rut than small-horned rams and that YOUNG RAMS WILL DIE OFF MORE RAPIDLY IF, DUE TO CIRCUMSTANCES, THEY ARE ALLOWED TO PARTICIPATE IN BREEDING AT THE SAME LEVEL AS OLDER RAMS" (emphasis ours).

If the cause of accelerated mortality is the same for both younger and older rams, Geist may be predicting the mortality rate for rams involved in rut should be similar regardless of age. That is, it represents the mortality-cost of dominance.

When maximum harvest of 3/4-curl rams is permitted, it allows younger rams to participate in breeding at the same level as older rams would if they were present. We reported on this situation (Heimer and Watson 1984) in Alaska at the last meeting of this symposium. Our data from Dry Creek in the Alaska Range showed the least squares line describing accelerated mortality among marked rams in a heavily hunted, 3/4-curl-managed population had "the same" slope as that for rams aged 8 years and older found in Murie's skull collection from unhunted McKinley Park (Murie 1944) (Fig. 1).

If we may assume our findings, which verify Geist's prediction about early death, are generally applicable, it becomes possible to predict the number of rams available to hunters under various ram harvest schemes at maximum harvest levels. Fig. 2 is used to make these predictions. In this figure, a survivorship curve for Dall sheep (adapted from Murie 1944, to fit production and recruitment levels at Dry Creek) is plotted, and the slope of the accelerated mortality phase for dominant rams determined. The ram age/status classes (as defined by Geist in 1971) have been superimposed on the abcissa at their corresponding ages for Dall sheep in Alaska. Predications of sustainable harvest with more permissive legal ram definitions are derived by shifting the best straight line for the accelerated mortality phase of the curve toward the left. If removal of dominants has a constant effect on the opportunity of young rams to participate in the rut, the extent of the leftward shift will predict the number of rams of any given cohort which would be expected to survive. Of course, the function is not continuous because rutting is limited to the winter rutting period, and some care must be exercised in placement of the line describing the anticipated accelerated mortality effect.

As a first approximation, we could place the accelerated mortality phase line so it intersects the survivorship curve at the first possible active rut in a ram's life. This is the second rut when a ram is aged 18 months. If rams in this age/status class had the same opportunity to rut as all other rams in the population, and suffered the consequent mortality increase, the predicted harvest would be about 200 of the 570 rams recruited as yearlings. However, Nichols (1972) gathered data on rutting behavior from a population heavily cropped at 3/4-curl. These data suggested the 1/4-curl rams (Class I) did not participate in rut as much as rams which are another age/status class higher (Class II). These data suggest the line describing the accelerated mortality phase should be placed so it intersects the survival curve at the rut before the beginning of age/status Class II, the 1/2-curls. When this is done, the prediction comes to about 275 rams. Here it is worth noting that Heimer and Watson (1984) reported marked rams began to disappear at the increased mortality rate at age 3 in Dry Creek (Fig. 1). This seems to support the argument that under these circumstances, Dall sheep begin actively participating in rut before age 3.

It is important to note that this prediction (a maximum sustainable harvest of 275 rams) exceeds the sustainable ram harvest empirically determined by maximal harvest at 3/4-curl in Alaska. Heimer (1980) reported the observed maximal harvest from steady-state non-lamb populations in Alaska was about 2.5% from four different areas throughout Alaska over a cumulative period of 14 years.

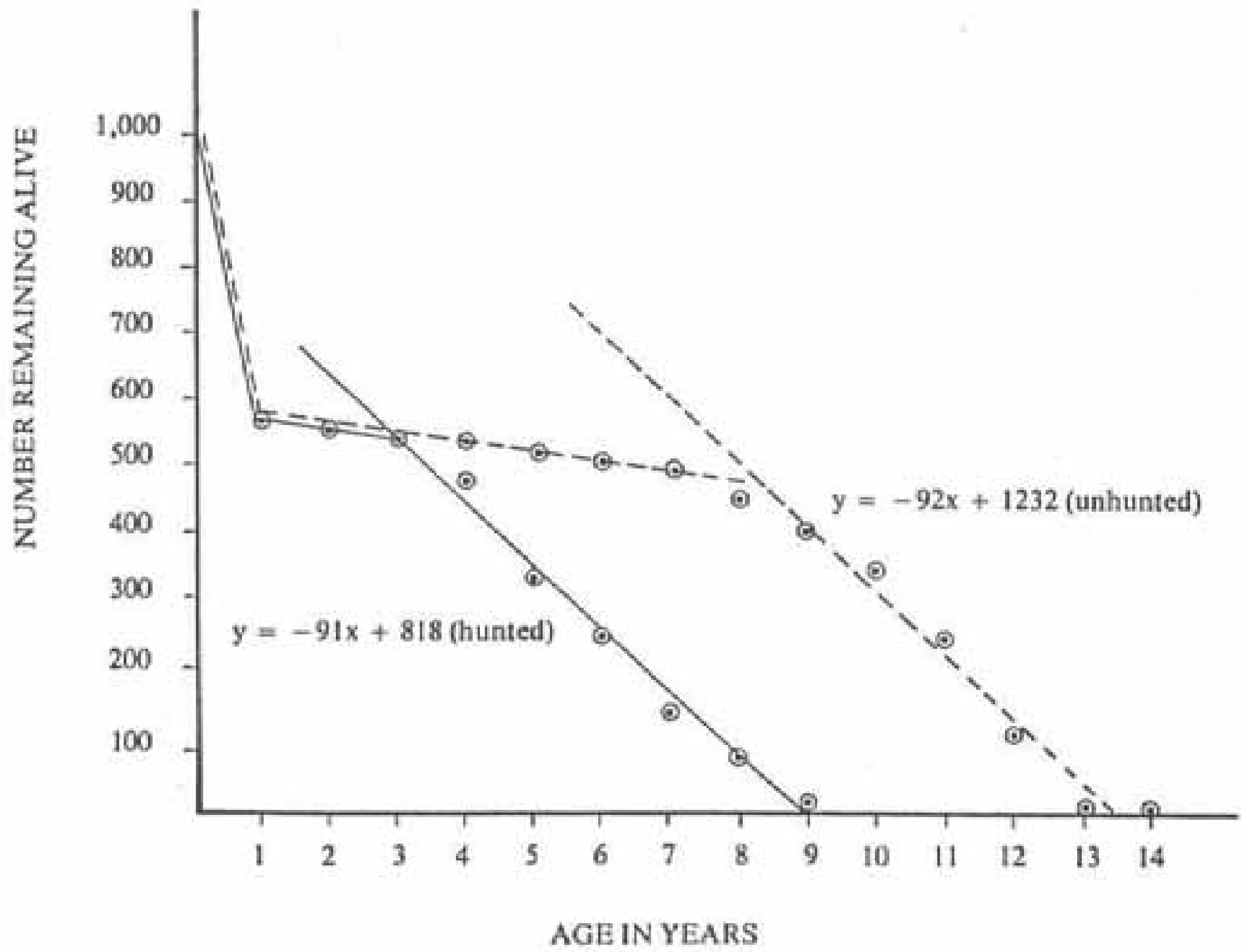

Fig. 1. Survival of Dall Rams in the heavily hunted (Dry Creek) and unhunted (Mt. McKinley Park) sheep populations.

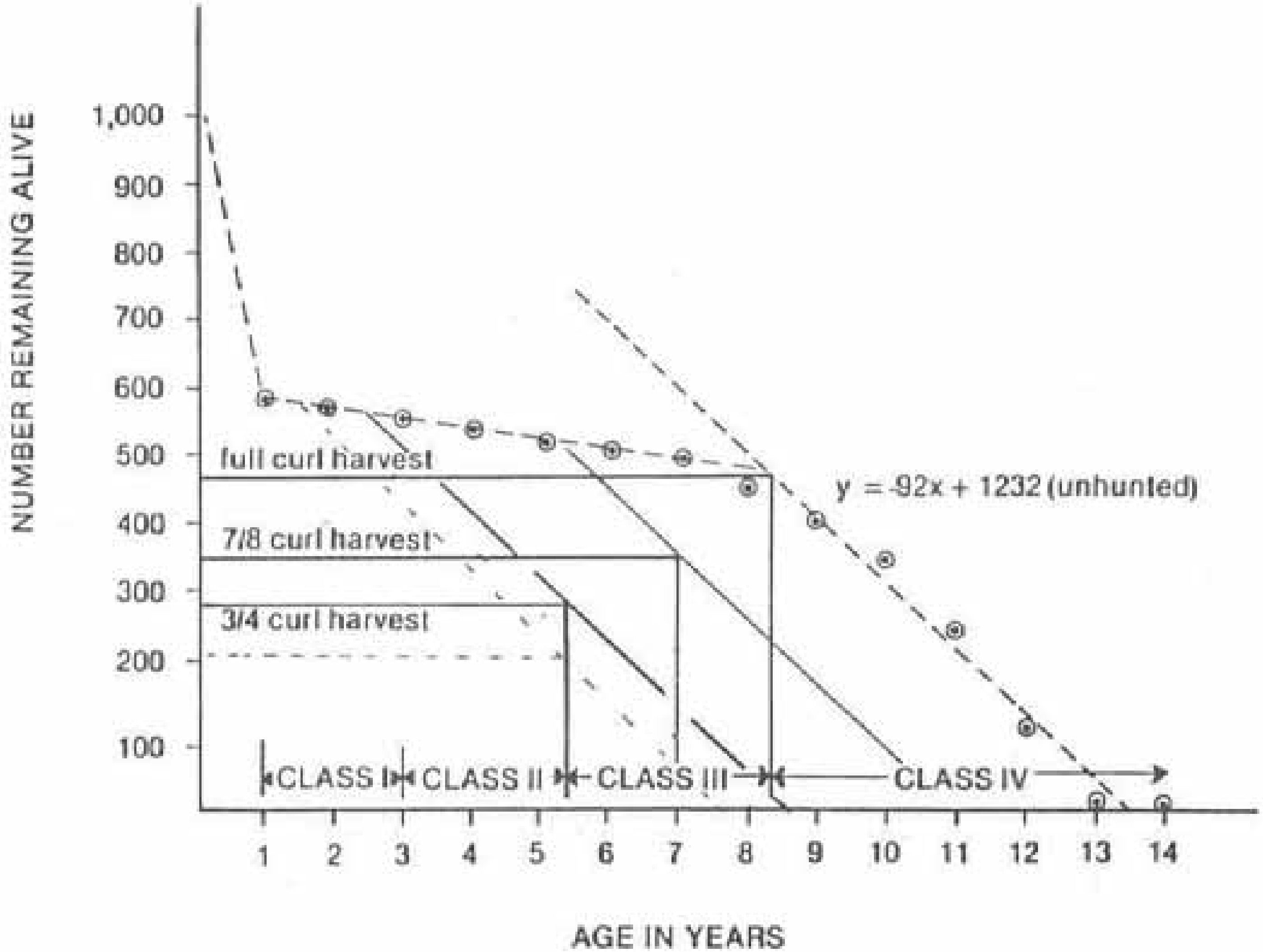

Fig. 2. Dall sheep ram survival in an unhunted population (dashed line) and survival of sublegal rams under different hunting regulations assuming maximum harvest of legal rams (from Murie 1944).

In Fig. 2, the sustainable harvest <u>rate</u> was estimated by calculating the number of sheep (excluding lambs) required to produce a "cohort" of 1,000 lambs. The sex ratio of mountain sheep is about 50-50 at birth (Hoefs and Cowan 1979), so the production of 1,000 rams lambs required the birth of 2,000 lambs. Based on the mean production rate required for stability in the Dry Creek population since 1970, 42 lambs/100 ewes, the number of ewes required to produce 2,000 lambs would be 4,671 ewes. Population composition in Dry Creek averaged 54% ewes during the aerial surveys of 1970, 1975, and 1980. When this mean figure is applied to the data, it yields a calculated population of 8,817 sheep (excluding lambs) required to produce 1,000 ram lambs. When the predicted sustainable harvest (275 rams) is divided by the non-lamb population, the result is a harvest rate of 3.0%. This prediction exceeds by 20% the sustainable cropping rate empirically determined in Alaska. Other factors may cause the theoretical rate to be greater than the observed rate. In any case, it appears that greater survival of recruited ram yearlings to shootable age when old rams are present will provide more rams for maximum harvest even if they must live to full-curl age/size than are available for maximum harvest at 3/4-curl age/size. This could lead to as much as a doubling of ram harvests of older (and larger) rams.

Further supportive evidence comes from marked rams in a full-curl regulated area in Alaska. Heimer and Watson (1984) reported a return rate of only 16% for ear tags placed on sublegal rams in the maximally cropped 3/4-curl area when the population was about 1,500 sheep. In contrast, at least 27% of rams marked in a similar manner from the full-curl area have reached full-curl as of this time--they survived not only to 3/4-curl age but to full-curl age/size. Harvest in the full-curl management area is submaximal, being limited by permit to less than the calculated recruitment to the full-curl age class, and many of the 33 marked rams have not yet reached legal status. Tag returns by hunters are expected to increase further as more of these rams become legal game.

The above data have important management implications. If the management goal is to practically maximize ram harvest, then higher harvest levels are likely to be sustained by taking rams from only the upper age/status class (Class IV). Certainly, some rams will be lost to natural mortality between Class III and Class IV, but the potential harvest may double if only Class IV rams are harvested (Fig. 2). If the limit is set at 7/8-curl, as in most of Alaska at the present time, the model predicts an increase in harvest of approximately 30% over that at 3/4-curl in areas of maximal harvest.

It is possible that the anticipated Class IV (full-curl for Dall and Stone sheep) harvest may not be fully realized. Based on computer simulations of horn growth, Nichols (1984) suggested that in some thinhorn populations up to 15% of the rams may never reach full-curl horn development. Should this prediction be correct, the efficacy of setting a legal age minimum as well as a degree of horn development (such as in British Columbia) when maximum harvest is desired becomes apparent. However, even a maximally restrictive full-curl rule could still be expected to increase sustainable thinhorn harvest, even though the increase would theoretically be less.

Establishing regulations which limit harvest to Class IV rams for thinhorn sheep is relatively easy. Thinhorn rams broom their horns less frequently and later in life than bighorns. Hence, setting a regulation defining legal sheep as full-curl or with both horns broomed (not worn) effectively limits harvest to Class IV rams. Establishing a regulation which will limit harvest to Class IV bighorn rams appears to be a more challenging management problem.

In practice, a noticeable increase in sustainable harvest rate has yet to be conclusively demonstrated by maximum harvest. Heimer (1980) reported a submaximal harvest percentage of the non-lamb population from the full-curl management area (where participation is limited by permit) of almost 4% (compared with 2.5% maximum at 3/4-curl in other populations). This harvest rate allowed maintenance of a 12-year horn size of 36.5 inches and a mean age of nearly 8 years for rams harvested from this population of about 1,800 sheep. Experimental full-curl regulations were established two hunting seasons ago in interior Alaska. To this time, there has been no notable increase in number of rams harvested. In these areas, maximal cropping for 7/8-curl rams had been in effect for the previous 5 years, so no increase is anticipated for another year. Still, the harvest has not declined, and harvest across the entire full-curl area in 1985 was the highest since 1977. Hunter success in 1985 equaled that for heavily hunted 7/8-curl populations and was comparable to hunter success for 3/4- and 7/8-curl rams in past years. Similarly, British Columbia has implemented a series of progressively more "restrictive" horn development regulations (Demarchi 1978). Their current full-curl regulations have been in effect since 1978, and no decline in harvest has been observed. In fact, harvests have increased (Demarchi, pers. commun.).

In summary, theoretical, experimental, and empirical approaches to the question of whether traditional 3/4-curl management provides maximal harvests of mountain sheep rams are in remarkable agreement that the answer is "no." It should be stressed here that these arguments are applicable where maximum harvest is the desired management goal. If submaximal harvest is the goal, or if hunting pressure is insufficient to take all legal rams, other harvest schemes may function within the biological capabilities of mountain sheep populations to meet these goals. However, our conclusion is that when maximum harvest is desired, and in fact, practiced, harvest levels will be greater, and population health improved by restricting harvest to Class IV rams.

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QUESTIONS AND ANSWERS

Daryll Hebert, British Columbia: I was just wondering if you had a similar ram mortality curve for any other area in Alberta besides Ram Mountain?

Wayne Heimer, Alaska: It's about the same.

Hebert: Wayne, the other question I have is, you've got as you mentioned tag returns on your 3/4 curl sheep area and your full curl sheep area. Is there going to be an attempt to reverse the harvest procedures to experimentally test whether you can change that around?

Heimer: There's going to be an attempt to try to get it done. I keep proposing that we go ahead and test these ideas. What we have done is, we've done it once where we do it really big in 3/4 curl shooting. We have those results. We've done it where we do it in full curl and trying to go back and re-establish another experimental situation at 3/4 curl maximum yield to try and just tighten things up a little bit here. Just send your money to Wayne Heimer.

Jim Ford, Montana: This is for Brian Horejsi, I wonder if you would care to comment on Wayne's presentation as it applies to bighorns maybe in Alberta.

Brian Horejsi, Alberta: Well, I believe Wayne is referring to a situation where they crop them all. In other words, its a clean sweep of our rams. Several years ago Geist suggested that for every 100 bighorns, you can expect about five trophy rams a year being produced. That's pretty close. We see about six trophy rams a year being produced. We crop maybe 2/3 of them, but there's still about 1/3 of them that go on to become larger. We don't wipe out all the big rams, but there may be some influence, we're not sure. Certainly that differential decline in rams versus the ewes in natural mortality, there's something going on there.

Heimer: I think it's quite probably that we're better at vacuuming all Dall rams off the mountain than bighorns. There you're hunting a white sheep standing on either a green or brown mountain. Its in the alpine exclusively. They can't hide in the trees. They like people. I think we can be a lot more efficient at taking Dall rams off a mountain than you probably can bighorns.

Kevin Hurley, Wyoming: I have a question for John McCarthy. With some of these different permits, the 1/2 curl or less or the ewe permits, how does that effect an individual's opportunity in subsequent years to draw a permit for a 3/4 trophy ram.

John McCarthy, Montana: We did away with the waiting period. We had a preference system and a waiting period until 1983. It was a stroke of business to get rid of both of them. It became a horrendous bookkeeping task to track the waiting period and preference. It got so far out of hand that when you had seven years preference, 95% of our sheep hunters had seven years preference. We were able to get rid of both the waiting period and preference. There's a move on right now to re-establish the waiting period.

Hurley: Yes, the reason I asked that question is because in Wyoming there's a five-year waiting period between drawing successive permits. In order to achieve the population control that you're talking about, by using ewe permits for example, the palatability of selling those permits would decrease because of a waiting period. I think your ability to sell those permits would be enhanced if it didn't effect an individual's opportunity to get a permit for a ram.

McCarthy: We went through the same thing. When the ewe permits were first initiated there was that five-year waiting period, but I don't think we had trouble selling them in most of the areas. We initiated them in the Sun River area, and for some reason, I can't sell a ewe permit. But if you go down to Thompson Falls, they're snapping them up left and right. Again, I am alluding to the accessibility. If you can't shoot a ewe right on the highway, then people are going to buy them and they'll take that five-year wait to do it. In the Sun River, if you've got to walk more than a mile away from the road, the percent success or the percent of people who even hunt drops dramatically. It's just amazing.

Heimer: I've got a question for John. You said that you thought the harvest of 1/2 curl rams and the low mortality period of their life was probably compensatory rather than additive. We struggled with this problem in our model saying that we can kill more sheep if we kill only the class 4 and up; on the other hand, we asked ourselves if we could kill them from all across the board. I'm just wondering if you could explain why it is you think that mortality is compensatory rather than additive. We just kind of have taken a simple minded approach and said you're never going to get to be an old ram if you don't be a young ram first. We are operating under the supposition that when you die, you're dead.

McCarthy: I guess that the way we're looking at it is that as long as we're cropping those age classes at a rate that is less than their natural mortality we will be able to take a certain amount of those. Again, we aren't looking at the clean sweep that you guys are on taking those older age classes, and I think that's also got something to do with the population structure.

No Name: Just for Dr. Olsen's benefit, we classify our ewe season as a non trophy season. We're just not after trophies.

we're after non-trophies. I don't think it makes much difference in terms what you call them, but maybe it does after hearing Dr. Olsen.

Jim Bailey, Colorado: John Emmerich, you gave some experiences with 1/2 curl regulations. Was there any evidence of an affect on ewe survival or lamb productivity in those seasons you describe?

John Emmerich, Wyoming: No, we didn't have the data. Really, the only area in the state we have good data is the Whiskey Basin herd. We're trying to get more data on some of these other herds, but in those particular areas we didn't have data to determine what effect there was on the production.

Hebert: Wayne, since you're having trouble convincing Alaska Department of Fish and Game about your full curl regulation, what does Alaska think about our over full curl regulation for Stone sheep in BC?

Heimer: It's not widely known in Alaska that there's a lot of other stuff going on. The prevailing sentiment seems to be that I just make all this stuff up, and if you'd care to drop a letter asking, I could give you some addresses to write to.

Mountain Goat Harvest Strategies

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HARVESTING MOUNTAIN GOATS: STRATEGIES, ASSUMPTIONS, AND NEEDS FOR MANAGEMENT AND RESEARCH

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Abstract: Mountain goats (Oreamnos americanus) are harvested (1) conservatively to avoid risk of population decline, (2) to maximize and sustain the harvest, or (3) to control herd size and distribution. Strategies for achieving these goals include control of roads, limiting and distributing the harvest, causing a density dependent increase in productivity as a response to harvest, estimating and harvesting each annual herd increment, harvesting mostly males, and monitoring population responses. Most strategies depend upon assumptions regarding the dynamics and ecologies of goat populations, and there is little empirical evidence for most assumptions, especially for local herds. Further, the accuracy and precision of monitoring are often unknown. There are opportunities for experimental management and research on goat populations. These studies will be most productive if specific hypotheses are tested by manipulating herd size or composition, or the herd environment, and if there are long-term commitments to the studies and to measuring several population parameters including reproduction and behavior.

This is an analytical review of the problems encountered in managing the harvest of mountain goats. Options and strategies, knowledge-base and assumptions, and needs for management and research are considered. My perspective derives from the literature and from experience with a herd of goats that was transplanted into Colorado in 1950. I am indebted to many students who have studied this herd, including B. Johnson, L. Adams, M. Masteller, K. Risenhoover, E. Rominger, D. Fieth, M. Opincarne, and J. Stone, all with support from the International Order of Rocky Mountain Goats. M. Masteller and R. Johnson made helpful comments on the manuscript.

HARVEST OPTIONS

Goals for harvesting mountain goats may be (1) to harvest conservatively and avoid the risk of a significant reduction of the base population; (2) to achieve a maximum-sustainable level of harvest; or (3) to reduce the numbers of mountain goats and/or limit geographic spread of a herd. In addition, harvest may be used to alter a population for research purposes.

A conservative harvest strategy may be justified because mountain goats have been easily overharvested (Foster 1977, MacGregor 1977). In particular, local populations that are newly accessible due to road expansion may be decimated quickly, as described by Chadwick (1983). In these locations, goats may be predictably present and available to hunters, and females may be shot at least as frequently as males.

Further, funds and methods for monitoring populations, especially local subpopulations, may be inadequate to detect population declines in time to effectively modify the intensity of harvest. These problems justify a conservative harvest strategy.

Agencies may strive for maximum sustainable harvest from a goat herd in order to maximize recreational opportunities, meat production, or income to support management activities.

Control of a goat population may be necessary when introduced ungulates are not consistent with the goal of naturalness in a national park (Houston 1968). In addition, mountain goats have been perceived as reservoirs of diseases that threaten other ungulates (Williams and Hibler 1982), and as serious competition for bighorn sheep (*Ovis canadensis*).

STRATEGIES, KNOWLEDGE AND ASSUMPTIONS

Conservative Harvest

Strategies for achieving a conservative harvest of mountain goats include limiting access with road control or closure, limiting the legal harvest, and control of illegal harvest. Road control or closure may be the most effective conservative strategy, especially for small herds, since (1) effects of any level of harvest on populations have seldom been measured; (2) adult females are often harvested; and (3) poaching may be difficult to control.

When goats are harvested conservatively, it is assumed that population monitoring will detect any serious population decline. Most monitoring of goat herds involves trend counts. These counts may have two limitations. First, each annual count may include several subpopulations. Trends for each subpopulation can be obscured in the total count. Second, counts are rarely replicated within years. Without knowledge of within-years variation of trend counts, short-term trends in population size cannot be detected (Harris 1986).

An unharvested or conservatively harvested goat population should be at or near ecological carrying capacity (Caughley 1976, 1979). The conservative harvest strategy assumes there are no important detrimental effects of this high ecological density upon the goats or upon habitat resources for goats or other species. (Ecological density is the number of animals relative to the quantity and quality of habitat resources; Bailey 1984). For mountain goats, there is very little empirical basis for or against this assumption.

Maximum-sustainable Harvest

Several non-exclusive strategies are used in attempts to maximize harvests from goat populations. These are (1) by reducing a herd, attain a density-dependent response of increased reproduction, recruitment, survival, and therefore, harvestable surplus; (2) regardless of density-dependent or density-independent variation in herd dynamics, measure and harvest a number of goats equal to the annual increment; (3) harvest primarily male goats; and (4) apply these strategies optimally to each subpopulation in a herd.

Density Dependence: While density dependence has been demonstrated for some herds of some ungulate species (Caughley 1970, McCullough 1979, Houston 1982), we cannot presume that density dependence is more, less, or equally important, relative to density-independence, for mountain goats; and we should expect variation among goat herds in the relative importance of density dependence. In goats, density dependence may be demonstrated (1) by comparing small, newly transplanted herds vs. larger, established or native herds; (2) by observing a herd during population growth; and (3) by comparing a herd before vs. after a natural or contrived population decline. When transplanted herds are involved in these comparisons, the effect of herd density may be confounded with an effect of herd age since establishment. Regardless of density, an older herd may have modified its environment, especially its habitat resources, in ways that are detrimental to herd performance.

Three studies involving transplanted herds indicate that density dependence may occur in mountain goats. Young, small herds have had, on average, higher rates of kid production than have older and presumably larger herds (Bailey and Johnson 1977). As two introduced herds have increased, rates of kid production have declined (Adams and Bailey 1982, Swenson 1985). In addition, Smith (1984) found weak evidence (not statistically significant) of density dependent rates of population growth in Alaska herds. A study involving reduction of a long-established herd in Olympic National Park, is currently underway (Houston et al. 1983).

In contrast, Kuck (1977a) reported that reduction of Idaho's native Pahsimeroi Mountain goat herd resulted in a declining rate of kid production. Similarly, a drastically reduced herd of introduced goats in the Crazy Mountains, Montana, has never recovered despite discontinued hunting. This suggests there was little or no herd benefit from reduced density (J. Swenson, personal communication).

There has been large density independent variation in the productivities of mountain goat populations. Several studies have indicated negative impacts of deep and/or persistent winter snow upon rates of kid production (Adams and Bailey 1982, Swenson 1985, and references therein). These studies imply that nutrition and/or energy demands during gestation influence fetal or neonatal survival. Stevens (1983) suggested that summer forage conditions in Olympic National Park have determined rates of kid production measured a year later. This implies that summer nutrition influences pregnancy rates. While density independence is well documented in mountain goats, concurrent density dependence may be detected if the critical weather data are used in covariant analysis (Bailey 1984, 1986) and if several years' data are obtained (Adams and Bailey 1982, Swenson 1985).

Delayed density dependence has been detected in populations of several vertebrate species. Delayed density dependence can be caused by development of population or environmental characteristics at one level of density (or ecological density); and persistence of these characteristics after a change in density (or ecological density). Persisting characteristics that have been documented for some vertebrates, but not for mountain goats, are (Bailey 1984):

I. Persisting population characteristics

   A. age structure
   B. physical and physiological conditions of animals
   C. genetic constitution

II. Persisting environmental characteristics

   A. condition of habitat resources
   B. prevalence of predators
   C. prevalence of disease

Since density independence is to be expected in goat populations, and since responses of a population to a change in density may be delayed, a hypothesis of density dependence and a harvest strategy that assumes density dependence cannot be refuted without many years of data. Thus a management strategy based on this assumption should include a long-term commitment to the strategy and to relatively precise monitoring of the population and of weather.

<u>Harvesting the Annual Increment</u>: If the annual increase of a goat population can be measured or estimated from other population data, and if harvest does not distort population sex-age composition, then a number of goats equal to the annual increment can be harvested annually without reducing the base population. In practice, the annual population increment has been estimated from population counts (or estimates) and sex-age classifications made annually or less often. More conservative harvests may be based upon the numbers of animals counted (the known-minimum population), without estimating the numbers of goats unseen. Using these counts or population estimates, the annual population increment has been estimated (1) from the kid:adult ratio, (2) from the yearling:adult ratio, (3) from indicated rates of population growth in recent years, based on annual counts or population estimates, and (4) from population modeling based on field data and "reasonable" estimates of mortality rates. In these four methods, each subsequent method uses more field data and requires fewer risky assumptions about herd population dynamics.

Several studies have shown that kid production varies greatly among years according to weather conditions (see above citations). During 11 years on our study area, kid:adult ratios have varied between 10 and 62 kids per 100 adults, 2+ years old (mean = 42, S = 13.7). Limited data indicate that overwinter survival of kids into the yearling class can also be highly variable. During 10 years on our study area, survival of kids has varied between 42 and 85% (mean = 59, S = 14.2); and over 11 years yearling:adult ratios have ranged from 5-45 per 100 adults (mean = 26, S = 10.2). Consequently, annual population surveys with post-survey designation of harvest objectives would be best for a strategy of harvesting each annual increment. However annual surveys can be expensive, particularly with helicopters (classification of yearlings from fixed-wing craft is questionable), and harvest permits are often issued before summer population surveys in order to meet social, rather than biological, objectives.

Based on one or more of the above four methods, most management agencies have chosen to estimate annual increments in goat herds conservatively and to harvest conservatively. Strategies intended to maintain sizes of native herds have been to harvest 4-5% of the population estimate (Hall 1977, Kuck 1977b); to harvest 10% of the known-minimum summer population (Ballard 1977); and to harvest 5% of the known-minimum number of at least 40 adults and yearlings (Kuck 1986). For young, introduced herds, which have been more productive than native herds, strategies have been to harvest an average of 7% of the population estimate (Adams and Bailey 1982); and to harvest 12-16% of the known-minimum population (Swenson 1985).

All these strategies are based on averages from past experience with individual herds. There is no guarantee they will be successful in the future or in other herds. Using average population increment, based on past experience, as a basis for harvest objectives will result in population growth in half the years, and population decline in half the years--even if herd dynamics do not change. Well-documented density independent variation in goat herds is unpredictable. Therefore, if herds and harvests are to be maintained, either a conservative harvest strategy is appropriate, or there must be monitoring of herd trend and probably of herd composition, as a basis for frequent adjustments in harvest strategy (Smith 1984).

Replacive Harvest: When harvest is replacive (substitutes for natural mortality), harvest will not reduce a population. This concept is related to the concept of density dependent mortality in which harvest reduces a herd, but survival rates are greater for the remaining smaller population. Intuition suggests that harvest is least likely to be replacive when the number of animals harvested is quite large and when prime-age, rather than older, animals are harvested. Kuck (1977a) concluded that harvest of more than 12-18% (my calculations) of the known-minimum population of goats at Pahsimeroi Mountain was additive mortality because the population declined. However, the population decline could also have been due to documented declining kid production and to harvest of nannies, with consequent loss of kid production. There appear to be no data to support or refute the assumption that goat harvests can be replacive mortality.

Harvesting Males: In polygynous, sexually-dimorphic species, harvest of greater numbers of males vs. females is often prescribed. Since males breed several females, there can be excess males, not necessary for maximum reproduction. In addition, where the sexes are not segregated in the critical season, removal of males may allow females more access to habitat resources, thus favoring survival and reproductive success of females in a density dependent manner. Neither of these two possibilities has been tested with mountain goats. By contrast, harvesting females rather than males will not only reduce numbers, but also the reproductive rate of a herd (unless harvest is replacive within the adult female segment).

Since mountain goats are polygynous, it is likely that larger harvests can be sustained if males are emphasized, producing a population sex ratio slanted toward females. However there is little sexual dimorphism in goats and in some studies females have been more easily and frequently observed than have males (Foster 1982, Risenhoover and Bailey 1982). Consequently, there is a tendency to harvest many adult females. On our study area, 45% of the harvest during 1967-1979 was females (Adams 1981). Throughout Colorado, despite a (non-mandatory) hunter orientation program, 59% of the 41 goats harvested in 1985 were females. It was suggested that poor weather during the 1985 hunting season diminished hunters' ability or interest in seeking male goats. Montana has recently published a hunter-education pamphlet, encouraging goat hunters to seek and identify males.

Subpopulations: There have been few long-term studies of goat populations with numerous marked animals. In a few studies, individual goats have shown strong fidelity to their winter ranges (Smith 1976, Kuck 1977a, Rideout 1977); but on our Colorado Study area, some nannies have used different winter ranges in consecutive years. In some populations, goats are consistently seen on isolated mountaintops or cliff-outcrops, and the extent of movement between these isolated habitats is poorly known, if at all (Smith 1982). It is suggested that some goat herds consist of somewhat discrete geographic subpopulations, particularly in winter. Ideally, harvest strategies would be formulated and applied to each subpopulation. But these subpopulations and the amounts of movement of goats between them are unknown for most administrative game management units. Further, census units for goats tend to be large, and data from more than one subpopulation are often combined. When hunting-season access varies among subpopulations, some can be overharvested while others are underharvested.

Population Recovery: Selection of a maximum-harvest strategy, rather than a conservative strategy, presents some risk that a population of goats will be overharvested and drastically reduced. This could result from inadequate population data, from erroneous assumptions regarding population processes, from unexpected levels of harvest on females, or from geographic concentration of the harvest. The impact of overharvest is lessened if goat populations can recover quickly once harvest is curtailed.

Mountain goats have a relatively low biotic potential. Although twinning is not uncommon, most nannies do not reproduce until 3 years old. Recovery of a decimated herd may also be delayed by the chance occurrence of detrimental (density-independent) weather, or by a delayed density-dependent response (see above). In apparently good habitats, reduced goat populations have been able to recover rather quickly (Smith 1984, Swenson 1985). But other herds have recovered slowly (Kuck 1977a, and the Crazy Mountain herd in Montana). Reasons for slow population recovery might include poor habitats, high predator-prey ratios, slow replacement of breeding-age nannies, or inbreeding depression of herd performance.

Population Control

Control of exotic species is a dominant and appropriate goal in national parks. We should maintain several large and relatively complete natural ecosystems in North America. Otherwise, as we alter more land, ever more intensively, we will have no basis for comparison. One day, we will not be able to know what we have done to the continent. Nor will we know all our options for managing our environment. Consequently, in national parks the scientific values of ecosystems, kept as natural as possible, are at least as important as the recreational values.

With exotic mountain goats, the difficulty of population control in and near national parks will depend upon access to the herds, and upon public acceptance of control as a goal. Public acceptance of control will vary directly with public awareness and understanding of the scientific values of natural ecosystems. This awareness and understanding is currently poor. Control of mountain goats in parks will also depend upon a willingness of state agencies to harvest goats intensively near park boundaries.

Mountain goats may compete with bighorn sheep, but this potential competition has many complex components (Adams et al. 1982) and has not been demonstrated. Goats carry diseases that can infect other ungulates but transmission has not been verified for at least some diseases and the role of goats as reservoirs is little known.

MANAGEMENT AND RESEARCH NEEDS

Management

If goats are to be managed intensively, there is a need for more and better local information on population size or trend, herd composition, and movements and distribution of herd segments. If funds are not available for obtaining this information, a conservative harvest strategy is justified. However, replication of ground-based trend counts, so that precision can be evaluated, may not be expensive. Marking and reobserving some goats will be of great value. Marked goats may provide the basis for a census, may permit evaluation of possible bias in herd composition data, may identify subpopulations in need of separate management, and may indicate differences between males and females in distribution and exposure to hunting.

There is a need to educate hunters on the importance of harvesting males rather than females, and on identifying males in the field. The hunter-education pamphlet used in Montana should be considered for use in other states and provinces. Hunter orientation classes, held in areas with high densities of goat hunters, are desirable.

Control of hunter access is needed in many areas. This may involve road location, road closure or opening, and timing of the harvest in relation to road conditions. Either reduced or improved access could be desirable. Reduced access may avoid overexploitation, legal and illegal, of local populations. Improved access could distribute a limited harvest over more subpopulations, or could allow hunters more time to find and harvest male goats. Hunting-unit boundaries might be modified according to road locations in order to achieve a good distribution of a limited harvest across subpopulations within a herd.

Lastly, biologists need an experimental approach to management (Bailey 1982). The efficacies of harvest strategies should be evaluated continually with population monitoring. Adequate testing of a strategy will require at least several years' commitment to the strategy and to monitoring the results.

Research

Research on census methods, trend counts, and classification counts of goat populations may be done by management biologists or by research biologists. Most management today is based upon trend and classification counts. There is very little consideration of either the accuracy or the precision of these two types of data. Studies of factors affecting accuracy and precision are needed.

Mark-reobservation methods show promise for censusing local populations (Smith and Bovee 1984). Since only a small proportion of a goat herd can usually be marked, confidence limits for the population estimate, based on a single sample of the marked-unmarked ratio, will be large. However, confidence limits can be narrowed by observing several samples of the marked-unmarked ratio, and basing confidence limits on the variance of the several independent population estimates. If male goats are less observable than are females (Risenhoover and Bailey 1982), the sexes should be marked in proportion to their occurrence in the herd, or a biased population estimate will result.

We know very little about factors affecting pregnancy rates, natality, neonatal survival and overwinter kid survival in mountain goats. Weather factors and population density have been shown to be involved in several herds. But variations in pregnancy rates, and in fetal and neonatal survival have always been submerged in the measured end product: the kid-adult ratio observed in summer or autumn. Further, how do weather or density affect reproduction and kid survival? Do they influence nutrition? energy costs? social intolerance? distribution according to social status? Does social status of a nanny affect her performance? or performance of her offspring? We have barely begun to observe these factors in untreated goat herds. We can learn much more if we experimentally modify a population or its environment.

In particular, we need to study density-dependence in mountain goats. This can best be accomplished with a long-term commitment to the study, and experimental modification of population size. Such a commitment should not be wasted by measuring only a few population parameters, perhaps imprecisely. Animals should be marked. Parameters of reproduction and survival should be measured. Movements, distribution and social factors should be observed. Forage conditions and weather factors should be measured. Can we assume, as we have been, that diseases need not be evaluated? Hypotheses regarding all these factors in relation to density are implied in the literature. They should be tested in planned experiments.

CONCLUSION

Our knowledge-base to support almost all harvest strategies for mountain goats is weak. For many herds, a conservative strategy, as promoted by Chadwick (1983), seems appropriate. There are abundant opportunities for basic and applied research in goat population dynamics. These studies will be most fruitful if herd size or composition, or the herd environment, are experimentally manipulated in planned tests of specific hypotheses.

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MOUNTAIN GOAT MANAGEMENT

IN BRITISH COLUMBIA

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ABSTRACT: British Columbia has the largest population of mountain goats (Oreamnos americanus) in North America. In the past, management practices allowed several populations to be severely overharvested. With the advent of compulsory inspection, limited entry hunting and improved surveys, most goat populations are being managed with a better understanding of their biological requirements. Although harvest was resticted during the 1970's it is now beginning to increase under a controlled system. The proportion of females in the harvest is relatively constant while average age is increasing slightly. Harvest rates vary from 0.36% to 9% and if distributed homogeneously throughout the population, could probably be increased. Coastal populations are generally regulated by density independent factors while interior populations may be more influenced by density dependent controls.

British Columbia supports the largest population of mountain goats in North America, approximately 50,000. Mountain goats inhabit a wide diversity of habitats, from coastal forests to alpine tundra. Similarly, their population dynamics range from highly productive, high density populations to less productive, more highly fluctuating coastal populations.

Most mountain goat populations in British Columbia (B.C.) were relatively unmanaged until severe overharvests were identified in the Okanagan (Bone 1978) and especially in the East Kootenay region of southeastern B.C. in the 1960's and 1970's (Phelps et al 1975). Consequently, season and bag limit changes were introduced to reestablish healthy goat populations (Hebert 1978).

Recognition of specific attributes of mountain goat ecology (Hebert and Turnbull 1977, 1978, Rideout 1977, Kuck 1980, Chadwick 1977, Foster and Rahs 1982, Smith 1984) encouraged an improvement in mountain goat management programs. At the same time, Blower (1977), attempted to estimate population size for each management region of the province, using biophysical estimate methods. Intensification of mountain goat management in B.C. proceeded from the southern portion of the province (Region 1, 2, 3, 4, 5 and 8) which had undergone increased access, demand, and habitat loss, while the northern regions (Regions 6 and 7) of the province which remained relatively untouched. Individual ecotypes (Hebert and Turnbull 1977) were recognized, and differing harvest rates were calculated for each (Hall and Bibaud 1978, Youds et al.1980). Data was accumulated in order to calculate rates of increase (Youds et al.1980) and basic population modelling was initiated (Hebert and Langin 1982). Recently, extensive surveys (Hebert and Woods 1984) were undertaken in B.C. and the data summarized to indicate similarities or differences in productivity and density of populations throughout the province.

During the past 7 - 10 years, B.C. has experienced relatively mild winters. As a result, productivity and survival in most mountain goat populations was high. Harvest has begun to increase in the southern portion of the province but has declined slightly over much of the northern portion due to the introduction of the Limited Entry Hunt (L.E.H.) system.

METHODS

Data were obtained from the Summary Statistics package of the B.C. Wildlife Branch. Statistical information is gathered from a hunter questionnaire and compulsory inspection reporting for age, sex and location. The hunter questionnaire is mailed to all hunters purchasing a goat tag and successful hunters must produce the horns, the lower jaw (to extract I_1 incisor) and the hide to confirm sex of kill.

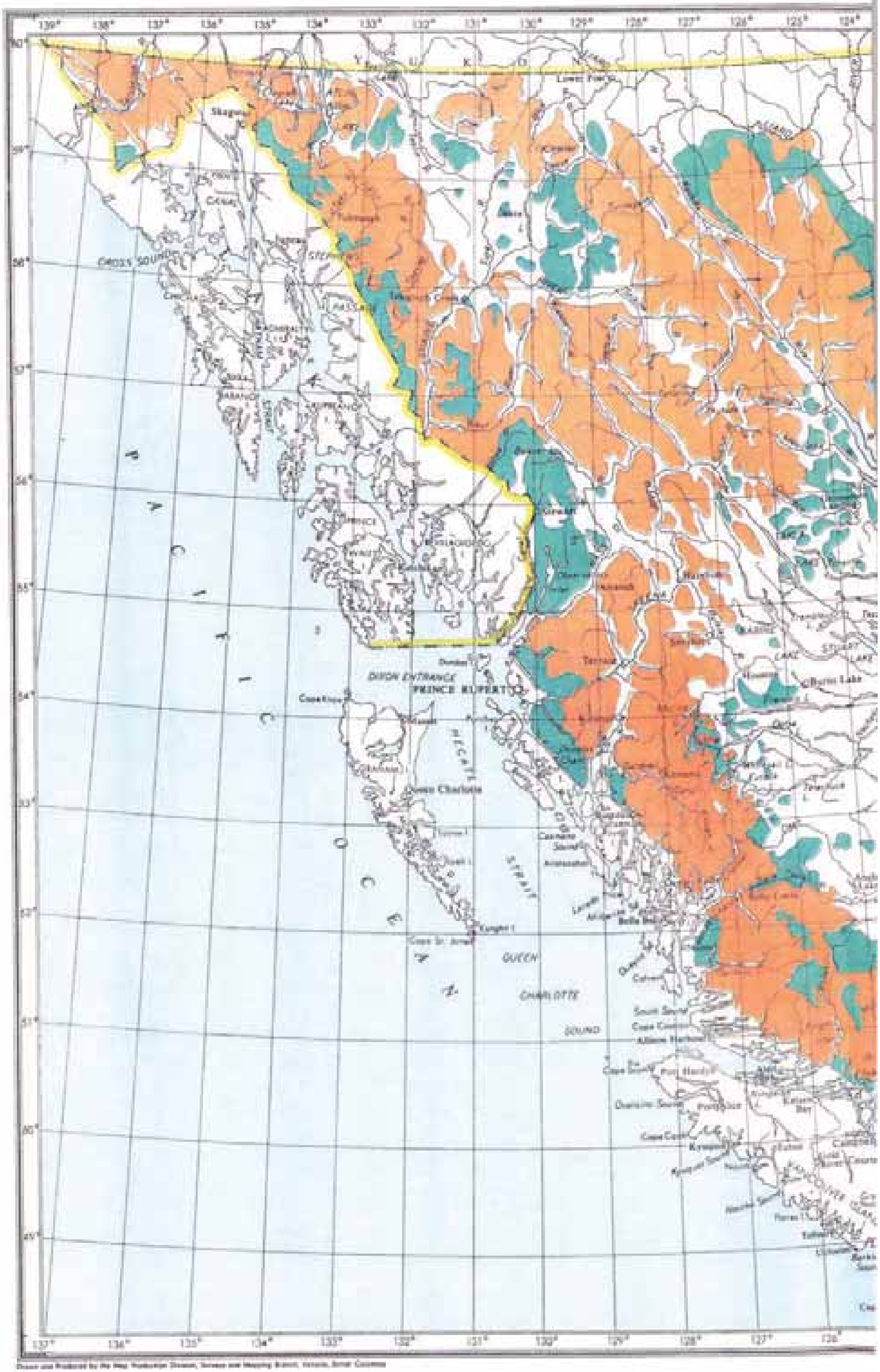
RESULTS

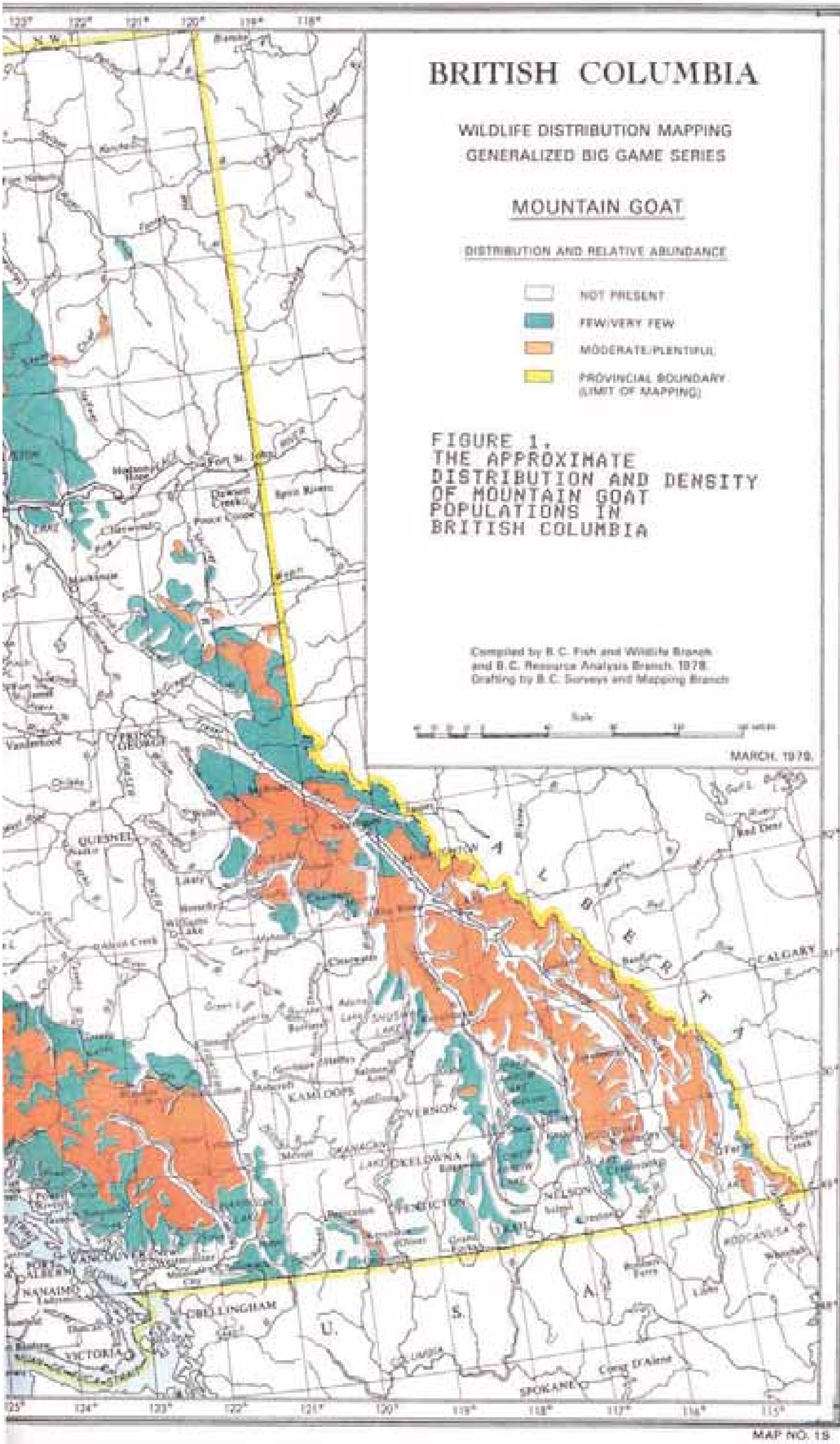
The extensive mountain goat population of B.C. is distributed throughout a wide diversity of habitats from coastal forest to alpine tundra (Fig. 1). Mountain goats are absent from the interior plateaus of the Okanagan and Cariboo. Generally, population densities and production are higher for interior populations than for most coastal populations (Hebert and Turnbull 1977, Hebert and Woods 1984). Population estimates (Table 1) were derived from mapped density estimates (Fig. 1) and only recently have portions of the area been verified by actual surveys.

Table I. POPULATION ESTIMATES FOR MARCH 1977 MOUNTAIN GOAT MAP

Resource Management Region	Estimated No. of Mountain Goats	Estimated Outside Limits	% of Provincial Total
1. Vancouver Island	1,300 †*	(800 - 1,800)	3 %
2. Lower Mainland	2,500*	(1,500 - 4,000)	5 %
3. Thompson Okanagan	2,500*	(1,500 - 4,000)	5%
4. Kootenays	5,000*	(3,500 - 6,500)	11 %
5. Cariboo	3,000**	(1,500 - 4,500)	6 %
6. Skeena	24,000**	(15,000 - 35,000)	52%
7. Omineca - Peace	8,000*	(4,000 - 12,000)	17%
Total ALL Regions	46,500	(30,000 - 65,000)	100 %

* Based partially on projection from abundance catagories.
** Based entirely on projection from abundance catagories.
† Mainland portion of region only.


CROSS SOUND
Skagway
Lower Post
DIXON ENTRANCE
PRINCE RUPERT
Terrace
Burns Lake
Queen Charlotte
HECATE STRAIT
QUEEN
CHARLOTTE
SOUND
Port Hardy
Quatsino Sound


BRITISH COLUMBIA
WILDLIFE DISTRIBUTION MAPPING
GENERALIZED BIG GAME SERIES
MOUNTAIN GOAT
DISTRIBUTION AND RELATIVE ABUNDANCE
NOT PRESENT
FEW/VERY FEW
MODERATE/PLENTIFUL
PROVINCIAL BOUNDARY (LIMIT OF MAPPING)
FIGURE 1. THE APPROXIMATE DISTRIBUTION AND DENSITY OF MOUNTAIN GOAT POPULATIONS IN BRITISH COLUMBIA
Compiled by B.C. Fish and Wildlife Branch and B.C. Resource Analysis Branch, 1978. Drafting by B.C. Surveys and Mapping Branch
MARCH, 1979.
PRINCE GEORGE
QUESNEL
KAMLOOPS
VERNON
KELOWNA
PENTICTON
NELSON
VANCOUVER
NANAIMO
VICTORIA
BELLINGHAM
SPOKANE
CALGARY
ALBERTA
U. S. A.

MAP NO. 19

Recent surveys in Region 5 (Hebert and Woods 1984) were used to calculate population size by mountain block. This method derived a regional population estimate of 3000, similar to Blower (1977). This does not confirm Blower's estimates in all other areas in the province.

Seasons have been shortened significantly since the 1950's and 60's but have changed little between 1980 and 1984 (Table 2). Where seasons were changed prior to 1980, they have been shortened from September 1 to September 10 in the southern portion of the province and from August 1 to August 15 in the northern portion.

The provincial harvest declined during the 1970's as harvest rates were reduced to coincide with population size, productivity and survival. Areas were closed as increased access resulted in excessive harvest. As populations recovered, L.E.H. authorizations increased, especially in southeastern B.C., Region 4 (Table 3). Other regions have increased L.E.H. numbers but not to the same extent. At this time, it is not possible to calculate the proportion of the land base or goat population under general open seasons or limited entry hunts.

Although goat harvest has become more restrictive in the last few years, hunter effort and harvest have increased (Table 4). Data are not available to determine the L.E.H. harvest vs the open season harvest, however, the largest increase in kill is in the Kootenays (Region 4) where L.E.H. has increased five-fold.

The proportion of males to females in the harvest appears to have remained constant while the average age increased slightly from 1980 to 1984 (Table 5). This occurred on a provincial basis and may mask the harvest on a regional basis. Variability in access, population size, management philosophy and other factors result in differing harvest rates in the province (Table 6). The rates vary from a low of 0.36% on the south coast to a high of 9% in the East Kootenays. Due to the recent mild winters, the present Kootenay goat population is probably higher, thus the harvest is probably only about 7%.

Table 2 GOAT OPEN SEASONS IN B.C.

Region	1980	1985
1	Sept. 6 - Nov. 30	Sept. 7 - Nov. 24
2	Sept. 6 - Sept. 28 Oct. 12 Oct. 26	Sept. 7 - Sept. 22 - Oct. 6 - Oct. 20
3	No Open Season	No Open Season
4	Sept. 15 - Oct. 31	Sept. 10 - Nov. 30
5	Sept. 1 - Oct. 31 Oct. 15	Sept. 1 - Oct. 27 - Sept. 29
6	Aug. 1 - Oct. 15 Aug. 15 - Oct. 19	Aug 1 - Oct. 15 Aug 15 - Oct. 19
7	Aug. 15 - Oct. 15 Sept. 1 - Sept. 30	Aug 15 - Oct. 15 Sept. 1 - Sept. 30
8	Sept. 10 - Oct. 31	No Open Season

Table 3 LIMITED ENTRY HUNTING AUTHORIZATIONS

Region	1981	1985
1	0	0
2	6	6
3	45	64
4	197	977
5	0	20
6	236	810
7	14	54
8	16	31
Total	514	1962

Table 4. NUMBER OF HUNTERS, HUNTER DAYS AND KILL BY REGION.

REGION	YEAR	HUNTERS	HUNTER DAYS	KILL
1	80†	29	82	11
	84	8	23	39
2	80†	57	202	13
	84	39	129	6
3	80†	25	82	11
	84	28	118	16
4	80†	113	391	89
	84	707	3314	446
5	80†	54	234	47
	84	67	218	35
6	80†	490	2354	330
	84	536	2611	270
7	80†	308	1823	264
	84	356	2025	169
8	80†	33	85	18
	84	18	45	10
TOTAL	80†	1165	5487	783
	84	1804	8799	955

† Non Resident not included in number of hunters or hunter days.

DISCUSSION

Following the restrictive seasons of the 1970's and the mild winters of the 1970's and 80's, most mountain goat populations in the province are stable to increasing and are harvested at less than 5%. However, inventory for most mountain goat populations in B.C. is still lacking, due to the cost of aerial surveys and because impacts from competing resource users are low. Few populations have been inventoried for the first time and even fewer are being monitored on a regular basis. For most populations, weather is usually the most significant factor affecting survival (Smith 1984). Snow density and depth, combined with low temperatures, sigificantly affect productivity and survival. Hunting probably regulated many goat populations in the 1960's and 70's but unlike weather, it can now be monitored and controlled. In order to monitor and/or modify the effects of hunter harvest and density independent factors such as weather, population monitoring is a necessity. Since each population in the province cannot be monitored, representative populations in each region, management unit or ecotype must be assessed at regular or specific intervals. Seasons or L.E.H. systems can then be altered in response to population change. Due to the lack of inventory, goat management programs rely almost solely on harvest data.

As shown in Table 5, average age has increased since 1980. This may indicate an expanding population but, without systematic plotting of harvest location, it is impossible to verify local overharvests or determine if previously inaccessible herds are being harvested. Although the proportion of females in the harvest is relatively stable, it may be high if the female harvest occurs in a few subpopulations. The sensitivity of the female harvest has been previously demonstrated (Hebert and Langin 1982, Youds et al 1980). In B.C. there are no male only seasons because of the lack of sexual dimorphism in mountain goats. Where possible, hunters are encouraged to select mature males.

Harvest rates appear conservative although harvest is usually clumped rather than distributed homogeneously throughout the range of a particular population. Harvest rates should increase as smaller goat harvest units are developed in conjunction with limited entry hunting and as previously inaccessible herds are accessed.

Table 5. PROVINCIAL GOAT HARVEST BY SEX AND AGE.

	MALE KILL	MALE AGE	FEMALE KILL	FEMALE AGE	JUV.	FEMALE IN HARVEST %
1980	508	5.1	273	5.8	2	35 %
1981	481	5.3	253	6.0	-	34 %
1982	487	5.5	243	5.6	2	33 %
1983	583	5.3	340	6.0	3	37 %
1984	639	5.6	313	6.0	3	33%

Table 6. A COMPARISON OF HARVEST IN RELATION TO POPULATION SIZE BY REGION

REGION	HARVEST 1980	HARVEST 1984	POPULATION ESTIMATE	PERCENT HARVEST
1	11	3	1300	.54
2	13	6	2500	.36
3	11	16	2500	.56
4	89	446	5000	1.78 - 8.92
5	47	35	3000	1.3
6	330	270	24000	1.4 - 1.1
7	264	169	8000	3.3 - 2.1

A preliminary comparison of population characteristics indicates at least two ecotypes: coastal and interior, for the southern portion of the province (Hebert and Turnbull 1977). Ecotypes may also vary from south to north and across the northern portion of the province. Short and long term population change for "natural herds" are postulated in Figure 2. Interior populations appear to have a higher reproductive rate, recruitment rate and potential density than some or all coastal populations. Population fluctuations appear to be reduced, recovery is faster and long term population growth appears to be greater in interior populations. Although density independent factors are operative in interior populations, the role of density dependent factors may play a significant role. By comparison, coastal populations of south central B.C. appear to have lower productivity, recruitment and density. Population fluctuations are more pronounced in coastal populations, however, recovery may be slow (Janz pers comm) in the south central coast of B.C. as compared to more rapid recovery in Alaska (Smith 1984). Density independent factors are highly regulatory in coastal populations while density dependent factors play a reduced role.

RECOMMENDATIONS

1. Identification of ecotypes in B.C. Variation along the coast should be determined.
2. Inventory should be improved and expanded. Representative mountain blocks should be identified and monitored at periodic intervals.
3. Small harvest units should be developed to prevent clumped harvests.
4. Female harvests should be monitored and/or reduced where heterogeneous harvest patterns are occurring.
5. The magnitude of population fluctuations should be recognized and significant season changes and harvest rates implemented where necessary.
6. Current provincial policy regarding regulation changes (three year stability in regulations) should not apply to mountain goats.
7. Harvest rates in experimental areas should be modified in order to test density dependent responses and survey techniques.

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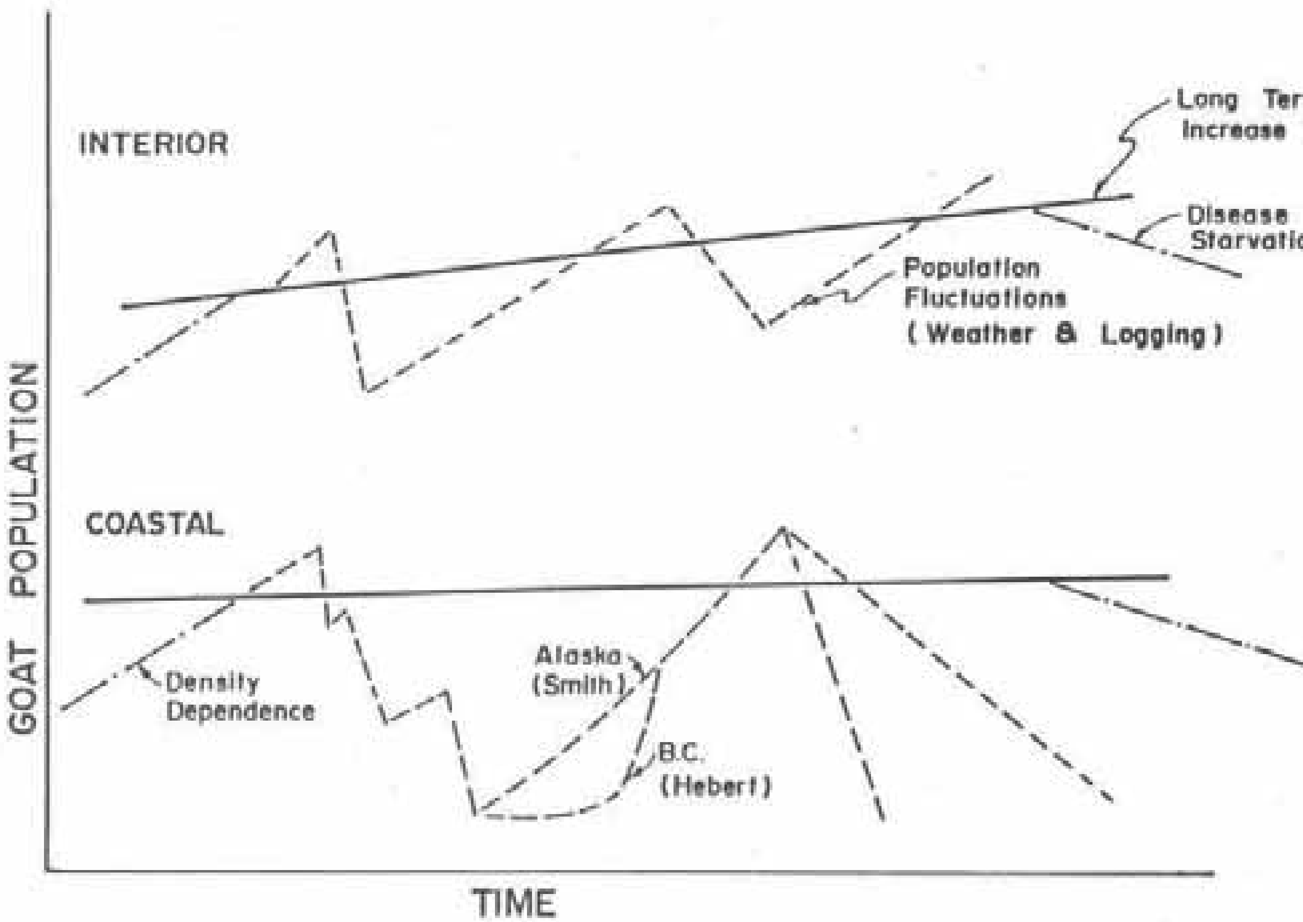

Figure 2. HYPOTHETICAL POPULATION CHANGE IN COASTAL AND INTERIOR ECOTYPES IN BRITISH COLUMBIA.

MOUNTAIN GOAT MANAGEMENT IN WASHINGTON

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ABSTRACT

Mountain goat hunting seasons have become much more conservative in the last few years in Washington. Hunting permit levels have been reduced and some permits allocated to primitive weapons hunters. The Washington Department of Game enlisted the help of volunteers in 1985 to conduct field surveys in major goat areas. Goat unit boundaries have been adjusted to manage each herd by goat unit. Over 50 goat herds have been identified. Access restrictions and age structure are considered in development of hunting permit levels.

MOUNTAIN GOAT HUNTING

Mountain goat sport hunting in Washington began in 1897, when the hunter was limited to two goats during a three-month season. In 1913, the hunter was restricted to one goat per hunting season. Hunting areas were restricted in 1917 and the hunting season closed completely in 1925. Mountain goat hunting resumed in 1948 after biologists found that the goats had reached carrying capacity. Since then, mountain goat hunting has been sanctioned every year on a controlled permit basis.

Permit levels have varied over the years from an initial level of 150 in 1948 to over 1,000 in 1968. In 1957, a unit system was developed in which goat areas were divided into 10 goat units and a quota of permits authorized in each unit. The trend over the years has been to decrease the size of goat units, along with number of hunters, to prevent overcropping of local areas.

The season length is currently about 5 weeks with seasons starting the last week in September and concluding the end of October. There are no mandatory checks for goats similar to those for bighorn sheep but a questionnaire is sent to each permit holder. Approximately 40 percent of the hunters return their questionnaire at the close of the season. (It is mandatory to return questionnaires within 10 days of the kill or 10 days after the season ends.) A follow-up questionnaire is sent to nonrespondents 2 weeks after the season ends. The follow-up questionnaire stimulates a 48 percent return so the total return is 88 percent.

HUNTING REGULATIONS

Aside from designated goat unit areas and dates the only restriction placed on mountain goat hunters is that they harvest goats with horns 4 inches long or longer. This protects kids of the year. Although goats of either sex may be legally taken, hunters are urged to refrain from shooting nannies with kids. Since this statement was included in the goat hunting pamphlet in 1977, the take has shifted to over 50 percent billies each year.

Prior to 1981 harvest levels were probably higher than recruitment. Research in Washington (Johnson, 1983), Idaho (Kuck, 1980), and British Columbia (Hebert and Turnbull, 1977) pointed out the need for much more conservative harvest programs. During the 1960's and 1970's the mountain goat harvest declined from 340 to 260. Last year, the goat harvest was 113 when 289 permits were authorized. We anticipate a slight increase in permits over the next few years and an annual harvest of 120 to 150.

In 1985, there were 36 units with 289 permits. Over half of these (nearly 62%) were available to hunters using any legal weapon. Several units, however, are reserved for primitive weapons hunters. Nearly 31 percent of the permits were reserved for archery hunters and 7 percent for muzzleloader hunters. The harvest by user group can be summarized in the following table.

TABLE 1. Mountain Goat Hunting Permits, Harvest, and Success Rate by User Group

Hunting Method	Permits	Harvest	Success Rate
Any Legal Weapon	179	84	55%
Archery Only	90	20	27%
Muzzleloader Only	20	9	56%

YEAR OF THE MOUNTAIN GOAT

This past year was the Year of the Mountain Goat in Washington. Wildlife enthusiasts from throughout the state joined the Department of Game field personnel in extensive goat surveys. These surveys enabled us to obtain better information on population numbers and distribution. Last year 121 surveys were conducted and 1,103 goats were observed. Approximately half of these goats were classified according to sex and age. Classification counts revealed 115 billies, 216 nannies, 209 kids, and 123 yearlings.

Research studies in Washington (Johnson, 1983) indicate normal survival of kids during the first winter is about 50 percent. These surveys produced a similar estimate of kid survival. Regional Wildlife Biologists estimate herd size based on sightings by volunteers, hunter reports, and Department of Game air and ground surveys. This past year's surveys have been instrumental in adjusting goat unit boundaries and establishing permit levels. Management guidelines sent to field personnel call for a harvest at the 4 percent level. Since hunter success averages close to 50 percent, permit levels are set at nearly 8 percent of the estimated herd size.

MANAGEMENT PROGRAMS

Age structure information is also used to formulate management recommendations. Each year for the past 3 or 4 years hunters have been asked to submit a tooth from their harvested animal for age determination according to techniques described by Matson (1981). Last year 84 teeth were processed and the statistics used to determine age structure by sex. The average age of billies taken was 5.2 years with a maximum of 11.5, median of 4.5, and mode of 3.5.

Nannies on the other hand, had a mean age of 5.8, maximum of 12.5, median 5.5, and mode of 2.5. These age categories are up slightly from the previous year.

We are also working with landowners to protect goats on critical ranges by preventing disturbances and conflicting uses. Road management programs are helping avoid unintentional harrassment that has become all too familiar on winter ranges. Winter recreationists, such as skiers and climbers are directed away from prime winter ranges. Mountain goats are also being considered in timber management programs. Road closures also help reduce poaching loss.

Overall, we are encouraged by the recent surveys as well as population and age structure information gathered over the last few years. A few changes in hunting unit boundaries and permit levels will be made but no major changes are anticipated.

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MOUNTAIN GOAT HUNTING STRATEGIES IN IDAHO

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Abstract: Historically when mountain goats were exploited under traditional game management principals many goat populations declined. Research findings in Idaho suggest that hunter mortality may be an additive rather than a compensatory mortality form for some mountain goat populations. A brief history of goat management in Idaho is presented. A management goal to increase goat numbers has been established in Idaho. Procedures to achieve this goal have been established through two five-year species management plans that cover the period from 1981 to 1990.

The statement, "If we don't learn from history, we're doomed to repeat it" probably best describes the historical perspective of mountain goat harvest strategies in Idaho. Throughout the range for this species there are now optimistic signs indicting that, as a profession, we have learned from history. However, the learning process has been slow, even painful, and at times difficult. Unfortunately, as we have struggled through this process some goat populations were extirpated and others were substantially reduced. This loss has not gone for naught, there are now signs that we have gained a better understanding of mountain goat response to exploitation by man.

Graeme Caughley (1976) once stated that "there has been little qualitative advancement in wildlife management theory and practice since the 1930's." Caughley himself admitted this was somewhat overstated, but it does mirror our profession's approach to mountain goat management. Although management and harvest principles that evolved from the study of muskrats and small game may have some application to some large ungulates such as deer, these principals now appear totally inadequate for goats. Unfortunately it took us nearly 50 years to learn.

Our approaches to mountain goat management had fallen into the same trap that effected the science of game management (Romesburg, 1981). If the profession of wildlife management is to become a science, we must establish a tradition of critically evaluating a wildlife management principles, theories and practices. Lacking this tradition, or in the absence of an effective forum for critical review, many untested theories and principles have gained respectability through repetition and practice, and eventually were unquestioningly accepted as institutions not to be challenged. Once institutionalized, they were applied to all species and situations, i.e., managing mountain goats as if they were muskrats.

In 1969, the Idaho Department of Fish and Game initiated a research program to determine why the Pahsimeroi mountain goat herd located in east central Idaho was declining. Mule deer competition during winter was originally hypothesized as the cause for this decline. However, despite a major reduction of mule deer, the mountain goat population continued to decline. Consistent with the philosophy of the day, our concerns shifted to the goat herd and its relationship with its winter range. It was generally assumed that goats, like other big game, were primarily limited by winter food supplies. Although untested for goats the size of the population was assumed to be a function of winter forage availability (Cole 1971).

As a result, a "sustained annual harvest program" was initiated for the Pahsimeroi mountain goat herd to maintain a "productive goat population within the carrying capacity of the available range" (Kindel 1961). Under this management scheme, the herd declined proportionally to exploitation and, contrary to Errington's "inverse density law" (Errington 1945), there was a strong positive correlation between population size and percentage of kids within the population. We were finally forced to admit that this herd did not respond to traditional game management practices and concluded that hunter mortality was an additive rather than a compensatory form of mortality (Kuck 1977).

When I presented these results at the First International Mountain Goat Symposium, my findings were received with interest but for the most part with skepticism. At the time, most accepted the Pahsimeroi results as an abnormality not applicable to other situations. However, during the ensuing years as one exploited population declined after another, even my strongest critics have had to concede that if hunter mortality in goats is not additive, then goats at least are extremely sensitive to exploitation. Even in Idaho my results were not initially received with enthusiasm. One administrator concluded that the direct relationship between hunting mortality and herd declines in Idaho was "too simple". One manager wondered aloud whether it would hurt to go another year or two with five permits for a unit with a known population of seven. Another manager's reaction was "I've made a mistake. I've let my supervisor read your study results. What do I do now?" For me the answer was simple, if in doubt, be conservative, back off on harvest. Although the answer seemed simple, translating research results into a management program was another matter.

Two major occurrences in the early 1980's triggered the transition to a more conservative approach to goat harvest in Idaho. The first was a special authorization by the Fish & Game Commission to helicopter inventory all mountain goat populations in Idaho. The second was the development and commitment to five year species management plans. Unfortunately, prior to this special inventory effort, our mountain goat management program for the most part could best be described as "benign neglect". As a result, the only direct management information we had was obtained secondarily during elk and deer helicopter counts. Goat management simply could not economically compete with the so-called "bread and butter species." Consequently, harvest success rates were primarily used to monitor the status of goat herds. As we now know, success rates almost always held up until a goat population was nearly lost. Then it was too late to initiate an alternative management strategy except to close the unit to all goat hunting.

Following completion of our statewide mountain goat helicopter surveys, our worst fears were realized. Some of our goat populations were gone and many others were severely reduced. Although some managers were reluctant to identify the cause for these declines, we had no alternative but to reduce mountain goat exploitation in Idaho.

Historically, conservative philosophies have dominated mountain goat management in Idaho. Idaho's legislature first established restrictions on goat hunting in 1903, when a 78-day season and one goat per year bag limit were implemented. By 1931, Idaho goat seasons were reduced to 10 days. In 1943, a specific 10-dollar goat tag was required in addition to the regular license. Concerns about overharvest led the Idaho Fish and Game Commission to order statewide mountain goat hunting closures in 1948, 1949, and again in 1951. By 1954, the Department created its first permit goat hunt. Idaho held its last general firearms season for goats in 1966.

Prior to the 1960s, when other big game were plentiful and hunter numbers were low, most hunters displayed little interest in mountain goats and few goats were taken annually. Idaho's annual goat harvest exceeded 100 animals in only two years (1933 and 1946) prior to 1960. Subsequently, hunting demand and access grew simultaneously. Information on goat numbers and distribution acquired through other big game helicopter surveys was followed by increases in permit allocations and units.

Idaho goat harvest increased substantially, reaching a peak of 161 goats in 1966 (the last year portions of Idaho were still open to general goat hunting), and again in 1968 (under a controlled hunt permit system). In 1967, Idaho established its first general archery seasons for goats in specific areas of the state to accommodate a growing interest in archery hunting. Permit allocations continued to increase through 1974, when 303 permits were authorized.

In 1976 when the results of the Pahsimeroi mountain goat study were available (Kuck 1977) and prior to our statewide mountain goat helicopter inventories, there were 276 gun permits authorized for Idaho and general archery seasons were still permitted. However, by 1982 authorized goat permits were reduced from 276 to only 48 permits for gun harvest. All general archery seasons were closed, and six controlled archery permits were authorized.

Development of our five-year species management plans provided the vehicle for incorporating our research findings into a statewide mountain goat management program. During the first planning period, 1981-1985, a conservative approach to goat management was adopted. The primary management goal was to increase goat numbers throughout the state. Regulations were modified to meet this goal. Many hunts were closed;

permit numbers were reduced in many units; general archery hunts were switched to controlled hunts; hunters were encouraged to take males; females with kids at side were legally protected; hunters were restricted to the harvest of only one mountain goat in a lifetime; and goats were transplanted into vacant habitats or into areas with suppressed populations.

This program of harvest regulations and management has been partially successful. Mountain goat distribution within Idaho has been expanded through the transplant program, and all of Idaho's transplants have been successful. Goats were first transplanted within Idaho during the summer of 1960. From 1960 - 1968, 22 goats were trapped on Snow Peak and Black Mountain in northern Idaho and released onto cliffs overlooking the eastern and southern shores of Lake Pend Oreille. This herd has provided a high level of nonconsumptive viewing by recreationists since its introduction, and has grown sufficiently to permit a limited hunt. Introductions into the Seven Devils mountain range in 1962 and 1964, and adjacent to the South Fork of the Snake River near Palisades Reservoir in 1969 and 1970, have proven to be extremely successful. Both herds have grown substantially, and now offer increased recreational opportunity for both nonconsumptive and consumptive users.

In 1982 goats were transplanted from Olympic National Park into the Selkirk and Lemhi mountain ranges. Although it is premature to assess the success of these programs, goat transplants into previously occupied habitats may be the most expedient venue to herd recovery in Idaho.

Our second planning effort to cover the period from 1986 to 1990 was further expanded to emphasize sensitivity of mountain goats to exploitation and management strategies required for herd recovery. For the first time, the nonconsumptive use of goats was officially recognized. Because of mountain goat sensitivity to exploitation, (1) a statewide inventory program will be implemented, (2) we will allow harvest only from populations with adequate up-to-date management information (1+ years) observed, (3) permits will be set at or below 5% of the adults for populations which appear to fully use their available habitat, (4) we will authorize hunts only if 40 adults are available for a population, and (5) encourage the harvest of males. Also new in this plan is a stipulation to allow expanded harvest on introduced populations up to 10-15% of the adults observed during the expansion phase for these types of populations (Swenson 1985)

I'm now convinced through the application of management strategies designed for goats, not muskrats, that the downward trends in our Idaho goat herds will be reversed.

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QUESTIONS AND ANSWERS

Gayle Joslin, Montana: Daryll, it looked like in region five you had 1.5% harvest of the population. If you could get a more random sample in the harvest...would you like to see that increase?

Daryll Hebert, British Columbia: Yes, we definitely would. I think we have room to increase the harvest by a reasonable amount. The distribution of the harvest is what produces problems most of the time, because when we survey and identify a population of 300 or 400 animals, we probably only have an accessible harvestable population of maybe 100. It gets very difficult to identify what the boundaries are for the population that is available for harvest, because quite often we don't have enough radio collar information in terms of movement, and we don't know what area some of those goats are in during the hunting season. We opened three new areas this year that had been closed for the last 7, 10 and 15 years respectively. In areas where we have overharvested,
goat populations, recovery has taken seven to ten years.

Jack Welch, Wyoming: Daryll, in your harvest strategies, do you have seasons that are designed to influence goat populations in relation to stone sheep populations? Do you have an identified competition between those species?

Hebert: Not as far as I'm concerned. We have goats and sheep overlapping in many parts of the province. Goats overlap with California bighorns, they overlap with Rocky Mountain bighorns, they overlap with stone sheep. We haven't looked at it specifically or very intensively, but most of the areas I am familiar with, I would say that we don't really have a problem with the overlap in terms of either niche selection for escape terrain or in terms of forage selection. Most of our animals overlap in the alpine, and we're not really short of that in British Columbia.

Jim Bailey, Colorado: I would like to respond to the other part of your question, Gayle, about hunter education classes. We have hunter education classes in Colorado. They are not mandatory. Hunters are encouraged to participate, particularly goat and sheep hunters. Classes are presented by the Division of Wildlife and by some private interest groups that are interested in sheep and goats. Goat hunters are appraised of the problem of harvesting more females than males, and of their obligation to try to harvest a male and then how to try to find a male. We feel that in some areas this approach gives us a harvest sex ratio approaching 50/50, when otherwise the harvest would probably be more females than males. The program is not totally successful in some situations. Last year in our study area there were five animals harvested, actually one male off the study area in the unit and four nannies on the study area. On Mt. Evans there were 12 animals harvested, 9 of those were nannies. Last year was a problem because of weather. Conditions were extremely difficult for the hunters. There was a greater chance that they would take the first goat available, because they were already snowed out by the time they got up into goat country. That might have been exascerbated by a change in access problems on Mt. Evans: the snow closed the roads and the weather they played out before they got to the first spot where they were apt to see goats, and that place, of course, is where they're apt to see females, not males. So those are all aspects of hunting mountain goats under adverse conditions.

Ted Benzon, South Dakota: I guess I would like to direct this question to Lonn. Several years ago I was talking with Lyman Nichols from Alaska, and he had the feeling when he was out in the field that if you harvest a nanny in the fall, you can possibly look at losing that kid to the winter. Did you get the same feeling?

Lonn Kuck, Idaho: It's just my guess that kids suffer high mortality when the nanny is shot. Bryan Foster marked some kids which became orphaned and they could not detect a real clear relationship there. I've theorized that the bond between nanny and kid evolved for a purpose, and that is to get the kid through the winter. A kid is not very large, and they must deal with high snow depths. I feel the mother/kid bond is very important.

Benzon: Lonn, when you set your harvest at 5%, and since you have about a 50:50 harvest ratio on the sexes, do you consider the loss of one kid for every female shot in the 5% that you recommend for harvest?

Kuck: yes

Joslin: I have a question for Rolf. You discussed a fairly extensive mountain goat education program for the public, could you elaborate a little on that? You also talked about a species of the year concept. Would you please discuss that briefly?

Rolf Johnson, Washington: Let's talk about the year of the goat. When we came to our director in a commission preview and said we're going to recommend X number of permits and its only 2/3 of what we recommended last year, he asked "Why?" We said, "Well, we don't have as many goats as we thought we did and we don't do the necessary surveys to find out how many we have got." Director Wayland asked why we didn't do the surveys. I explained that it was an issue of funding. After a long pause, Director Wayland said, "Well, I can't give you money, but why don't you drum up public interest and get the public to go out there and get that information. It would be good for us to get the public involved in what we're doing." We responded with The Year of the

Goat. We had about 121 surveys and those people saw about 1,100 goats. We had asked for volunteers, and then we became concerned that in the urban areas like Seattle, we'd have hoards of people descend upon us and say they wanted to help do the surveys. So we didn't advertise very much, and we were somewhat selective in who we asked to help. We had orientation sessions to help volunteers identify, age and sex mountain goats, and it worked out really pretty well. We haven't finished. We completed about half of the state last year, and we're going to continue this year. I'm not sure how many people were involved, but the Seattle region alone over 400 man days were put into the surveys.

Harvest Impacts

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REPRODUCTIVE RESPONSE OF THE ABSAROKA MOUNTAIN GOAT POPULATION TO AN EXPERIMENTAL REDUCTION

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Abstract: Previously published data from the introduced mountain goat (*Oreamnos americanus*) population in the Absaroka Mountains in southwestern Montana indicated a compensatory reproductive response to changes in population size. This led to the prediction that maximum kid production would occur if the number of older goats was reduced by about 25% from the 1983 level. One of the methods used may have been inappropriate to infer density dependence, so the data are reanalyzed here. The reanalysis supported the original conclusion of density-dependent reproduction and predicted maximum kid production at about 28% fewer older goats than the 1983 level. The only conclusion that changed in the reanalysis was that density of older goats and winter severity appeared to be equally important in determining the number of kids observed in the surveys, rather than density being more important. In 1984, permits were increased to reduce goat numbers towards the predicted optimum for maximum kid production. The 1985 survey showed 11% fewer older goats than in 1983, and the observed number of kids (21) was close to the predicted number (23). The increase in kids with a reduction in older goats further supported the conclusion of compensatory reproduction to hunter induced population reduction in this mountain goat population.

Published studies of compensatory responses in reproduction by mountain goats to changes in population size have yielded conflicting results. No compensation was found by Kuck (1977) or Hebert and Turnbull (1977) in native populations, but Adams and Bailey (1982) and Swenson (1985) reported compensatory reproduction in introduced populations. The differences among these studies may be due to the relative position of the populations in the ungulate irruptive sequence (Caughley 1970), with introduced populations in the "initial increase phase" best able to respond reproductively to reductions in numbers (Swenson 1985).

An analysis of past population fluctuations and reproductive rates of an introduced mountain goat population in the Absaroka Mountains of southwestern Montana, which was judged to still be in the "initial increase phase," suggested compensatory reproduction to hunter induced reductions in the number of older goats (Swenson 1985). Swenson (1985) predicted that maximum production of young would occur after the number of older goats was reduced by 25% from the 1983 level. However, one of the analytical methods used may have been inappropriate to test for density dependence. The purpose of this paper is to present a reanalysis of the question of density-dependent reproduction and to discuss the first-year results of an experimental reduction in the population through hunter harvest.

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STUDY AREA AND METHODS

The study area, located in the southern portion of the Absaroka Mountains in southwestern Montana, has been described previously (Swenson 1985). The mountain goat population resulted from the introduction of 23 goats during 1956-58 and has been hunted with a limited permit system since 1964.

Data on population trends and age ratios were collected during intensive aerial surveys with a pilot and observer in a 150 hp Piper Super Cub on calm, clear days (Swenson 1985). The 1985 survey was conducted on 24 and 25 August. The study area is relatively easy to survey, compared with most goat areas (Swenson 1985), due to open slopes above and below the cliffs.

Snow depth data are from the Soil Conservation Service snow course at Monument Peak (2,682 m), 3 km from the study area boundary; the 1 May readings were used as an index to winter severity. Harvest estimates are from the Montana Department of Fish, Wildlife and Parks telephone hunter survey. An attempt was made to contact all hunters, and the results were corrected for those not contacted, assuming that their responses would have been similar to those of the contacted hunters.

Statistical methods for testing curvilinear regressions using an $\underline{F}$ test follow Snedecor and Cochran (1967:453-456). Multiple regressions were calculated using a computer package (Lund 1983).

RESULTS

Reanalysis of Density-dependent Reproduction

In my first analysis of the data (Swenson 1985), I used a multiple regression with kids:100 older goats as the dependent variable and older goats observed and snow depth as independent variables to test for density-dependent reproduction. The resulting regression was statistically significant ($\underline{R} = 0.942$, $P < 0.005$, Swenson 1985). However, regressing a ratio on an independent variable can lead to autocorrelation when the independent variable is the denominator of the ratio (Eberhardt 1970). Plotting the number of young against the number of older goats from such an equation yields a hyperbolic curve (Eberhardt 1970), which is what I did to determine the number of observed older goats that would result in the greatest number of observed young (Swenson 1985).

I reanalyzed the data in Swenson (1985) to determine if the multiple regression of number of kids observed on number of older goats and snow depth was curvilinear. The hypothesis of linear regression was abandoned ($F = 7.93$, 1,5 df, $P < 0.05$), indicating significant curvilinearity in the regression, which was consistent with my original conclusion.

The multiple regression using a quadratic equation for number of older goats observed and a linear equation for snow depth explained 69% of the variation in the number of kids observed ($R = 0.832$, $P < 0.05$). Using this equation, and assuming average spring snow depths, the maximum production of young would be expected when 57 older goats were observed in the study area. This compares with 60 older goats calculated using the multiple linear regression reported in Swenson (1985). The new analysis did reveal one difference from the previous analysis, however. Swenson (1985) reported that the number of older goats (density) was more important than snow depth in determining kid:100 older goat ratios. The present analysis showed these two factors to be similar in imporance in determining the number of kids observed (R partial for number of older goats = 0.789, R partial for snow depth = -0.744; both $P < 0.05$). The higher correlation coefficient for number of older goats found in the first analysis may have been the result of autocorrelation.

Experimental Reduction

In 1984, 30 permits were issued for the Absaroka Mountains, an increase from the 1977-83 level of 15-18, in an effort to reduce the number of goats towards the optimum number for maximum kid production, as suggested in Swenson (1985). The hypothesis for this experiment, based on the previous analysis, was that reducing the number of older goats would result in an increased number of kids and that the increase in kids would be predictable from the multiple regression.

An estimated 29 mountain goats were taken by hunters in the Absaroka Mountains in 1984. This was a record high harvest since hunting was initiated in 1964. Eighteen of these goats came from the study area, based on the harvest survey and goats checked by department personnel.

During the 1985 aerial survey, 70 older goats were observed, a reduction of 11% from the 1983 survey (Table 1). The number of kids and the kid:100 older goats ratio increased 24% and 36%, respectively, so the total number of goats observed declined only 5% (Table 1). Using the multiple regression formula based on the data from 1966-83, 23.2 ± 4.5 kids (95% C.I.) were expected to be observed on the study area in 1985. The 21 actually seen (Table 1) were within the predicted range.

Table 1. Results of aerial surveys for mountain goats and spring snow depths in the Absaroka Mountains, 1966-85.

		N goats				
Year	Date	Older goats	Kids	Total	Kids:100 older goats	Spring snow depth (cm)
1966	5 Aug	30	18	48	60	150
1967	3 Aug	--	--	56	--	---
1969	1 Sep	59	27	86[a]	46	180
1972	24, 25, 27 Jul	66	19	85	29	218
1974	27 Jul	50	17	67	34	234
1977	4 Aug	40	20	60	50	119
1978	5, 7 Aug	42	18	60	43	193
1981	8 Sep	64	26	90	41	135
1982	19 Aug	76	16	92	21	221
1983	6 Aug	79	17	96	22	163
1985	24, 25 Aug	70	21	91	30	145

[a]Adjusted total, see Swenson (1985).

DISCUSSION

Reanalysis of the data supported the original conclusion that reproduction in the Absaroka mountain goat population is density dependent. Although this is based on correlative analysis, it is further supported by the increased reproduction observed following the experimental population reduction in 1984. Also, the negative correlation found by Swenson (1985) between goat numbers and population trends independently supported the conclusion of density-dependent reproduction, because the goats were better able to increase from lower densities.

The management recommendation in the first paper appears to still be appropriate. This population should be reduced until about 57-60 older goats are observed during the surveys on the study area, or a further reduction of 14-19% from the 1985 level. Using the multiple regression based on all 10 data points (Table 1), the expected number of kids observed = -5.172 + (1.353)(number of older goats) - (0.01189)(number of older goats)^2 - (0.05974)(snow depth in cm); $\underline{R} = 0.818$, $\underline{P} < 0.025$. Assuming mean spring snow depths, the maximum calculated number of kids observed from this equation would result from 57 observed older goats. This population should be reduced further and the reduction should be viewed as an experiment to further test the hypothesis of density-dependent reproduction in this goat population.

I agree with Bailey and Johnson (1977) that introduced mountain goat populations should be managed at an intermediate level before they reach an irruptive peak and decline to lower numbers and productivity. The management objective of introducing goats into unoccupied habitat should be maximum harvest for sport hunters. Besides providing more goats for harvest, managing populations at this initial increase phase should result in less impact to the native vegetation than if the exotic ungulate were allowed to reach an irruptive peak.

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QUESTIONS AND ANSWERS

Leslie Chow, California: Did you say there was an actual increase in the number of kids seen?

Jon Swenson, Montana: On our surveys, yes, by about 25%.

Daryll Hebert, BC: John, are you recommending that the population be maintained in a high reproductive capability for any specific period of time?

Swenson: Yes, I am recommending that we keep it that level of 57-60 adults that we see on our survey. Try to always keep it below the eruptive peak in that initial increase phase.

Hebert: How much evidence do you have if you let it go to that eruptive peak its going to do any damage?

Swenson: Well, we have evidence from the Crazy Mountains which is the next mountain range north where that happened. The population peaked at about 350 goats and then it declines just the way Lonn Kuck's population declined. As the population numbers declined, the reproduction declined and it was significantly correlated. There was also high harvest at that time and the decline was also correlated with that. The Crazy Mountains goats haven't been hunted for 10 years, and there's about 1/7 the number of goats now that there was at the peak, and the reproduction is still very low - in the low 20's per 100 older goats.

Hebert: I don't know what kind of winters you get in that particular area you're talking about, but with some of the other information that's around in terms of density dependent vs. density independent, if you leave that population at a higher level of reproductive capacity, remembering that for the last 7-10 years in western North America we've had some pretty mild winters, I think you're leaving yourself wide open for a major density independent factor to knock that population way down.

Swenson: Well, that's true, we get our best regressions when we put snow depth in there.

Hebert: I don't think you've seen all the snow depths yet that you might see.

Swenson: That could be. We've got data that goes back to the mid 60's. I guess the alternative is that if you let it go too high and we could see it crash like we did in the Crazy's, then we have a population that acts a lot more like these native populations.

Hebert: I think you've probably got a lot of flexibility between the two levels, though.

Swenson: Its hard to measure to know where that is.

Jim Bailey, Colorado: I don't understand Daryll's point. It seems to me that if there is going to be a major density independent adverse effect, it should be, if anything, less adverse to this population if its held at the level you want to hold it as opposed to if it is allowed to grow further and impact its resources before that event.

Swenson: Yes, that's a good point. I would agree with that.

Hebert: The point being that it depends on what segment of the population that that effect is going to take place on, and its probably more likely to take place on the kid component which you're pushing up then it is on a slightly higher population with fewer kids and more adults.

Swenson: But the overall long term effects on the population would probably be less if you leave it at a lower level. You'd have percentage wise a less of a drop due to a density independent factor like that.

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TIME AND AREA SPECIFIC VARIATIONS IN DALL SHEEP LAMB PRODUCTION: AN EXPLANATORY HYPOTHESES

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Abstract: Lamb production as indicated by lamb:100 ewe ratios was studied in two differing Dall sheep (*Ovis dalli dalli*) populations. One population was affected by changes in hunting and predator management; the other population was subjected to little change in management. Lamb production was more variable in the population with variable management history. Lamb production correlated significantly ($P < 0.01$) with an aggregate weather index which included weather influencing breeding condition of ewes, weather during gestation, and weather during lambing. However, weather did not seem to be an important factor in other determinants of lamb production: ovarian activity, age at 1st reproductive success, and frequency of reproductive success. Decreased ram abundance and the concomitant skewing of ram age structure toward young rams were associated with maximum 3/4-curl harvest and maladaptive changes in lamb production. Reproductive frequency and age at first breeding appear to have been reestablished at levels found in unhunted populations following establishment of the 7/8-curl regulation in the heavily hunted Dall sheep population.

A long-term comparative study of two Dall sheep (*Ovis dalli dalli*) populations in the eastern Alaska Range revealed notable variations in lamb production data between the populations. One population, Dry Creek, was considered the experimental situation. Over the last 16 years, during which lamb:100 ewe ratios were collected, changes in hunting pressure, predator abundance, weather conditions, and changes in ram harvest regulations from 3/4 curl to 7/8 curl affected this population. A control population, Robertson River, was similarly monitored for 11 years. Throughout this study period, weather conditions were the main influence on this study population. Hunting pressure in the Robertson River was held below that required to harvest estimated annual recruitment to the full-curl ram class by lottery permit to meet a trophy management goal. The number and age distribution of rams was, thus, influenced little by hunter harvest.

METHODS

Study Area

Both study areas are located on the north side of the Alaska Range east of Mt. McKinley (Fig. 1). Characteristics of each study population are listed in Table 1.

Study Components

Lamb production is influenced by many components. We investigated ovulation rate, age at onset of reproductive activity, frequency of observed reproductive success, and general weather conditions. The methods for each component are detailed below.

Lamb Production: Lamb production was determined by classifying sheep from both populations as they used important mineral licks during the last half of June. Heimer (1974) detailed the reasons for this sampling period. Sheep were classified as lambs, yearlings, ewes, and rams according to degree of horn development. Observations were made with the aid of 15-60X spotting scopes and binoculars at distances up to 200 m. Results of these classification counts were used to calculate lamb production ratios for the sample period and expressed as lambs:100 ewes excluding yearlings.

Ovulation Rate: Ovaries were collected from ewes in each population from 1972 through 1979. Ewes were shot at random, and ovaries were preserved in 10% formalin as soon as possible after death. Ovaries not preserved within 48 hours were discarded. Fixed ovaries were trimmed of connective tissue, measured, weighed, and the volume estimated by water displacement. They were then sliced in 1 mm sections along the longitudinal axis and examined. Pigmented areas were counted in each ovary as described by Kirkpatrick (1980). Faces of individual slices were sketched and labeled so gross structures could be correlated with structures observed microscopically. Individual slices were then embedded in paraffin, sectioned at 6-7 microns, and stained by hematoxylin and eosin. When pigmented bodies could not be classified using this procedure, Masson's stain for connective tissue was used. Sectioning and staining were necessary because some of the pigmented areas discernible upon gross examination are not the result of ovarian cycling. Confirmation of the exact nature of each pigmented body requires sectioning, staining, and microscopic examination.

The number of significant ovarian events was considered equal to the sum of *corpus luteum* bodies (produced by ovulation) plus the number of *corpora albicantia* (produced by degenerating *corpora lutea*). The number of active breeding seasons possible in the life of each ewe was computed from her age, after establishing that 1st ovulation occurs at 18 months. Ovulation rates were then expressed as the quotient of possible active years divided into the events recorded in ovaries from each ewe. Mean ovulation rates were determined for each population, and Student's *t*-test of ratio estimators was used to establish the probability that observed differences were due to sample variance (Cochran 1977).

Age at First Successful Lamb Production: Successful reproduction was documented by observing marked ewes suckling or mothering lambs between

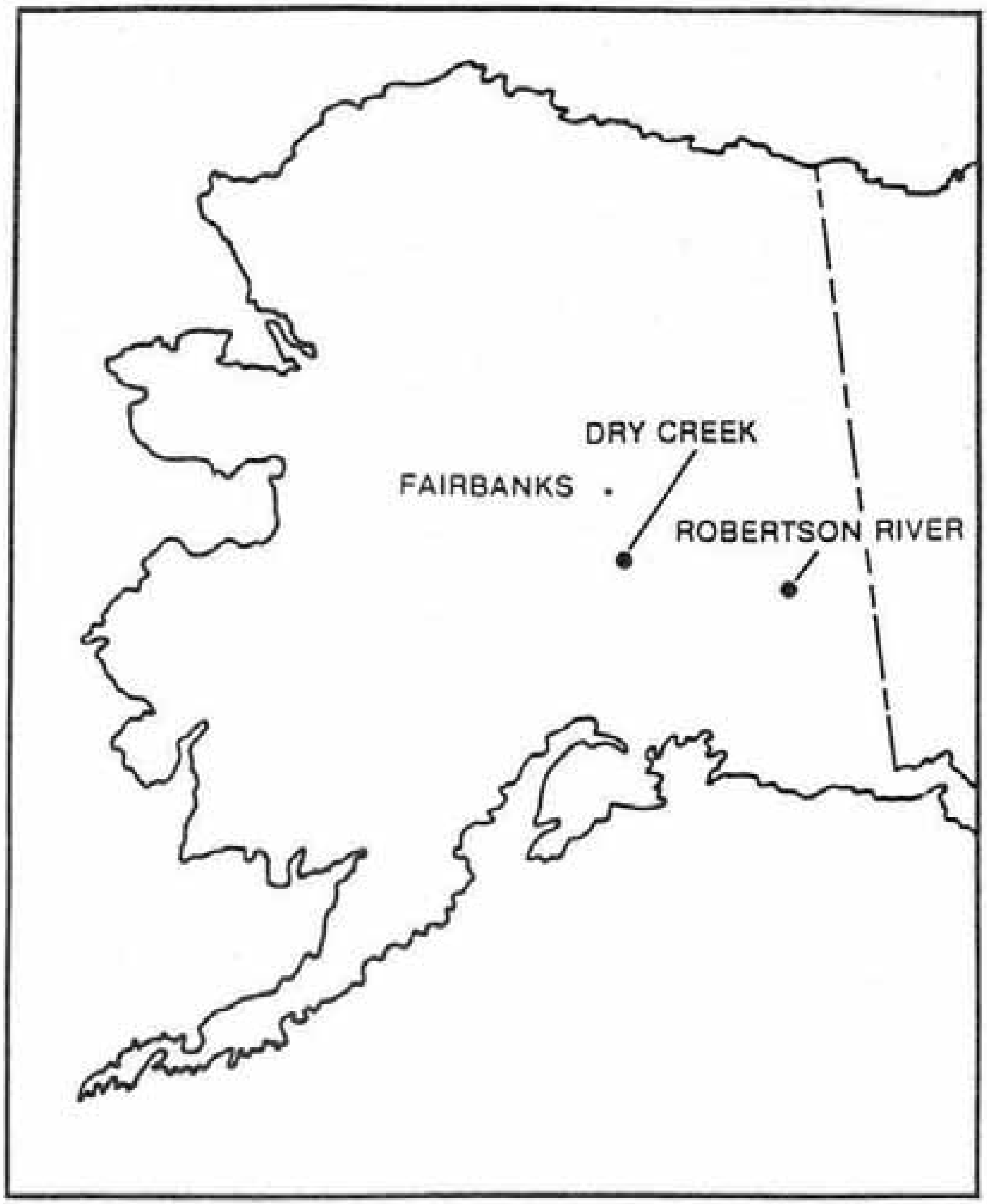

Fig. 1. Location of Dall sheep study areas within Alaska.

Table 1. Characteristics of Dall sheep populations from the Dry Creek and Robertson River study areas in Interior Alaska.

Dry Creek	Robertson River
Population ranges defined by movement study of marked Dall ewes.	Population ranges defined by movement study of marked Dall ewes.
Summer range size: 680 km^2 (260 mi^2)	Summer range size: 750 km^2 (290 mi^2)
Population size: 1,200-1,500 sheep	Population size: 1,000-1,200 sheep
Habitat character: gentle hills; short drainages; elevation relief 830 m; glaciers absent	Habitat character: steep hills; long drainages; elevation relief 990 m; glaciers present
Mean summer range density: 2-2.5 sheep/km^2 (5-6 sheep/mi^2)	Mean summer range density: 1-1.5 sheep/km^2 (3-4 sheep/mi^2)
Mean winter range density: 5 sheep/km^2 (14 sheep/mi^2)	Mean winter range density: 2 sheep/km^2 (5 sheep/mi^2)

1 June and 31 June. The earliest age at which ewes successfully reproduced was determined by three methods. The reproductive status of each ewe trapped and marked in June (Heimer et al. 1980) was determined by examination of external genitalia and mammary development. Also, yearling ewes were marked in both study populations. Careful observations of reproductive activity were made when these ewes were annually resighted at mineral licks. Limited numbers of ewes age 18 and 30 months were collected from both populations in April. Reproductive activity in these ewes was determined by autopsy.

Frequency of Observed Reproductive Success: Once marked ewes became reproductively active, they were observed each June as they came to the mineral lick. If they were observed mothering or suckling lambs, or if they had distended, depilated mammaries, they were classified as reproductively active that year.

Weather Conditions

Weather Effects During Gestation: Conditions which are likely to be unfavorable for gestation, severe cold, and/or deep snow which precludes feeding, should cause low observable lamb:100 ewe ratios. Snow depth along transects established by the USDA Soil Conservation Service to predict spring runoff were used as indices of winter severity to determine effects on gestation. Lamb:100 ewe ratio was regressed against mean snow depth across the north side of the Alaska Range averaged for Tok, Ft. Greely, Big Delta, and Lake Minchumina snow transects.

Weather Effects at Parturition: Weather conditions which promote heat loss from newborn lambs should lower observable lamb:100 ewe ratios. These conditions include low temperatures and precipitation. To derive an index of weather conditions for the experimental (Dry Creek) population during the lambing period, we used temperature and precipitation data gathered at Big Delta, Alaska. Big Delta is 65 km (40 mi) northeast of the Dry Creek study area. The weather at Big Delta is more indicative of Dry Creek weather than any constantly maintained weather station along the Alaska Range. We averaged the daily minimum temperatures for the parturition period (26 May-7 June) for each year. Deviations from the mean (either plus or minus) were calculated. These deviations were then multiplied by the total precipitation for the lambing period in each year. Indices were arbitrarily adjusted so the least favorable (coolest and dampest) year was equal to zero for purposes of statistical computation.

Weather Effects on Breeding Condition: Hoefs (1984) reported statistical correlations of presumably favorable growing conditions with good lamb production the next year in Kluane, Yukon Territory. He found high rainfall (which accompanies cool weather in Alaska) was correlated with increased food production. Presumably better plant production lead to better breeding condition. We evaluated this relationship in Dry Creek by taking Big Delta temperature and precipitation data from summaries published by the U.S. Weather Bureau for the months of June, July, and August. Mean low temperature for each month was averaged, and total precipitation recorded for the 3-month period. Then a weather index combining temperature and rainfall was calculated as described above for the lambing period. Similar weather data from the Robertson River study area were not available.

Aggregate Weather Index: Once weather indices relating to breeding condition, gestation, and parturition period were derived, the overall mean and standard deviation for all years for each parameter were calculated. The deviation of each year's index from the mean was arbitrarily expressed as either positive or negative depending on which side (favorable or unfavorable) of the mean weather condition it fell. The distance from the mean in "half standard deviation" units was then calculated for each parameter each year. The algebraic sum of these deviation units was then totalled for each year, thus producing an overall or aggregate weather index. Lamb:100 ewe ratio was regressed on this aggregate index of weather influence.

RESULTS

Lamb Production

Lamb production, expressed as lambs:100 ewes, was more variable in the Dry Creek population than in the Robertson River population. In Dry Creek (Table 2), the values for lamb production ranged from 15 to 67 lambs:100 ewes with a mean of 49 lambs:100 ewes (SD = 15). The standard deviation for Dry Creek was 31% of the mean. Also in Dry Creek, good lamb production and poor lamb production occurred in groups of consecutive years which appeared to be separated by identifiable changes in environmental variables (Table 2). Lamb production was significantly lower during the 1972-76 period than for years before ($P < 0.014$) or since ($P < 0.008$) when tested using the Mann-Whitney U-test (Cochran 1977).

In the Robertson River population, the lamb:100 ewe ratio also averaged 49 lambs:100 ewes, but the standard deviation (12 lambs:100 ewes) was only 24% of the mean (Table 3). The poorest production period for this population was 1982-85 ($\bar{x}$ = 44 lambs:100 ewes; SD = 11). Production was highest for the years 1977-81; lamb production averaged 59 lambs:100 ewes (SD = 7). There was no significant difference between mean lamb:100 ewe ratios for these periods ($P > 0.05$) using the same statistical test.

Relative lamb production varied more at Dry Creek than in the Robertson River population. This may suggest greater variations in environmental components in Dry Creek.

Ovulation Rate

Dall ewes from the Robertson River study area (n = 13) had significantly ($P < 0.05$) higher ovulation rates than ewes from Dry Creek (n = 19). The chance of mistakenly concluding the observed differences in ovulation rate are not due to sample variance is only 0.01 as indicated by Student's t-test for ratio estimators (Cochran 1977). Histological examination of corpora lutea and corpora albicantia indicated ovarian function occurred at a rate of 0.70 ovulations per ewe-year in the Dry Creek ewes and 0.99 ovulations per ewe-year in the Robertson River populations (Tables 4 and 5).

Table 2. Relative lamb production and ecological influences for the Dry Creek, Alaska study area, 1968-84.

Variables	Year	Rams: 100 "ewes"	Lambs: 100 ewes		
3/4-curl regulation	1968	--[a]	63		
Light harvest	1969	--	64	$\bar{x}$ = 58	
Human use increases	1970	32	55	SD = 7	
	1971	--	50		Difference significant
Unusually severe winter	1972	--	15		$P \leq 0.014$
Very heavy harvest	1973	--	38	$\bar{x}$ = 29	
from 1972 on	1974	--	28	SD = 7	
	1975	17	28		
Wolf control begins	1976	--	36		
					Difference
	1977	--	58		significant
	1978	--	41		$P \leq 0.008$
7/8-curl regulation	1979	--	65		
Wolf control ends	1980	32	67	$\bar{x}$ = 54	
	1981	--	60	SD = 12	
	1982	--	31		
	1983	--	57		
Full-curl regulation	1984	39	51		
		$\bar{x}$ = 49			
		SD = 15			

[a] Data not collected.

Table 3. Relative lamb production in the lightly hunted Robertson River, Alaska Dall sheep population 1974-85. Full-curl, restricted permit hunts in effect since 1974.

Year	Lambs:100 ewes		
1974	56		
1975	43	$\bar{x}$ = 45	
1976	35		
1977	52		
1978	57		
1979	63	$\bar{x}$ = 59	
1980	69		
1981	52		Difference not significant ($P \geq 0.05$)
1982	29		
1983	43	$\bar{x}$ = 44	
1984	45		
1985	57		
	$\bar{x}$ = 49		

Table 4. Ovarian activity of Dall sheep ewes collected in Dry Creek, Alaska Range, 1973-79.

Accession number	Possible reasons of ovarian avtivity (total ruts experienced minus 1)	Ovarian events recorded as CL or CA[a]
3559	3	3
3580	5	4
3624	10	8
3696	10	2
3888	9	7
3889	10	6
3890	10	8
3891	7	6
3892	9	5
3894	1	1
3895	6	4
3896	7	3
3897	4	1
4385	9	6
4741	0	0
4743	5	5
4745	10	9
5009	7	3
5012	10	7
5036	7	5
Total	139	93

[a] CL = corpora lutea; CA = corpora albicantia.

Table 5. Ovarian activity of Dall sheep ewes collected in the Robertson River, Alaska Range, 1976-79.

Accession number	Possible seasons of ovarian activity (total rut experienced minus 1)	Ovarian events recorded as CL or CA[a]
4569	0	0
4594	2	2
4596	5	4
4598	4	6
4599	4	8
4601	7	6
4762	0	0
4763	7	8
4765	1	1
4767	7	5
4768	5	4
4992	0	0
4994	4	2
4995	5	2
5042	8	7
5043	3	4
Total	62	59

[a] CL = corpora lutea; CA = corpora albicantia.

The lower ovulation frequency among Dry Creek ewes coincided with low lamb:100 ewe ratios, low pregnancy rate, and extended lactation. This low ovarian activity also accompanied low population numbers, and, because most collections occurred right after the wolf reduction program, presumably low predator densities.

Age at First Successful Lamb Production

The age at first successful lamb production appeared to be different between the 1972-77 and 1981-84 periods in Dry Creek, but the change was not statistically significant ($P > 0.05$). During the 1972-77 period, 7 of 30 2-year-old ewes (23%) successfully produced lambs. In the latter period (1981-84), only 2 of 22 2-year-olds (9%) produced lambs ($X^2 = 1.94$, $P > 0.05$). In contrast, 2 of 40 (5%) 2-year-old ewes from the Robertson River population successfully produced lambs between 1978 and 1985. This was significantly less than in Dry Creek ($X^2 = 4.448$, $P < 0.05$) (Table 6).

In the Robertson River population, 25 marked ewes were monitored between 1978 and 1985. Only 1 ewe (4%) successfully reproduced at age 2, at least 19 (77%) brought lambs to the lick at age 3 years, and 5 (25%) were first observed to lead lambs at 4 years of age.

Frequency of Observed Reproductive Success

Documented reproductive frequency in the Dry Creek study population varied markedly between the 1972-76 period and the 1981-84 period. During the former period, the frequency of observed consecutive-year reproduction was 6%. In the latter period, the frequency of observed consecutive-year reproduction in the Dry Creek population increased to 40%. This same statistic was never lower than 44% in the less disturbed Robertson River population (Table 7). The difference in the early and later Dry Creek consecutive-year success frequencies is statistically significant ($P < 0.05$). The chance of mistakenly concluding that the differences are real with respect to the variability is less than 0.005.

Weather Conditions

Weather Effects on Breeding Condition: Warmer and drier weather during the June-August growing season was positively correlated with increased lamb production the following spring. The equation generated by linear regression of lambs:100 ewes as a function of this composite weather index was $y = 0.824X + 28.7$ ($r = 0.639$; $P < 0.02$) (Table 8).

Weather Effects During Gestation: The relationship between mean snow depth on the north face of the Alaska Range and lamb production the following spring was not strong. Linear regression of lambs:100 ewes on mean snow depth on 1 April produced an equation, $y = 0.25X + 27.5$; $r = 0.457$; $P < 0.01$ (Table 9).

Weather Effects at Parturition: The relationship of weather during the period of parturition to lamb:100 ewe ratio was not strong. There was a tendency to observe higher ratios when weather during parturition had been warmer and drier. Linear regression of lambs:100 ewes on this composite weather index was $y = -1.073X + 65$ ($r = 0.3557$; $P < 0.15$) (Table 10).

Table 6. Number of reproductively successful 2-year-old ewes determined by 3 methods from Dry Creek (1972-77 and 1981-85) and Robertson River (1978-85), Alaska Range, Alaska.

Method	Reproductively active ewes		Reproductively inactive ewes
	Dry Creek 1972-1977		
Genital inspection	5		18
Collection/Autopsy	1		0
Observations of marked yearlings	1		4
Total	7		22
Frequency		7 of 29 (24%)	
	Dry Creek 1981-1985		
Genital inspection	2		9
Observations of marked yearlings	0		11
Total	2		20
Frequency		2 of 22 (9%)	
	Robertson River 1978-1985		
Genital inspection	0		18
Collection/Autopsy	1		0
Observations of marked yearlings	1		17
Total	2		35
Frequency		2 of 39 (5%)	

Table 7. Reproductive frequency patterns observed in the heavily hunted Dry Creek and lightly hunted Robertson River Dall sheep populations in the Alaska Range, 1972-84.

Consecutive-year reproductive performance	Dry Creek 1972-77 (n = 88) (%)	Dry Creek 1981-84 (n = 73) (%)	Robertson River 1979-81 (n = 74) (%)	Robertson River 1981-84 (n = 137) (%)
With/with lamb	6	40	66	44
With/without lamb	26	24	13	28
Without/with lamb	24	21	17	17
Without/without lamb	44	15	4	15

Table 8. Composite weather index from temperature and precipitation for June, July, and August 1970-85, and regression equation of composite weather index on next June lamb:ewe ratios at the Dry Creek mineral lick, 1970-85.

Year	Mean low temp. (F)	Deviation from overall mean low (F)	Total precipitation (in)	Index[a]	Standardized index[b]	Next June's lamb: 100 ewe ratio
1970	47	-1.3	3.84	-4.95	12	50
1971	47	-1.3	5.46	-7.10	15	15
1972	49	+0.7	5.88	+4.12	21	38
1973	46	-2.3	7.36	-16.93	0	28
1974	47	-1.3	6.96	-9.15	8	28
1975	48	-0.3	8.29	-2.49	14	36
1976	50	+1.7	7.40	+12.58	30	58
1977	51	+2.7	7.59	+20.49	37	41
1978	50	+1.7	5.51	+9.37	26	65
1979	51	+2.7	8.60	+23.22	40	67
1980	49	+0.7	5.74	+4.02	21	60
1981	48	-0.3	5.99	-1.79	15	31
1982	47	-1.3	7.15	-9.30	8	57
1983	48	-0.3	8.06	-2.42	15	51
1984	47	-1.3	12.47	-16.32	1	

$y = 0.824x + 28.7$
Average index = 18 ± 6.65 (95% CI)
$r = 0.639$
$\underline{P} \leq 0.02$

[a] Index equals deviation from mean temperature (+ or -) times total precipitation.

[b] Index standardized by setting most negative values to zero (add 16.93 to each value).

Table 9. Mean snow depth on the north face of the Alaska Range in April and lambs:100 ewes in June and regression equation relating snow depth to lambs:100 ewes, 1968-82.

Year	Mean snow depth (in)	Lambs:100 ewes
1968	18.0	63
1969	18.0	64
1970	5.5	55
1971	26.3	50
1972	24.3	15
1973	12.8	38
1974	17.3	28
1975	20.3	28
1976	17.5	36
1977	13.7	58
1978	15.8	41
1979	20.7	65
1980	17.0	67
1981	8.8	60
1982	22.5	31

$y = -1.07x + 65$
Average depth = 17 inches ± 3.3 (95% CI)
$r = 0.3556$
$\underline{p} \leq 0.10$

Table 10. Composite weather index for weather during peak lambing period and regression equation for composite weather index on lamb:ewe ratios in June, Dry Creek study area, Alaska, 1970-85.

Lamb: 100 ewe ratio	Year	Mean minimum temperature 26 May-7 Jun (F)	Deviation from overall mean (F)	10X total precipitation (in)	Index[a]	Standardized index[b]
55	1970	44	-0.2	3.90	-7.8	76
50	1971	43	-1.2	0.01	-0.1	84
15	1972	43	-1.2	9.10	-10.9	73
38	1973	40	-4.2	6.50	-27.3	57
28	1974	42	-2.2	8.40	-18.5	66
28	1975	47	-2.8	7.80	-21.8	62
36	1976	40	-4.2	20.00	-84.0	0
58	1977	48	+3.8	5.00	+19.0	103
41	1978	43	-1.2	7.60	-9.1	75
65	1979	47	+2.8	1.60	+4.5	89
67	1980	49	+4.8	0.20	+9.6	94
60	1981	46	+1.8	12.30	+22.1	106
31	1982	--[c]	--	--	--	--
57	1983	45	+0.8	10.00	+8.0	92
51	1984	40	-4.2	11.50	-48.3	36
--	1985	45	+1.8	11.70	+11.7	96

$y = 0.25x + 27.5$
Average index = 74 ± 15.5 (95% CI)
$r = 0.4570$
$P \leq 0.12$

[a] Index equals deviation from mean temperature times 10X total precipitation.

[b] Index standardized by setting most negative values to zero (add 84.0 to each value).

[c] Data not available.

Table 11. Aggregate weather index of potential influences on lamb production and regression equation of aggregate weather index to lamb:ewe ratio, Dry Creek, Alaska, 1970-81.

Lamb: 100 ewe ratio	Year	Effect on breeding condition	Lambing weather	Gestation weather effect[a]	Index[b]	Standardized index[c]
50	1971	-1	+3	-3	-2	+2
15	1972	-2	+1	-3	-4	0
38	1973	+1	-1	+2	+2	+6
28	1974	-3	+1	-1	-3	+1
28	1975	-2	+1	-2	-3	+1
36	1976	+1	-4	-1	-4	0
58	1977	+2	+5	+2	+9	+13
41	1978	+4	+3	+1	+8	+12
65	1979	+2	+4	-2	+4	+8
67	1980	+4	+4	0	+8	+12
60	1981	+1	+5	+3	+9	+13
31	1982	-1	0	-2	-3	+1

$y = 2.231x + 29.6$
$r = 0.7734$

[a] Units (+ or -) = 0.05 standard deviations from mean for available data, 1970-82.

[b] Index equals algebraic sum of component deviation units from mean for each parameter.

[c] Index standardized by setting most negative values to zero (add 4 to each value).

Aggregate Weather Index: The aggregate weather effects index was significantly correlated with lamb production ($r = 0.773$; $P < 0.01$) (Table 11).

DISCUSSION

Variations in lamb production in the Dry Creek population correlated significantly with the aggregate weather index. This seems to provide justification for the common, empirical observation that good weather leads to high lamb production. Still, it is worth noting that the correlation of lamb production with the aggregate index is much better than for any of the individual indices. This may indicate there are more weather influences on lamb production than winter severity as it influences foraging ability during gestation. Weather is probably not closely related to ovarian activity or age at first breeding.

However, weather may influence the frequency of consecutively observed reproductive success. For us to document consecutive-year reproductive success, a ewe must ovulate, breed, carry the fetus to term, deliver a living lamb, and bring it to the lick. At the lick, we must verify the pair-bond. Then, the next year, the sequence must be repeated. If a marked ewe delivered a lamb, and the lamb died before we could verify the pair-bond or observe lactating udders at the mineral lick, the ewe would be recorded as reproductively inactive. This probably happened and the frequency of its occurrence is unknown. When unfavorable weather occurs at lambing, this frequency probably increases because more lambs are likely to die than when conditions are good. Thus, we are always likely to underestimate the actual frequency of consecutive-year reproductive activity. The technique is more likely to underestimate it in years of unfavorable lambing weather than in favorable years.

During the years (1972-77) when observed consecutive-year reproduction was only 6% in Dry Creek (Heimer 1978), the lambing aggregate weather index had a value of -3. For the second period (1981-84), the aggregate index had a value of +12 (Table 11). The real meaning of this difference is unknown, but it probably indicates weather-influencing components of lamb production were more favorable.

We may gain some insight into the magnitude of the influence weather had on this reproductive parameter by considering mean lamb:ewe ratios for the two differing periods. During the period 1972-77, when consecutively observed reproductive success was 6%, the mean lamb:100 ewe ratio was 29. For the second period, 1981-84, when consecutively observed success was 44%, the mean lamb:100 ewe ratio was 50. This is an increase of 1.7 times. If our ability to document consecutive-year production were directly proportional to changes in lamb:100 ewe ratio, we should have seen a consecutive-year increase in frequency of 1.7 times. The documented increase was 7.3 times. This increased frequency is 4.3 times greater than should be expected on the basis of increased lamb:100 ewe ratio. Something besides weather appears to be influencing changes in frequency of consecutively observed reproductive success.

We do not think changes in range resources could account for this change. We doubt there could have been sufficient deterioration in range resources from the early (1968-71) period of high lamb production, to cause the low lamb production of the middle period (1972-77), followed by sufficient range recovery to produce and maintain the high lamb productions of the latter (1981-84) period.

These are two likely possibilities (Table 2): wolf control, and changes in ram harvest level and age. Reduction in wolf populations began in 1975, and was followed by stabilization of the declining Dry Creek sheep population (Heimer and Stephenson 1982). Then, in 1979, hunting regulations were changed from 3/4 curl to 7/8 curl for legal rams (Heimer 1980). We suspect these actions may have worked in concert to effect a change in ram abundance and age structure. Survival of lambs to yearling age in the years when wolves were most abundant, from 1970-75, averaged 66%. This is the highest average survival for any period of years in Dry Creek. This indicates wolves were not preferentially taking lambs after the month of June. Heimer and Stephenson (1982) suggested wolves take sheep in an opportunistic manner. Murie (1944) observed that wolves took sheep that were easiest to catch. We think young rams in Dry Creek may have been the sheep most readily available to wolves during this period. We propose the following explanation:

Ram abundance was relatively high before 1972. An aerial survey of the Dry Creek study area in 1970 showed a total of 32 rams per 100 "ewes." (Aerial classification of ewes is imperfect because yearlings and rams less than 2 years of age cannot be consistently identified from aircraft.) There were 12, 3/4-curl and larger rams for each 100 "ewes" classified. Following winter 1972, the most severe recorded for sheep in the Dry Creek area, few old-age animals would have survived (Heimer and Watson 1984). Compounding this natural lowering of old ram numbers was an increase in hunter pressure on the Dry Creek populations. The net result was that legal, 3/4-curl rams were very scarce, and ram populations were generally depleted. Another survey of the area in 1975 indicated the ratio of total rams per 100 "ewes" had dropped from 32 to 17. The 3/4 curl and up ratio was found to be 8:100 "ewes." The total number of rams seen on the equivalent surveys dropped from 173 seen in 1970 to 78 seen in 1975.

In terms of vulnerability to wolves, this could have meant that ram bands had less than half the number of individuals to watch for predators, a social adaptation cited by Geist (1971). It also meant that older rams which presumably had more experience with predator avoidance were absent. Furthermore, the surviving young rams should also have been compromised by their unscheduled participation in rut because of the absence of dominants. Geist (1971) postulated that in circumstances such as these, young rams would be in unusually poor physical condition. All these factors may have predisposed these young rams to early mortality.

Whatever the cause, the early mortality apparently took place. Heimer et al. (1984) reported greatly increased mortality among young rams in the Dry Creek populations during this period. They speculated that the energetic and behavioral causes listed above were operative, but failed to factor the likelihood of increased wolf predation into their explanation.

We note that the occurrence of good lamb production correlates not only with good weather conditions but also with high ram abundance. The period before the difficult winter of 1972 was one of high lamb production averaging 58 lambs:100 ewes. This coincides with the high ram:100 "ewe" ratio and the high 3/4-curl ram:100 "ewe" ratio given above. There is little reason to suspect the population composition from the 1970 survey was not typical of that period. Following the severe winter of 1972, a period of poor lamb production occurred in which lamb:100 ewe ratios averaged 29. This went with the low total ram and 3/4 and larger rams ratios (17 and 8, respectively) reported for the 1975 survey. Following wolf control, if young ram survival increased, the number of rams should have increased. This possible increase was amplified when, in 1979, the legal harvest definition was raised from 3/4 curl to 7/8 curl. This certainly would have led to more rams in the population (even disregarding possible survival benefits) (Heimer et al. 1984) because there were two more cohorts of rams on the mountain, and age at 3/4 curl is roughly 2 years less than age at 7/8 curl. This change (or perhaps these changes) coupled with good recruitment in lamb productions before 1972 could have resulted in higher ram:100 ewe ratios. In 1984 another aerial survey was flown. It showed the total ram:100 "ewe" ratio had risen to 39 and the 3/4-curl-and-larger ram:100 "ewe" ratio was 16 rams per 100 "ewes." The mean lamb production for this period was 54 lambs:100 ewes. We think these data suggest that ram abundance and possibly age structure also influence lamb production.

This is neither a new nor a revolutionary idea. Allison (1977), working with domestic sheep, related decreasing ram:ewe ratios to a lower probability of ewes becoming pregnant. More importantly, Nichols (1978) also reported a significant correlation ($r = 0.616$, $df = 16$, $\underline{P} < 0.01$) between the ratio of Dall rams:100 ewes and the ratio of lambs produced per 100 ewes when all years and all data from his three Kenai Peninsula study areas were combined. He wrote (Nichols 1978:578) "Correlation could not be discerned within herds, however, probably due in part to the smaller sample sizes involved. The critical ratio of rams to ewes, below which lambing success suffered, was not determined. I suspect it may depend upon age distribution of rams as well as upon numbers present."

The hypothesis that ram abundance or perhaps ram age structure influences lamb production serves well in rationalizing the data presented here on ovarian activity and age at first successful reproduction.

How might the proportion of old-age rams relate to a higher frequency of estrus in populations with high ram:ewe ratios? If rutting groups of ewes are small and widely dispersed, it is possible that estrous ewes could be "missed" by breeding rams. In such a situation, induction of subsequent estrous periods by ram presence or courtship would be quite important. In domestic sheep, the presence of rams affects beginning and synchronization of estrus (Redford and Watson 1957, Watson and Redford 1960, Fraser 1968). If Dall rams somehow facilitate or induce the 1st or subsequent estrous periods, and if more socially and physically mature rams (such as would be present at much higher frequency after years of limited full-curl hunting) are more likely to induce estrus, it follows that lowering the total number of rams present, and greatly reducing the number of mature rams, as in Dry Creek, should result in decreased ovarian activity. Bunnell (1980, 1982) reported that Dall ewes in the unhunted Kluane Park population of the

Canadian Yukon were frequently bred during later estrous cycles. Survival of lambs conceived during 2nd estrus has not been determined.

There may be some concern regarding the methods chosen to determine ovarian activity. However, the origin of corpora albicantia in ovaries is well understood, and ovarian examination as a means of determining past activity has been proven reliable (Hadek 1958).

Likewise, some criticism may reasonably be a result of our aging techniques. Aging ewes by counting horn annuli is difficult, and age determination is variable among observers (Hoefs 1984a). Geist (1966) states only a minimum estimate of age is attainable. In this study, errors should be consistent for both populations because 1 individual aged all sheep. Also, when the ewes 9 years and older from the Dry Creek data set are considered separately, the ovulation frequency changes little (from 71.8% to 73.1%). We conclude possible errors in age determination did not materially affect the results in this comparison.

The observation that age at first breeding was different in the Robertson River and Dry Creek populations is also consistent with the hypothesis that ram abundance is a determinant of lamb production. Delivery of lambs on their second birthday seems to be associated with low ram numbers or the absence of old rams in Dall sheep populations. Hoefs and Cowan (1979) reported lambs in unhunted Kluane Park usually did not deliver lambs until their third birthday. Similarly, 2-year-old ewes in the unhunted sheep populations of Denali National Park have not been observed leading lambs in three searches, on foot, of the the Savage River summer ranges. Palmer (1941) concluded ewes in the vicinity of the then virtually unhunted Dry Creek population were characterized by breeding at 30 months and lambing on their third birthdays. In contrast, Nichols (1978) reported that 3 of 4 ewes collected before their second birthdays were pregnant. These ewes were taken from a Dall sheep population where 3/4-curl hunting removed every legal ram on the mountain each year. We are aware of no reports of 2-year-old ewes routinely delivering lambs in relatively undisturbed populations. We have observed and handled a total of 17 2-year-old ewes since the changes which followed wolf control and the 7/8-curl regulation occurred in Dry Creek. Only one of them has had a lamb.

Other evidence that ewes are capable of delivering lambs at 24 months of age comes from captive animals. Four Dall ewes held in captivity in Fairbanks, Alaska delivered lambs at 24 months of age. These ewes were bred by 18-month-old rams. Similarly, Hoefs and Cowan (1979) reported that captive 18-month-old Dall ewes from populations which regularly produce lambs on their third birthday in the wild, produced them on their second birthday in captivity. The ram age structures in captive herds where Dall ewes bred early is not known to us. We do know that Dall ewes kept in the Milwaukee County Zoo deliver lambs at 2 years of age, when immature rams are present.

Data from the Dall sheep breeding program at the Milwaukee County Zoo (1971-79) indicate 12 of 15 ewes delivered lambs on their second birthday. These lambs were sired by young rams, the oldest being a 4-year-old ram which bred one ewe. Three lambs were sired by 2.5-year-old rams, and the remaining eight were sired by rams aged 1.5 years. In a breeding pen where all rams had access to all ewes, the one mature ram, aged 9.5 years, did not mate with ewes below the age of 3.5 years (Bullerman, pers. commun.).

In an earlier paper, we proposed a behavioral mechanism, operative in the absence of mature rams, that leads to early breeding of 18-month-old ewes (Heimer and Watson 1982). We suggested juvenile rams harassed 18-month-old ewes into copulation even though the ewes were not behaviorally mature. This explanation must center on preferential courtship of these young ewes. Given the differences in body size between young rams and mature ewes, this appears plausible when one reads Geist's (1971) accounts of the difficulty bighorn yearling rams experience in attempting to dominate their dams. Two-year-old Dall rams are typically subordinate to mature ewes in Dry Creek. Relative body size is important in these interactions and may function in aspects related to courtship as well as to ram hierarchy during the rut.

We conclude early breeding by ewes in the Dry Creek population was most likely a consequence of ram scarcity or the young age structure among breeding rams. Scarcity of rams above the age at 3/4-curl horn size (approximately 5.5 years) probably resulted in rutting participation by young rams. The consequences of this circumstance included not only a lowered ovarian activity, but an earlier breeding age. We do not view this as an advantageous, compensatory population response. Breeding domestic sheep at first estrus commonly results in offspring of low survivability and compromised reproductive fitness in the dam. Rattray (1977) showed early breeding in domestic ewes resulted in a reproductive advantage only if heavy supplemental feeding followed during both gestation and lactation. A similar requirement has been shown for domestic cattle (Minsh and Fox 1979). Supplemental feeding of early-breeding Dall ewes in the wild is clearly impractical in Alaska at this time. In the wild, small ewes have lesser status and must get by on forage not selected by more dominant sheep (Geist 1971). Therefore, we think early breeding among wild Dall ewes is maladaptive.

We think these findings indicate that Dall sheep reproductive ecology is much more complicated than current management models seem to indicate. Weather appears to have a definable effect on lamb production, and there appears to be sufficient reason to investigate in greater detail the hypothesis that ram abundance or age structure is also a determinant of lamb production level.

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QUESTIONS AND ANSWERS

Jim Bailey, Colorado: There's a rule around that "sperm is cheap," "sperm are cheap," I guess it is. Why would an old ram with the opportunity to breed young ewes refuse that opportunity if he's an animal that has evolved to increase his relative fitness. Can you rationalize that problem?

Wayne Heimer, Alaska: First, I would stress that I am reporting an observation. Our ability to rationalize the observation within the concept of fitness as we interpret it today should not challenge the observation. Second, it may not increase a ram's relative fitness to mate with a ewe before she is physically mature. An 18-month-old ewe is not physically mature; they're small. If they are similar to domestic ewes, the young first-heat ewe will produce a less than optimally fit offspring. Unless you can provide supplemental feeding for earl-breeding domestic ewes during both gestation and lactation, the future reproductive fitness of both the ewe and the lamb will be compromised. Evolutionary selection has probably favored ewes that are behaviorally as well as physically mature.

Bailey: Yes, but sperm is cheap. Why save your sperm for the older ewe when you can distribute it loosely; and if you save the ewe, you perhaps don't save her for yourself. There's no selection for that kind of a ram.

Heimer: In a situation where there is an abundance of mature rams, young ewes apparently do not breed. An ideal situation would seem to call for ignoring young ewes until they are both physically and behaviorally mature. This would increase fitness for everyone.

Bailey: Yes, I can't rationalize how evolution can produce rams, or possibly Canadians as you suggested, who avoid young, estrous females.

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BIGHORN RAM SURVIVAL AND HARVEST IN SOUTHWESTERN ALBERTA

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ABSTRACT: The survival of individually marked bighorn rams was monitored over 6 hunting seasons in southwestern Alberta. The study area included the Sheep River Wildlife Sanctuary, where sheep are easily accessible and hunting is prohibited, and the surrounding areas where hunting is allowed in September and October. Rams with horns exceeding 4/5 of a curl ("legal rams") can be harvested. The number of permits issued is not limited. Seventy-eight rams were tagged. Of these, 43 were or became legal, and 20 were harvested. The median age at which rams became legal was 5 years (range 3-8). The median age at harvest was 6 years (range 4-13), and legal rams survived on average 1.6 hunting seasons (range 0-6). Yearly harvest was about 27% of the legal ram population, and a minimum of 61% of legal ram deaths was due to hunting. Motor vehicle access to most hunting areas is severely restricted. At least 26% of rams that survive to yearling age, however, die before reaching legal horn size. This unexpected mortality of young rams warrants further research. Increasing use of the Sanctuary as a refuge may reduce ram harvests in the study area.

Bighorn sheep (Ovis canadensis) are managed as a trophy animal (Hebert et al. 1985; Thorne et al. 1985). The "ideal" management strategy should result in the production of good trophies and the harvest of most of these trophies, while maintaining an age distribution not drastically different from that expected in the absence of hunting. The quality of the hunt, and hunter satisfaction, should also be incorporated in a management scheme. The definition of an harvestable ("legal") ram must be functional, so that it can be used both by hunters in the field and by conservation officers checking the harvested rams.

Heavy harvest of 4- to 6-year-old individuals may result in poor trophy quality (Barichello and Hoefs 1985) and may affect the social behavior and mortality pattern of the population (Geist 1971; Heimer et al. 1984). On the other hand, regulations limiting harvest to full-curl rams may result in the loss of the segment of the population that does not reach this horn size (Nichols 1985). This problem may be especially important for populations where heavy brooming of the horns is common.

It is therefore important to know the effects of different management strategies on ram mortality and trophy quality. These effects have been assessed in thinhorn sheep (Ovis dalli) by analyzing ram harvests (Barichello and Hoefs 1985) and ram survival data (Heimer et al. 1984). Here I report on the survival of individually marked bighorn rams in southwestern Alberta, under an unlimited-entry, 4/5-curl management strategy. I also discuss the effects and potential applications of restricting access to hunting areas as a management tool.

This study would not have been possible without the initiative, support and friendship of W.D. Wishart. Field assistance was received from J.T. Jorgenson, W.J. King, O. Pall and D. Richardson. The Alberta Fish & Wildlife Division and the Natural Sciences and Engineering Research Council of Canada provided financial support. I thank W.E. Heimer for reviewing the manuscript.

STUDY AREA

The study area in southwestern Alberta included the Sheep River Wildlife Sanctuary, established in 1973. The Sanctuary is predominantly a ewe winter range (Festa-Bianchet 1986), but rams can be found in it at any time of the year, with peak numbers in early June and early October (Festa-Bianchet in press). Hunting is prohibited in the Sanctuary and permitted outside it in September and October. Motorized vehicle access is restricted to the main road along the Sheep River. Although many areas used by rams east of the Sanctuary are within a few minutes walk of the road, hunting in the rest of the study area involves backpacking or horseback riding, and very few areas used by rams are less than two hours walk or ride from the road: most sheep hunters camp out one or more nights.

To be legally harvested, rams must have horns of 4/5 of a curl or greater. A legal ram (or trophy sheep) is defined as one whose horn tip extends beyond the continuation of a line drawn from the anterior base of the horn to the front of the eye. Only residents are allowed to hunt in the area, but the number of permits issued is not limited. Successful ram hunters cannot buy a trophy sheep tag in Alberta the year after their kill.

MATERIALS AND METHODS

Rams were captured with tranquillizing drugs as described in Festa-Bianchet and Jorgenson (1985), or in a corral trap, and tagged with plastic ear tags. Data reported here were collected from September 1980 to February 1986. During this period, 43 tagged rams were or became legal. Rams were aged by counting horn annuli (Geist 1966). Information on hunter harvests was obtained through the collaboration of Conservation Officers of the Alberta Fish & Wildlife Division and field staff of the Alberta Forest Service, interviews of hunters in the study area, and by checking registration forms: all trophy sheep harvested in Alberta must be registered with the Fish & Wildlife Division within 30 days of the kill. Rams were assumed to be dead when they were not seen for over eight months.

RESULTS

Forty-three rams were captured when they were aged between 1 and 2 years. Of these, 17 survived until they reached legal status, 9 were still alive but not legal at the time of writing, and 17 died before reaching legal size. Of the latter, 8 died during a major pneumonia die-off late in 1985, although clear evidence of disease was found in only two. Cuse of death of the 9 rams that died outside the die-off could not be determined.

Rams reached legal status at ages 3-8, and over 70% were legal by age 5 (Fig. 1). The average age at harvest was 6.8 years (Fig. 2), and legal rams survived on average 1.6 hunting seasons (Table 1) (legal rams alive at the time of writing were not included in this calculation). During this study, 43 tagged legal rams provided 73 legal-ram-seasons. Since 20 rams were harvested, hunters removed 27% of the available legal rams each year. Harvest of tagged legal rams ranged from 0/6 (0%) in 1980 to 7/16 (44%) in 1983. Hunter harvests accounted for at least 61% of legal ram deaths (Table 2).

DISCUSSION

This study revealed that a sizeable proportion of bighorn rams die after one year of age and before they reach legal status. Even if those that died in the 1985 die-off are excluded from calculations, and those alive but not legal at the time of writing are assumed to all survive to legal size, a minimum of 26% (9/35) would be lost. Mortality among young rams is assumed to be low (Geist 1971), but Heimer et al. (1984) suggested that it may increase if these young rams were to actively participate in the rut. This study, and those of Heimer et al. (1984) and Jorgenson and Wishart (1986) have shown considerable mortality of rams aged 1-5. Geist (1971) suggested that physical exertion during the rut would lead to heavier overwinter mortality. If hunting removed most or all of the older rams, younger ones may take over as breeders, and as a consequence suffer an increase in death rate. In most of North America, mountain sheep rams are not hunted between age 1 and when they reach legal status on the assumption that survival of young rams is very high (ram lambs can be hunted in Alberta as non-trophy sheep). The loss of over one quarter of the young ram population indicates a strong need

Table 1. Hunting seasons survived by bighorn rams in southwestern Alberta after their horns had grown to legal size.

Years survived	No. rams	%
0	13	43.3
1	6	20.0
2	4	13.3
3+	7	23.3

Table 2. Causes of death of tagged bighorn rams with legal-sized horns (N = 33)

Cause of death	No. rams	%
Hunter kill	20	61
Poached	2	6
Total man-caused	22	67
Other	3	9
Unknown[a]	8	24

[a] Rams that disappeared. Probably includes some hunter kills

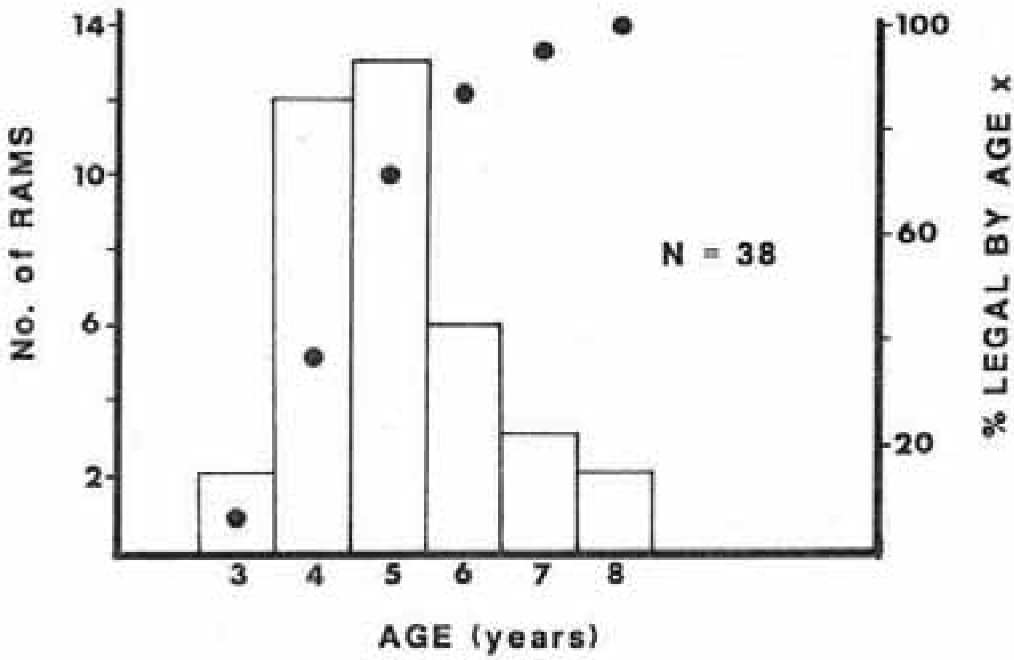

Fig. 1. Age of bighorn rams when their horns grew to legal size.

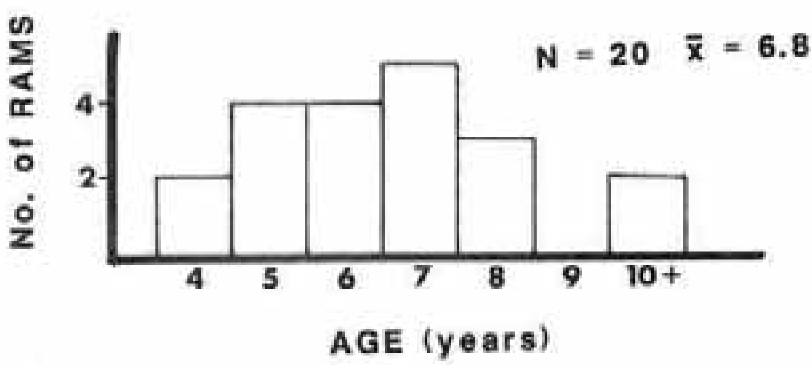

Fig. 2. Age of bighorn rams harvested by hunters in the study area.

for research to determine the causes of this mortality. This research should involve a study of ram social behavior and nutrition, to test both the hypothesis put forward by Geist (1971) and Heimer et al. (1984), that removal of mature rams will affect the behavior of younger ones, and that advanced by Clutton-Brock et al. (1985), that young males may suffer heavy mortality under food stress because of their greater requirements. At Sheep River, 27% of legal rams were harvested each year, and 23% survived three or more seasons. If this relatively low level of ram harvest resulted in major alterations of social behavior, more severe consequences may be expected in areas where a much larger proportion of legal rams is removed during the hunting season (Nichols 1978).

Despite the fact that rams spent much of the hunting season within the Sanctuary (Festa-Bianchet in press), hunter harvest accounted for a minimum of 61% of legal ram deaths. Therefore, protection of rams within the Sanctuary did not result in a major loss of hunting opportunities.

It appears that a combination of protection within the Sanctuary and limits on access to hunting areas has a number of beneficial effects. It limits harvest, likely allowing some rams to grow greater than the minimum legal size, and preventing a more severe alteration of the age structure. Within the Sanctuary, rams are tame and provide good viewing and photographing opportunities, enhanced by the presence of a few exceptionally large individuals. Hunting in the alpine areas west of the Sanctuary provides the serious sheep hunter with a challenging wilderness experience, in contrast to the killing of tame rams within a short distance of the road that takes place east of the Sanctuary.

While there is at present no evidence that rams are altering their normal migration patterns to use the Sanctuary as a refuge from hunters, this possibility merits further investigation. In the absence of excessive harassment from hunters, rams should continue to spend time outside the Sanctuary for at least part of the hunting season. Protection from hunting within easily accessible ranges and limits to motorized access to hunting areas should be considered a valuable and effective tool in the management of mountain sheep.

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QUESTIONS AND ANSWERS

John Emmerich, Wyoming: Marco, what's your post-season ratio of class 3 and 4 rams to ewes?

Marco: Over the past 5 years, the ratio of rams with horns of 3/4 curl or greater to ewes has averaged 0.25, one ram every four ewes. This ratio has ranged 0.20 to 0.32 over the years. If all rams are included, the ratio averages 0.37.

Emmerich: What's the lamb/ewe ratio in that herd, Marco, in the post-rut?

Marco: It's variable. The past year by October, it was down to 0.5 so 50 lambs per 100 ewes. In 1981 it was 0.8, in 1982-84 it averaged close to 70 lambs/100 ewes. So it's very variable.

Emmerich: But it's pretty high on the average?

Marco: It's pretty high if you exclude last year.

Daryll Hebert, BC: Marco, I'm not sure of how often Orval is tracking those cougars, and the preliminary finding is that it appears that cougars are selecting for rams after the rut, and maybe selecting for them as late as January or February.

Marco: He's tracking them quite regularly, but maybe I should explain that there's a cougar study going on in the area, and the person doing it has about 20 cats radiocollared, so I think he's got most of the cats in the area. He finds elk, mule deer and moose kills fairly regularly. When he finds evidence of a kill he goes in and checks it. He had evidence of only one male lamb taken by a cougar, and this study has gone on for 4 years. Last year a ewe was apparently attacked by a cougar and had a large wound in the neck, but those are the only two episodes of cougar predation on sheep that we know of. Cougars live right in the Sanctuary but for some reason won't go after the sheep. Often the sheep are close to the road, and possibly cougars avoid the road.

Hebert: yes, you have a much more varied prey base than we do. The main prey is our study area is sheep with some mule deer. So that may make a difference in terms of cougar predation.

Marco: Could be very different if there were more wolves in the area.

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THE EFFECTS OF TROPHY HUNTING ON DALL SHEEP RUT BEHAVIOR AND RAM SURVIVORSHIP IN ALASKA

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ABSTRACT

We conducted an investigation, 1981-84, into the possibility that the removal of larger-horned rams of Dall sheep (*Ovis dalli*) reduced the survival of younger rams due to their subsequent increased rut participation and also that this resulted in greater harassment of ewes during the rut. We hypothesized that a negative correlation between the numbers of $\geq$3/4-curl rams and <3/4-curl rams in a herd would suggest depressed survivorship of young rams from heavy removal of old rams. The sample included 17,657 sheep classified primarily from a helicopter, 1981-84, and 42,208 sheep classified from a Super Cub, 1962-84. The samples included data collected before 1979 when the Alaska curl regulation was $\geq$3/4 and after 1979 when the regulation became $\geq$7/8-curl. There was no correlation between the number of $\geq$3/4-curl rams and <3/4-curl rams for the helicopter surveys ($r = -0.18$, $P = 0.38$), however, the relationship was positive but still not significant for the Super Cub surveys conducted where the 3/4- and 7/8-curl regulations applied, respectively ($r = 0.21$, $P = 0.29$; $r = 0.12$, $P = 0.57$). Three hunted mountain count units, however, two of which were in Wrangell-St. Elias National Preserve and Surprise Mountain on the Kenai Peninsula had less <3/4-curl rams than expected (Chi-square = 10.03, d.f. = 1, $P < 0.001$). In another four count units near Anak tuvuk Pass, ewe numbers increased only 2% four years after inclusion of the area into Gates of the Arctic National Park and protection from hunting, but young rams increased 20%, suggesting survival of young rams might have been depressed before protection.

Rut behavior was studied in two unhunted herds in Denali National Park in 1983 and 1984 and in a herd where nearly every 7/8-curl and larger ram was removed every hunting season. Interaction time (interaction behavior per hour of observation) was not influenced by area (hunted versus unhunted), but was greateer when an estrus ewe was present ($F = 37.67$, d.f. = 1, $P = 0.0001$) and was greater in 1984 than 1983 ($F = 28.35$, d.f. = 1, $P = 0.0001$, 3-way Analysis of Variance with area, estrus, and year as treatments). Estrus ewes moved further per hour of observation in the hunted herd ($F = 7.50$, d.f. = 1, $P = 0.006$). Ewes in the hunted herd moved about 3 times as far from the younger 1/2- and 5/8-curl rams than they did from those horn curl classes in the unhunted herd ($F = 5.28$, d.f. = 1, $P < 0.03$). Ewes ran away more from courting rams in the hunted herd (43 run away responses per 100 behavior patterns by ewes in the hunted herd versus 27 in the unhunted herd). However, the increased ewe harassment was slight and no differences in reproductive performance were

detected. Lamb and yearling ratios did not differ during two years of data collection on the Denali National Park unhunted and nearby hunted areas, nor during 15 years on heavily-hunted Surprise Mountain versus the nearby Cooper Landing Closed Area. We propose that removal of older rams results in greater rut participation by young rams, but this participation results in depressed survivorship only in those cases where removal of large-horned rams included all 7/8-curl and most 3/4-curl rams.

QUESTIONS AND ANSWERS

Jon Jorgenson, Alberta: Did you maybe see differences in the age at first breeding? Did you have any yearlings breeding, and if so, did you notice any difference between young rams and old rams as to what kind of interactions there were?

Francis Singer: yearling ewes breeding?

Jorgenson: yes

Singer: We did not see very much of that at all. We did see a 3/4 curl ram breed a yearling in the Park in the unhunted herd. However, Lyman Nichols had some limited rut observations for a couple of years in his study areas and he never saw it, and that was in the same area that he went in and collected four yearlings, three of them were pregnant. I believe he was doing the rut observation work at that same time. So there's a possibility that even when it happens you're not seeing it much.

Jorgenson: OK, so you're saying that you didn't see very much.

Singer: No, one case and it happened in the Park.

Jorgenson: OK, but what about even though the yearlings it appears didn't breed, was there a lot of behavioral activities directed towards them by the ram groups.

Singer: We did not see a difference in that between the two populations, but the one thing I'll emphasize again is that when we started the study we thought we had a classic hunted study area with no legal rams left. We found out later during both years, that was not the case. We also found no depressed ram survivorship in this hunted herd that we did the rut study in. So in other words these two populations, this hunter population does not fit Wayne's category of a highly disturbed population after all. The presence of just two or three 7/8 curled rams appear to effect things quite a bit. That's our impression. Just a small number of larger horned rams.

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MANAGEMENT OF BIGHORN SHEEP TO OPTIMIZE HUNTER OPPORTUNITY, TROPHY PRODUCTION, AND AVAILABILITY FOR NONCONSUMPTIVE USES

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ABSTRACT

This paper describes management of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) to optimize: 1) hunter opportunity, 2) trophy availability/quality, and 3) availability of sheep to nonconsumptive users in a single Montana hunting unit. This system involves hunting with unlimited permits and conservative annual quotas during September - early November and a limited number of permits for trophy hunts on a winter range heavily used by wildlife viewers and photographers. Relocations of 12 marked rams defined seasonal movement patterns for two major population segments within the hunting district. Marked rams from the Cinnabar Mountain segment were in areas accessible to hunters during the general hunting season in 10 percent (3 of 30) of relocations. Rams from the Tom Miner segment were outside Yellowstone National Park in 4 of 22 (18 percent) hunting season relocations and within 2 kilometers of the Park boundary in an additional 77 percent of the relocations. Sixty-six percent of legal (3/4-curl) rams harvested during the general sheep season were taken from the Tom Miner segment. Mean age of legally harvested rams from this segment during 1979-85 was 6.2 years. The mean age of rams harvested in late season hunts on the Cinnabar Mountain segment (1980-85) was 6.7 years. Hunter success was 4 percent and 87 percent in the general and late seasons, respectively. Sheep response to vehicular and foot approaches on winter range after the late season hunts was similar to or less intense than prior to the late hunts. Tolerance to humans of groups with legal rams was similar to or greater than groups without legal rams. Legal rams were apparently not precluded from active participation in the rut by winter range hunts.

INTRODUCTION

A bighorn sheep population can theoretically be managed to maximize one of three objectives: 1) the number of hunters afforded an opportunity to hunt, 2) the number and quality (within genetic/environmental constraints) of trophy heads available for hunters, and 3) the opportunity for nature study, photography, or aesthetic enjoyment by a recreation-seeking public (Geist 1975). Geist (1971) also maintains that hunting may result in abandonment of areas by rams. In the short term, hunting during the rut could disrupt the mountain sheep social system at a time that is critical to the continued maintenance of population size. In the long term, hunting during the rut might select against breeding by dominant, high quality, older rams and for opportunistic breeding by young rams that may or may not carry "high quality" genetic traits (Martin 1985). Unregulated rutting by young rams could potentially lead to increased energy expenditures by females and less efficient use of sheep habitat (Geist and Petocz 1977, Heimer and Watson 1982).

This paper describes the management system in a Montana hunting district that attempts to incorporate all three of the previously defined objectives through a combination of unrestricted hunter numbers on summer-fall range with harvest limited by quotas and limited entry hunting on a winter range heavily used by photographers and wildlife viewers. The ram distribution patterns and population monitoring methodology which facilitate this system are described. The effects of winter range hunting on sheep behavior and ram access to ewes were monitored during 1982-86, and the preliminary results are presented here.

STUDY AREA

Montana Department of Fish, Wildlife, and Parks (MDFWP) bighorn hunting district 300 (HD300) was established in 1977 and includes approximately 1,500 square kilometers of suitable mountain sheep habitat. The unit is located in the Gallatin Range of southwestern Montana between the Yellowstone (east boundary) and Gallatin (west boundary) Rivers. Its southern boundary coincides with the northern boundary of Yellowstone National Park (YNP). HD300 contains two major bighorn sheep population segments:

Tom Miner (TM) - This segment includes 100-250 sheep in three or more populations with winter ranges less than 1 to 5 kilometers north of and summer-fall ranges straddling the YNP boundary.

Cinnabar Mountain (CM) - This segment consists of 80-150 sheep with winter range centered on Cinnabar mountain, 10 kilometers north of YNP, and summer range areas in and outside YNP.

Two sheep hunting seasons have been established in HD300. During September - early November an unlimited number of hunters are allowed to compete to fill a quota of legal (3/4 curl) rams throughout HD300. Each successful hunter is required to present the head to a MDFWP biologist or warden within 48 hours of harvest and to provide the date and location of the kill. Rams are aged by horn annuli counts (Geist 1966) at this time. When the quota is reached, the hunting season is closed on 48-hour notice.

From early November through mid December a limited number of permits awarded through drawings are valid for harvest of 3/4-curl rams from the CM population segment. The heads of harvested animals must be presented to a MDFWP official within 48 hours.

METHODS

During 1980-84, 12 rams (7 from the CM and 5 from the TM segments) were fitted with radio transmitters (Table 1). Fixedwing aerial and ground relocations of these animals were used to define seasonal movement patterns. Ten of the instrumented animals provided data on distribution during one or more hunting seasons. Ages at capture ranged from 1 1/2 - 5 1/2 years. Sublegal rams were used to define ram distribution during hunting season only if they were observed with ram bands.

Data on harvest in HD300 from 1976-85 were taken from MDFWP files and used to determine numbers and ages of harvested rams from the TM and CM population segments. Numbers of hunting permits sold in the general unlimited hunt and numbers of permits issued for late hunts were also available from MDFWP records.

Minimum population size and minimum number of legal rams after the close of hunting were determined for the CM and TM segments using the highest count per distinguishable age/sex class in a series of winter range surveys (Geist 1966, Stewart 1975). The CM winter range is easily accessible and 4-16 close range ground surveys were made per winter during 1978-86. Population estimates using the Schnabel (1938) method in the 1982-83 through 1985-86 winters indicated maximum counts represented 60-80 percent of the actual population (Irby, Swenson, and Stewart in prep.).

Winter ranges in the TM area are located at higher elevations and are much less accessible than the CM winter range. Minimum population estimates were based on 1-4 ground and/or

Table 1. Capture sites, dates of capture, ages at capture, and last relocation dates for 12 bighorn rams used to define movement patterns for rams in HD300.

Site	Ram ID	Date of capture	Age (yr)	Last relocation	Fate
CM	0411	Jan 80	2 1/2	May 83	Unknown
	0204	Mar 80	4 1/2	Feb 83	Unknown
	0212	Mar 80	1 1/2	Feb 81	Unknown
	4201	Feb 84	2 1/2	[a]	
	4210	Feb 84	4 1/2	Oct 84	Poached
	4204	Feb 84	2 1/2	[a]	
	4306	Feb 84	1 1/2	Feb 85	Avalanche kill
TM	0203	Mar 80	5 1/2	Apr 83	Unknown
	2201	Feb 82	2 1/2	Sep 83	Hunter kill
	2210	Feb 82	2 1/2	Jul 83	Unknown
	2306	Feb 82	1 1/2	May 82	Predator kill
	2308	Feb 82	5 1/2	[a]	

[a] Alive in winter 1985-86.

fixed-wing aerial surveys per winter. Limited sightings of marked animals during surveys suggested that minimum population estimates were 25-50% of actual population size.

Data on behavioral responses to humans prior to and after the late hunt on the CM winter range were collected during the 1983-84 through 1985-86 winters. Distance to humans or vehicles, activity of humans, age/sex makeup of sheep bands, and response of sheep to humans (1 = no detectable response; 2 = sheep alert but no movement to avoid disturbance; 3 = slow and/or short distance, less than 25 m, movement to avoid disturbance; 4 = rapid, long distance movement towards escape cover to avoid disturbance) were recorded for incidents in which sheep were within 400 meters of humans or vehicles during winter range surveys. Numbers of legal rams counted during surveys prior to, during, and after late season hunts were used as an index of ram abundance on winter range. Chi-square tests were used to test pre and post hunting season responses (Steel and Torrie 1960).

RESULTS

Radio relocations for six of seven rams captured on the CM winter range (Figure 1) indicated a general pattern of northward spring expansion from winter range followed by a southerly movement to summer range deep within YNP in May or June. Movement out of YNP varied, with individuals leaving the Park between August and November. The seventh ram, collared as a 2 1/2-yr-old, moved northwest to summer in the TM area. Summer and early autumn relocations of this ram were in YNP, but limited late autumn observations suggest he returned to the CM winter range through lands outside YNP.

Relocations for five rams collared on winter ranges in the TM area (Figure 1) indicated winter - spring range was almost exclusively on lands north of YNP. Summer - fall ranges for four rams followed through these seasons straddled the YNP boundary.

Rams captured on the CM winter range were located outside YNP on 8 of 30 (27 percent) relocations during the general sheep season (Table 2). Most (5 of 8) hunting season locations outside YNP were on a single ranch or on U.S. Forest Service land with access controlled by the ranch. The outfitter controlling hunting on this ranch specialized in elk hunts and seldom guided sheep hunters.

Four of 22 (18 percent) hunting season relocations of males captured on TM winter ranges were outside YNP and an additional 77 percent were within 2 kilometers of the Park boundary (Table 2). TM rams outside the Park were located in areas customarily hunted by the public or on lands with access controlled by outfitters that regularly guided sheep hunters.

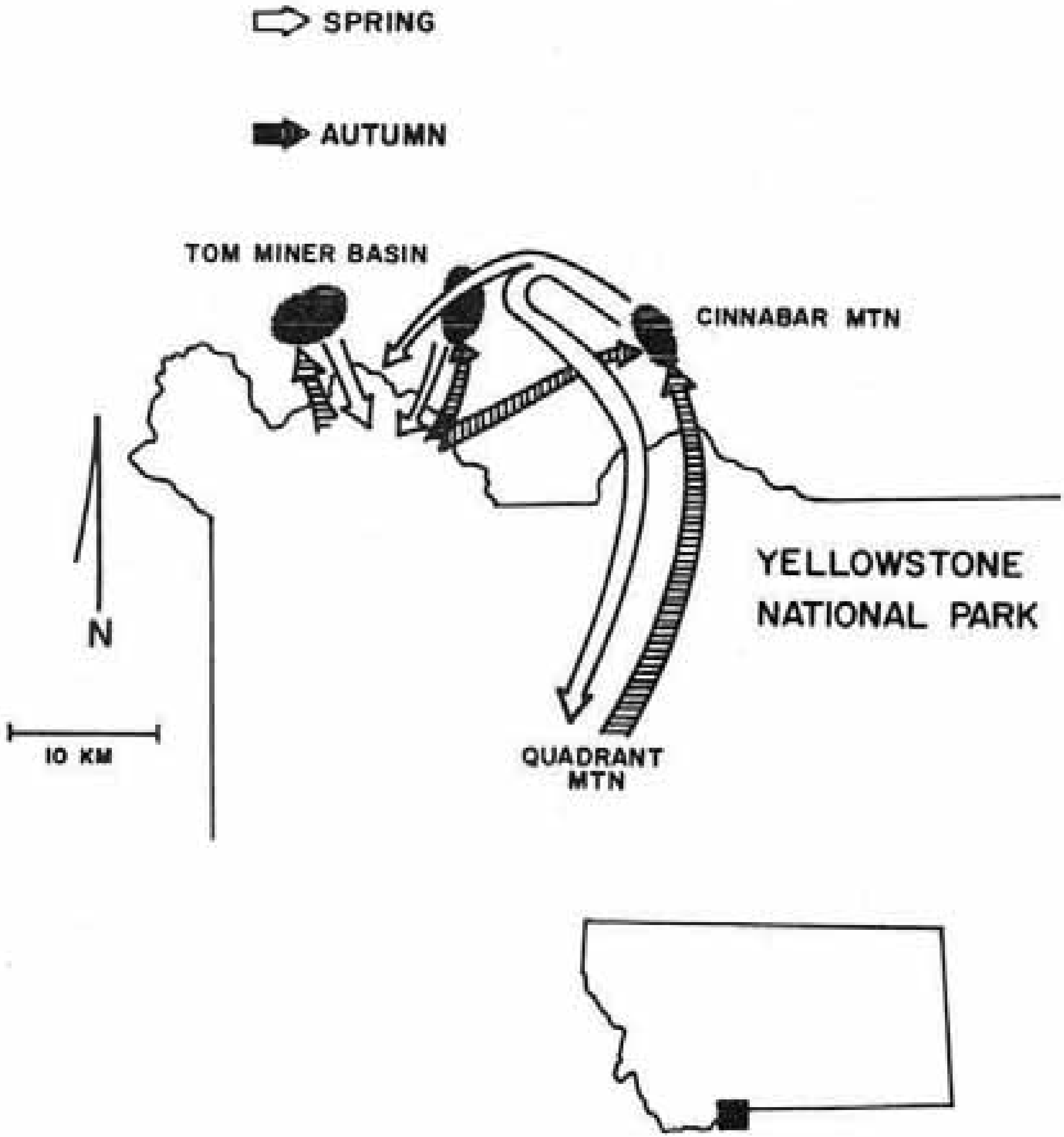

Fig. 1. Map of the study area showing generalized spring and autumn movement patterns for rams in the Cinnabar Mountain and Tom Miner sheep populations. Shaded areas indicate winter ranges.

Table 2. Relocations of radiocollared bighorn rams relative to the Yellowstone National Park (YNP) boundary during the general bighorn hunting season (September - early November) in HD300, 1980-85. The number of rams contributing to relocations are given in parentheses.

Population segment	Outside YNP	<2km in YNP	2-5 km in YNP	>5 km in YNP
CM - Quadrant summer range (n=5)	7	4	2	12
CM - TM summer range (n=1)	1	3	1	
TM (n=4)	4	17	1	

Table 3. Number of general season hunters, general season quotas, late season permits, and annual legal (3/4-curl rams) and known illegal (<3/4-curl or 3/4-curl shot after season closure) harvest in the HD300 area, 1974-85.

Year	General Season		Late season permits	Harvest	
	Hunters	Quota		Legal	Illegal
1977	62	6		6	
1978	102	5		4	
1979	116	5		2	
1980	72	6	5	6	
1981	134	5	3	9[a]	
1982	117	5		4	1
1983	105	5	3	7	6
1984	76	3	2	5	1
1985	110	3	2	5	

[a] One ram was legally killed during the 48-hour grace period after the quota was reached.

From 1977 to 1985 an average of 99 hunters per year participated in the general sheep hunt in HD300 (Table 3). Hunter success rate averaged 4 percent. Quotas were exceeded four times in the past nine years, and the total legal kill during the general season was 86 percent of the total quota. Sublegal rams were known to be killed in three years. Since 1977, 66 percent (23 of 35) of the general season legal harvest was in the TM area, 23 percent in the CM area, and 11 percent from small herds in other portions of HD300 (Table 4).

Mean age of harvested rams in the TM area increased from 4.5 years (standard deviation = 1.5, sample size = 7, range = 3.5-7.5) in 1976-78 to 6.2 years (standard deviation = 1.6, sample size = 20, range = 3.5-10.5) in 1979-85. Mean age of rams harvested in the CM area (1977-85) during the general season was 4.9 years (standard deviation = 1.2, sample size = 8, range = 3.5-5.5). The lower age of rams harvested from the CM area during the general season is presumably due to earlier return to winter range, the only area where rams are accessible to hunters during the general season, by younger rams than by older rams.

The late permit hunt on the CM winter range was initiated in 1980. Fifteen permits were issued between 1980 and 1985 (Table 3) and 13 legal sheep were harvested. Two permit holders elected not to participate in the hunt. Ages of rams harvested ranged from 5.5-9.5 years with a mean of 6.7 years (standard deviation = 1.3, sample size = 13). Older rams (8.5-10.5 years) were available in most years, but hunters selected younger rams with larger horns.

General season quotas in HD 300 have never exceeded the minimum number of legal rams seen on TM winter ranges the previous winter (Table 5). Legal rams as a percentage of the minimum population estimate showed no significant trends during the 1978 to 1986 period for which data were available (CM: correlation coefficient = +0.40, slope = +12.8; TM: correlation coefficient = +0.33, slope = +10.8; $p>0.10$). Absolute numbers of rams increased and then decreased during this period in the CM unit and evidently decreased in the TM unit. Numbers of legal rams in both areas were positively correlated with minimum population estimates (correlation coefficients: CM = 0.76; TM = 0.67; $p<0.10$).

The proximity of the CM winter range to a maintained county road and its visibility from a major highway attract large numbers of photographers and wildlife viewers throughout late autumn and winter. Sheep seldom reacted overtly to humans or vehicles at distances of 100 meters or more. Responses of sheep to human and vehicle approaches to within 50 meters on the winter range during the 1983-84 through 1985-86 winters (Figure 2) indicated decreased response levels to vehicles following the

Table 5. Post-hunting minimum estimates of 3/4-curl rams, minimum population size, and legal males as a percentage of the minimum population estimate in the CM and TM population segments of HD300, 1978-86.

Winter	CM			TM		
	Legal rams	Total sheep	Legal rams as percent of total	Legal rams	Total sheep	Legal rams as percent of total
1978-79	9	66	14	14	115	12
1979-80	11	103	11	16	112	14
1980-81	10	84	12	10	87	11
1981-82	17	91	19	8	68	12
1982-83	22	127	17	8	114	7
1983-84	14	101	14	3[a]	52	
1984-85	13	71	18	8	50	16
1985-86	12	83	14	8	54	15

[a] Twenty-three of 39 males sighted could not be reliably classified as legal (3/4-curl) or sublegal (<3/4-curl).

Table 4. Distribution of bighorn ram harvest among population segments in HD300, 1974-85.

Year	CM		TM	Other[a]
	General	Late		
1977	3		3	
1978			4	
1979			2	
1980		4	1	1
1981	1	3	4	1
1982	2[b]			
1983	2	2	8[c]	1
1984	1[b]	2	2	1
1985	1	2	2	

[a] Rams harvested in one of three minor population segments.

[b] Includes one illegal kill.

[c] Includes six illegal kills.

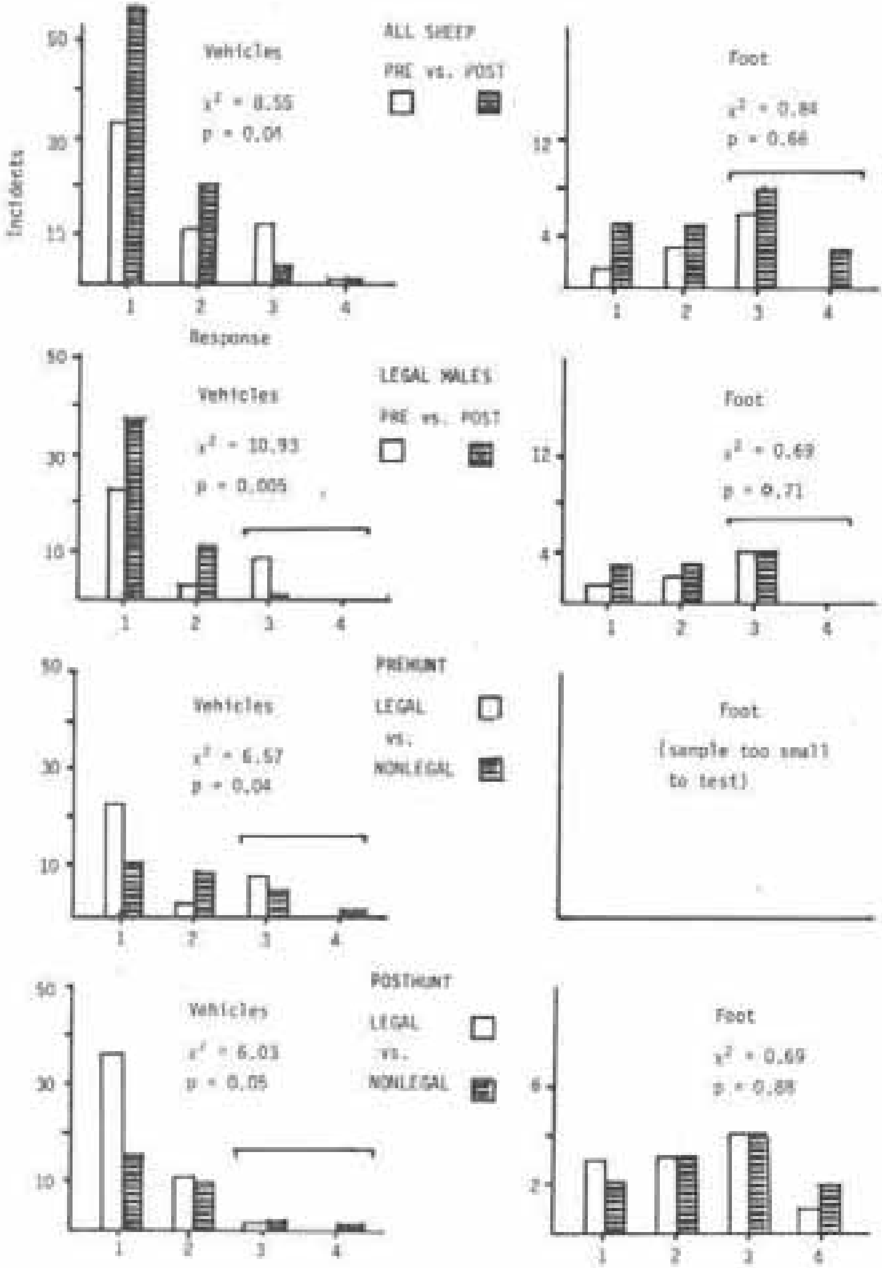

Fig. 2. Histograms contrasting distribution of sheep reactions to humans and vehicles approaching to within 50 m among four response categories (1 = no detectable response, 2 = sheep alert but no movement to avoid disturbance, 3 = slow and/or short distance movement, <25 m, to avoid disturbance, 4 = rapid, long distance movement towards escape cover to avoid disturbance). The disturbance type (human or vehicle), the sheep category (groups with legal rams, groups without legal rams, all sheep), and the timing of the disturbance (pre or post-hunt) are given for each histogram. Chi-square and p values for tests are also shown. Brackets over histograms indicate categories that were merged in tests.

late hunt and no significant difference in response to humans on foot. Groups with legal rams either did not react differently from groups without legal rams or exhibited lower response levels for categories with sufficient sample sizes for testing (Figure 2).

Counts of legal rams during winter range surveys were similar throughout the November - January period during a year without a hunt and in pre and post hunt periods during years with hunts (Table 6). During 1985-86, numbers of rams sighted during the hunt were higher than numbers before and after the hunt.

DISCUSSION

The available evidence indicates that the management system in HD300 has met its objectives. Approximately 100 hunters per year are afforded an opportunity to hunt in a sheep population complex with fewer than 400 accessible sheep. The mean age of harvested rams in general and late hunts, 6 years, indicates hunters have the opportunity to take mature rams. Low hunter success in the general season is acceptable to most hunters because HD300 is one of the few areas in the contiguous United States where sheep hunting opportunity is not determined by an over-subscribed lottery.

The accessibility of the CM winter range allows hundreds of wildlife viewers and photographers to observe bighorn behavior at distances of 5-100m. Animals visible from the road include an average of 6 3/4-curl rams on any day during the height of the rut.

The late season hunt has not displaced a detectable segment of the older ram population from the winter range, nor has it led to marked decreases in tolerance of sheep to human approaches. Older rams have frequently been observed displaying, fighting, and tending ewes immediately adjacent to the road.

The success of this management system is partially due to unique characteristics of HD300. Unlimited hunting opportunity is feasible because rams have a secure refuge in YNP. Refuge availability combined with minimum horn size requirements for harvest allow a reasonable number of rams to reach the 6 - 10 year age classes where trophy quality is highest. Accessibility to nonconsumptive users is facilitated by the CM population's choice of a winter range bisected by a county road and visible from the main highway that leads to the north entrance to YNP. Colonists established themselves on the range, apparently attracted by low snow cover, convenient escape terrain, and relatively abundant winter forage, in the early 1960's (Keating 1982) and have been exposed to local vehicle traffic and casual observation by humans since establishment.

Table 6. Mean numbers of legal (3/4-curl) rams seen during winter surveys of the CM winter range, 1982-86. Only surveys between 1 November and 31 January are included. No permits were issued in 1982-83, and surveys were divided into pre (1-24 November), during (25 November - 6 December) and post (6 December - 31 January) hunting periods. Hunting periods were too short to include a "during hunt" category except in 1985-86.

Winter	Prehunt		Hunting		Posthunt	
	Counts	Rams (SD)	Counts	Rams (SD)	Counts	Rams (SD)
82-83	4	6 (4)	5	5 (3)	6	7 (6)
83-84	8	6 (4)	a		6	6 (3)
84-85	3	5 (3)	b		7	7 (1)
85-86	5	6 (2)	2	8 (1)	4	5 (2)

[a] All animals were harvested on 4 December.

[b] Animals were harvested on 28 November and 2 December.

The minimal response of sheep to a hunt on winter range was not surprising given the situation in the CM winter range. Sheep moving onto this winter range were exposed to deer (*Odocoileus hemionus*) and elk (*Cervus elaphus nelsoni*) hunters in November and local traffic and photographers throughout late autumn and winter. Many sheep have been habituated to winter rifle fire during December - February late elk hunts adjacent to and on the winter range. The sheep permit holders add a minute amount to the level of human activity and create a disturbance lasting only a few hours on one to three days. The ease of monitoring sheep population structure on the CM winter range serves as insurance against overharvest since decreases in rams can be detected and the season modified quickly.

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QUESTIONS AND ANSWERS

Lynn Irby: The question was why weren't they affected by the Chlamydia outbreak in Yellowstone National Park. I don't know what the extent of the ram contact between the populations is but I know there is some. That year, the Cinnabar rams evidently did not come in contact with sheep that had Chlamydia. The two winter ranges are 13 kilometers apart. We were waiting for the other shoe to drop all that winter and nothing ever happened.

Daryll Hebert, BC: Do you have any food habit data on that particular population?

Irby: Yes, in winter 80-81, they ate about 25 percent agropyrons, but we weren't able to distinguish crested wheatgrass from bluebunch, which is a dominant native agropyron there, and about 25 percent sage.

Hebert: Are they taking the crested wheatgrass year round or just in the winter?

Irby: Some stay on the crested wheat grass from October through April unless elk come in and mow it down. I'm not an advocate of crested wheat grass but its really amazing how they go for that stuff. They're still down there now eating this year's greenup and they probably won't leave for 2 to 3 weeks.

Jim Ford, Montana: What do you expect will happen since the reintroduction of domestic sheep into the area?

Irby: That's another shoe waiting to drop. Domestic sheep have been there for four years. There hasn't been any virulent die off, but on the other hand, the population started declining the years after they put the domestic sheep in. Whether there's a relationship or not, I can't say.

Ford: You haven't see any effect so far?

Irby: We haven't seen any dead bighorns that could be definitely attributed to interactions with domestic sheep. Right now, the domestic sheep are not on the core winter range, but the ranch that runs the domestic sheep has spent a lot of time and money replanting hay meadows down river from the core bighorn range and I'm just waiting for the bighorns to discover them. There also is overlapping use of spring range. The spring range that the bighorns are using is a mix of private and Forest Service land. If the ranch owners want to run sheep on their place then I don't know what we can do about it. The Forest Service is going to quite a lot of trouble to make sure there's no contact between domestic sheep and bighorns on their lands, but the bighorns move between public and private lands according to their own schedule. If you brought up Cinnabar as a transplant site, I'm sure it would have been eliminated in the first round, but the sheep pitched up there and seem to be hanging on.

General Session

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DALL SHEEP HUNTING IN ALASKA: WHAT IS IT WORTH?

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Abstract: Economic values for Dall sheep (*Ovis dalli dalli*) hunting in Alaska are needed for comparison with economic values of competing development alternatives for sheep habitat. Such alternatives include grazing, settlement, agriculture, and mining. A mail survey was used to question all who hunted Dall sheep in Alaska in 1983. Eighty-eight percent responded. Expenditures by respondents exceeded $5.9 million with 85% of the expenditures occurring in Alaska. Nonresident hunters contributed 50% of this total even though they accounted for only 17% of the hunters. The total value of Dall sheep hunting to hunters was over $9.6 million as determined by hunters' expenditures (costs) and consumer surplus (net benefits). Use of the willingness-to-accept-compensation contingent valuation technique for varying degrees of lost hunting opportunities showed the total value to hunters of future Dall sheep hunting opportunities was between $3.2 billion and $28.4 billion.

This study was conducted in response to concern that no economic values were yet established for Dall sheep (*Ovis dalli dalli*) for comparison with economic values of proposed alternative uses of sheep habitat. Examples of proposed alternatives include grazing of domestic animals, mining, and homesites, all of which may not be compatible with wild sheep.

The purpose of this study was to determine economic values for Dall sheep habitat based on the expenditures associated with hunting and on the value sheep hunters place on their hunting experience. These values represent minimum values for Dall sheep habitat as they do not include other values for sheep such as viewing, just knowing they are "out there," and the value of providing wildlife resources for future generations. Values for these nonconsumptive uses are more difficult to define and were not addressed in this study.

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BACKGROUND

Dall Sheep Hunting in Alaska

Approximately 2,600 people hunt Dall sheep each year in Alaska and harvest approximately 1,100 sheep in the 40-day season (10 August-20 September). Approximately 80% of the hunters are residents and 20% are nonresidents (Alaska Department of Fish and Game, unpubl. data).

Sheep hunters in Alaska can choose from a variety of hunting opportunities in eight major mountain ranges, each having its own unique characteristics of terrain, weather, and accessibility (Fig. 1). When deciding where to hunt, hunters may consider the sheep populations within these mountain ranges. Some have particular characteristics of horn growth (Heimer and Smith 1977) and population density which may affect hunter success. Hunters interested in trophy animals may choose to hunt in different areas than those hunters who are content with sheep whose horns just meet legal minimum size.

However, sheep hunters do not have unlimited opportunities in Alaska. Hunting is restricted in national parks and monuments where about 27% of the approximate 70,000 sheep in the state reside (Heimer 1985). State regulations include restrictions to one ram per hunter, minimum horn length of rams, and area-specific restrictions on transportation. All hunters are required to purchase a hunting license and obtain a harvest report form. Nonresidents must purchase a Dall sheep tag and must also hire a guide unless hunting with a resident within the second degree of kindred.

Despite restrictions, those who hunt sheep in Alaska enjoy a greater potential of hunting opportunities than in any other state in the U.S. (Thorne et al. 1985, Weaver 1985). The Alaska Department of Fish and Game would like to ensure that these opportunities continue.

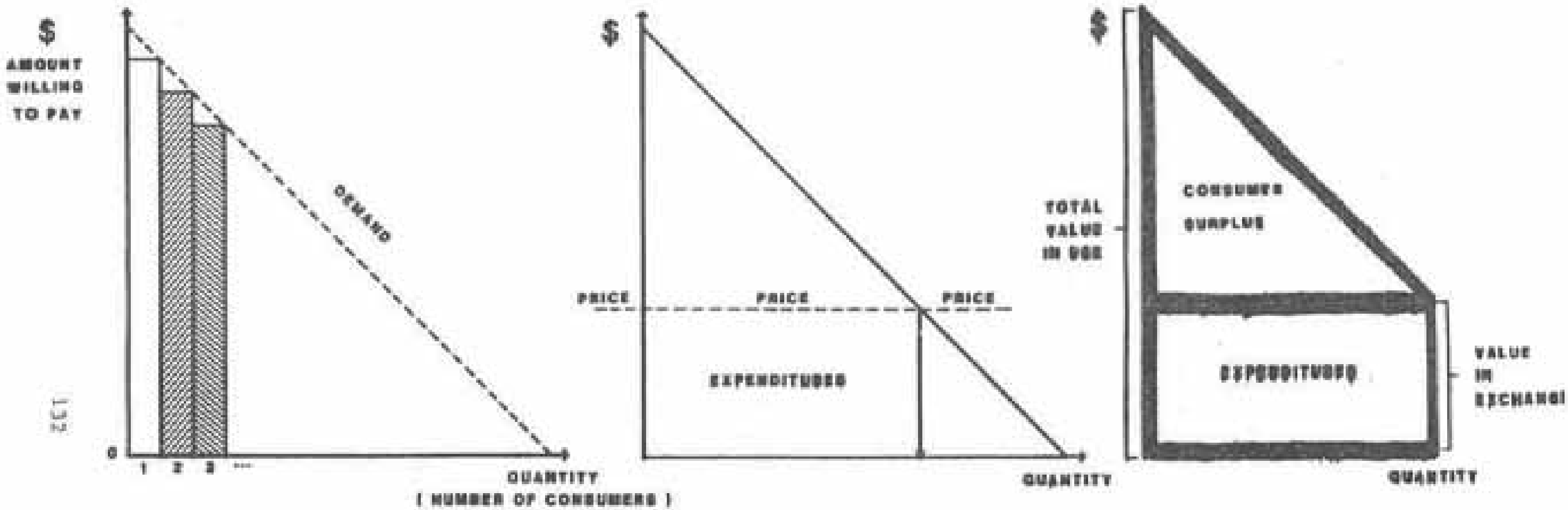
Alaska is undergoing rapid changes since major land ownership decisions were made by legislation such as the Alaska Native Claims Settlement Act (1972) and the Alaska National Interest Lands Conservation Act (1980). Alaska is subjected to a degree of land use planning probably never exceeded in history (Gallagher 1985). Many land use decisions are and will be made weighing the economic importance of alternative uses. Economic valuation is a procedure which is increasingly being used by natural resource managers for determining maximum benefit. Economic valuation recognizes that tradeoffs must be made and provides an objective and consistent basis for comparing different uses of the same land. The economic value of areas used for wildlife habitat must be determined if wildlife habitat is to be considered among the alternative uses of land.

Natural Resource Economic Valuation

Value-in-use:

Economic value to the consumer may be defined in two general ways. Value-in-use is the total satisfaction the consumer receives from one

Figure 1. The eight major Dall sheep ranges in Alaska.



2A. 2B. 2C.

Figure 2. The amount different consumers are willing to pay for a good or service form a demand curve (Fig 2A). The price actually charged for a good or service multiplied by the quantity of consumers willing to pay at least that price equals expenditures. Those consumers not willing to pay the price will not buy the good or service (Fig. 2B). Expenditures are the total value exchanged for the good or service. The amount above the price consumers were willing to pay is termed consumer surplus. Consumer surplus added to the expenditures is one way of expressing the total value in use of a good or service (Fig.3C).

unit of a good or service. In this study, the unit is the sheep hunt or the opportunity to go sheep hunting. Value-in-use is measured by the maximum amount the consumer would be willing to pay to gain this satisfaction. The amount of satisfaction gained from a good or service varies from person to person. Generally, only a few are willing to pay a great deal and an increasing number of individuals are willing to pay as price levels decline. When graphed, this is called the "demand curve" for one unit of the good or service (Fig. 2A). The area enclosed by the plot is the total willingness to pay or the total value-in-use for the consumers.

Another way to define value-in-use is to determine the minimum amount the consumer (a hunter) would have to be compensated for the loss of one unit of the good (one less sheep hunting opportunity). This is often determined by asking the consumer what minimum price value they would place on the good. Both methods have their advantages and disadvantages and serve for much discussion among economists (Larson and Workman 1983).

Value-in-exchange:

Value-in-exchange is the price consumers actually have to pay for the good or service. For most goods, the price is usually set on the open market via the interaction of supply and demand. The price applies to all consumers and is not tailored to fit each individual's willingness to pay. The area under the price designation on the demand curve equals the total expenditures, or the total value-in-exchange, for the good. The amount of satisfaction some consumers gain above the price is termed "consumers' surplus" (Fig. 2B and 2C). (If the price is greater than the value-in-use, that is, if the good costs more than its worth to the consumer, the consumer is not likely to buy.)

Comparison of the consumer surpluses or the net benefits is the basis for many economic decisions. It answers a manager's problem: "Where will the money do the most good?"

Defining these values for wildlife is difficult because wildlife is usually considered a "public good" as it is available to all and is not diminished by use. The nonconsumptive use of wildlife resources on public lands has virtually no price or nearly zero value-in-exchange to consumers. Even the price hunters must pay for the opportunity to hunt, the cost of a hunting license, does not truly express value as determined by the interaction of supply and demand. It is difficult for consumers to express their value-in-use for something they do not normally pay for. Because of this situation, the total value-in-use for wildlife is often called "priceless" and left undefined. "Priceless" cannot be used in economic analyses and, with such a designation, wildlife may not be considered among the economically important alternatives. If only expenditures are used, the value for wildlife may be set artificially low and, when compared with other land uses, protecting wildlife habitat can look like a poor investment. In this study, therefore, I used three measures of economic value.

METHODS

Economic values of Dall sheep hunting were measured using a questionnaire prepared by ADF&G biologists with help from economic and social research experts from the University of Alaska. The questionnaire was mailed to all hunters who legally hunted Dall sheep in Alaska during the 40-day season of 1983. We did not survey about 75 hunters who hunted in the 9-month-long subsistence season. The design of the questionnaire and the mailing strategies are described in Watson (1984).

The questionnaire asked 2,517 hunters about their hunt expenditures (value-in-exchange) including costs of transportation, equipment, and time off from work without pay (foregone income). Because many nonresident hunters come to Alaska for reasons other than for hunting Dall sheep, they were asked what fraction of the total expenditures could be attributed to their sheep hunt.

To estimate hunters' consumer surplus, the questionnaire asked how much more they would have been willing to pay before deciding not to go sheep hunting. Their answers, when added to their expenditures, would estimate total value-in-use. Value-in-use was also estimated using the alternative question of how much would they charge for the sale of their opportunity to go sheep hunting. This was presented as a series of questions which were time and area specific.

The questionnaires were coded and entered into a computer system for analysis using SPSS-PC (Norusis 1984) software.

RESULTS

Questionnaire Response

Ninety-two (4%) of the 2,517 questionnaires mailed to hunters were returned as undeliverable. Of the remaining 2,425 questionnaires, 2,127 (88%) were returned by the hunters (Table 1). Two percent of the returned questionnaires were not usable in the analysis. Most of those were from residents. The results represent only the sample (although a large one) of sheep hunters who provided usable information and do not necessarily represent the values of all sheep hunters.

Expenditures

Hunters spent at least $5.2 million on sheep hunts in 1983. They purchased hunting licenses, camping equipment, guns and ammunition, transportation, food, lodging, and other items. Some hunters also took time off from work without pay to go sheep hunting. This cost hunters $1.4 million in foregone income. In addition to the expenditures listed above, nonresident hunters spent over $682,000 hunting other game species, visiting relatives, or vacationing. This brought total expenditures associated with sheep hunting to almost $5.9 million. Almost $5 million (85% of the total expenditures) was spent within Alaska.

Nonresident hunters accounted for about half of the expenditures even though they accounted for only 17% of the hunters. Nonresidents had higher transportation costs and, by law, had to hire a guide unless hunting with a resident relative within the second degree of kindred.

Resident hunters spent an average of $1,519 on each sheep hunt (Table 2). Ninety-six percent of this was spent in the state. Nonresident

Table 1.

NUMBER AND PERCENT OF ALASKA'S 1983 DALL SHEEP HUNTERS, BY RESIDENCY, WHO RECEIVED AND RETURNED QUESTIONNAIRES AFTER FIRST MAILING, REMINDER POSTCARDS, AND SECOND MAILING.

	RESIDENTS	NONRESIDENTS	TOTAL
TOTAL QUESTIONNAIRES DELIVERED 20-27 FEB 1984	2035	390	2425
RETURNED BY 12 MAR 1984 (REMINDER POSTCARDS SENT)	1052 (52%)	182 (47%)	1229 (51%)
RETURNED BY 30 MAR 1984 (SECOND MAILING)	1415 (70%)	239 (61%)	1654 (68%)
RETURNED BY 25 APR 1984	1756 (86%)	307 (79%)	2063 (85%)
RETURNED BY 15 JAN 1985	1806 (89%)	351 (90%)	2127 (88%)
NUMBER USABLE IN ANALYSIS	1728 (85%)	351 (90%)	2079 (86%)

Table 2. Mean expenditures by commodity for the surveyed resident and nonresident Dall sheep hunters of Alaska in 1983.

Commodity	Residents (n = 1728)	Nonresidents[a] (n = 351)
Camera and film	$ 93	$ 237
Camp gear	184	230
Entertainment and restaurants	27	137
Forgone income	535	1,427
Guide fee	30	4,477
Guide tip	1	196
Guns and ammunition	183	518
License and tag fees	18	570
Lodging	14	106
Miscellaneous	126	119
Taxidermy	103	449
Tourism and gifts	5	243
Travel in Alaska	258	224
Travel to Alaska	--	973
Average total	$1,567	$9,850

[a] Nonresident expenditures not adjusted to reflect only sheep hunting costs.

hunters spent an average of $9,850 in total expenditures with $7,780 (79%) spent specifically on their sheep hunt. Seventy-eight percent of their total expenditures went directly into Alaska's economy.

Hunter expenditures were also analyzed by hunt area using the eight major mountain ranges as area designations (Table 3). More money was spent for sheep hunts in the Wrangell Mountains than in any other area due to its popularity with resident hunters and the number of guides operating in the area. Resident hunters spent more on hunting in the Brooks Range than in any other location due to high transportation costs. Nonresident hunters paid the highest average costs (excluding the Unspecified Area designation) for permit hunts in the Tanana-Yukon Uplands, although the sample size for nonresidents in this area was very low and resident hunters incurred little more than average costs there. The Brooks Range had the second highest costs to nonresidents. Both residents and nonresidents spent the least amount of money on sheep hunting in the Kenai Mountains.

Consumer Surplus

As a group, hunters would have been willing to spend at least another $4.4 million before deciding not to go sheep hunting in 1983. Residents would have spent another $1.3 million ($\bar{x}$ = $821) while nonresidents would have spent $3.1 million ($\bar{x}$ = $9,897) (Table 4).

Value-in-use

The value-in-use of sheep hunting, when defined as the value-in-exchange (costs) plus consumer surplus (net benefits), for survey respondents was over $9.6 million. When value-in-use was defined by the amount hunters would have to be compensated for the sale of their opportunity to go sheep hunting in their 1983 hunting area the following year, the statewide total value-in-use was over $3 billion (Table 5, Fig. 3). When their foregone opportunity for sheep hunting the following year was not limited to their hunt area but was expanded to hunting anywhere in Alaska the following year, they asked for over $4.5 billion in compensation (Table 6). If these respondents had to give up hunting in their 1983 hunting area forever (as might be the case if an alternative land use were to preclude sheep and/or sheep hunting), the total amount of compensation required would be at least $16.6 billion (Table 7). And when this situation was expanded to preclude hunting anywhere in Alaska, the lowest price charged would be over $28 billion (Table 8).

Many of the hunters indicated they had difficulty answering some or all of these specific questions. They indicated this either by not answering the questions or writing "priceless" instead of a price. The number of such hunters increased from 18% to 57% through the question series. Residents and nonresidents had similar percentages of "priceless" answers or no response until asked how much they would charge for the sale of all of their future opportunities to hunt Dall sheep in Alaska. Sixty-two percent of the residents gave such answers while 33% of the nonresidents said priceless or gave no answer.

Indications of value were also inferred from comments written on the back and in the margins of the questionnaires. These included "sheep

Table 3. Total and average expenditures of the sample of Alaska's 1983 Dall sheep hunters (by residency and hunt area).

Location		Residents	(n)	Nonresidents	(n)	Total	(n)
AK Range, east of DNP[a]	$	585,056	(394)	$ 383,911	(49)	$ 968,967	(443)
	$\bar{x}$=	1,485		7,835		2,185	
AK Range, west of DNP[a]		162,098	(101)	381,625	(49)	543,723	(150)
	$\bar{x}$=	1,605		7,788		3,625	
Brooks Range		437,577	(191)	652,606	(76)	1,090,183	(267)
	$\bar{x}$=	2,291		8,587		4,083	
Chugach Mtn Range		358,498	(259)	260,228	(39)	618,727	(298)
	$\bar{x}$=	1,384		6,673		2,076	
Kenai Mtn Range		90,078	(125)	38,767	(8)	129,845	(133)
	$\bar{x}$=	721		4,971		976	
Talkeetna, Chulitna, Watana Mts		214,020	(175)	173,250	(25)	387,270	(200)
	$\bar{x}$=	1,223		6,930		1,936	
Tanana-Yukon Uplands		59,747	(38)	19,720	(2)	79,467	(40)
	$\bar{x}$=	1,572		9,860		2,684	
Wrangell Mts		704,442	(417)	632,042	(81)	1,336,484	(498)
	$\bar{x}$=	1,689		7,803		2,684	
Unspecified Area		12,537	(7)	39,790	(3)	52,327	(10)
	$\bar{x}$=	1,791		13,263		5,233	
Total	$	2,624,053	(1,707)	$ 2,582,940	(332)	$ 5,206,993	(2,039)
	$\bar{x}$=	1,537		7,780		2,554	

[a] DNP = Denali National Park

Table 4. Total and average increased costs by area and residency) given by the sample of Alaska's Dall sheep hunters in response to the question: "How much greater would your total 1983 costs have to have been before you would have decided not to go sheep hunting?"

Location		Residents	(n)	Nonresidents	(n)	Total	(n)
AK Range, east of DNP[a]	$	354,075	(372)	$ 65,513	(50)	$ 419,588	(422)
	$\bar{x}$=	952		1,310		994	
AK Range, west of DNP[a]		69,455	(91)	55,300	(47)	125,755	(138)
	$\bar{x}$=	763		1,177		904	
Brooks Range		181,275	(176)	2,747,325	(75)	2,928,600	(251)
	$\bar{x}$=	1,030		36,631		11,668	
Chugach Mtn Range		169,392	(248)	42,300	(34)	211,692	(282)
	$\bar{x}$=	683		1,244		751	
Kenai Mtn Range		67,013	(116)	22,500	(6)	89,513	(122)
	$\bar{x}$=	578		3,750		734	
Talkeetna, Chulitna, Watana Mts		95,060	(163)	30,625	(24)	125,685	(187)
	$\bar{x}$=	583		1,276		672	
Tanana-Yukon Uplands		32,487	(38)	1,250	(2)	33,737	(40)
	$\bar{x}$=	855		625		843	
Wrangell Mts		337,530	(392)	128,888	(70)	466,418	(462)
	$\bar{x}$=	861		1,841		1,010	
Unspecified Area		9,175	(6)	4,025	(5)	13,200	(11)
	$\bar{x}$=	1,529		805		1,200	
Total	$	1,315,462	(1,602)	$ 3,097,726	(313)	$ 4,413,188	(1,915)
	$\bar{x}$=	821		9,897		2,305	

[a] DNP = Denali National Park

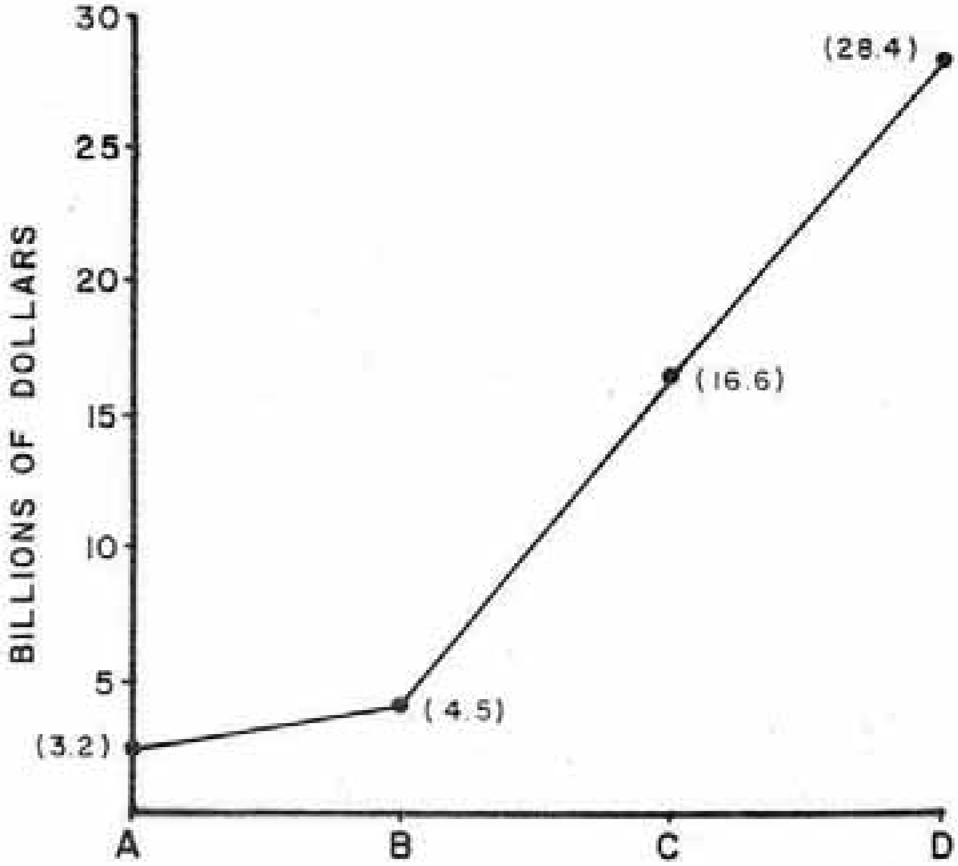


Figure 3. Total dollar amounts the sample of Alaska's 1983 Dall sheep hunters gave in response to the following questions:

What is the lowest price you'd charge for the sale of:

A....your opportunity to hunt Dall sheep in 1984 <u>in your 1983 hunting area</u>?

B....your opportunity in 1984 to hunt Dall sheep in <u>any</u> mountain range in Alaska?

C....<u>all</u> of your future opportunities to hunt Dall sheep in <u>your 1983 hunting area</u>?

D....<u>all</u> of your future opportunities to hunt Dall sheep <u>in Alaska</u>?

Table 5. Total and average price (by hunt area and residency) given by the sample of Alaska's 1983 Dall sheep hunters in response to the question: "What is the lowest price you would charge for the sale of your opportunity to hunt Dall sheep in 1984 in your 1983 hunting area?"

Location		Residents	(n)	Nonresidents	(n)	Total	(n)
AK Range, east of DNP[a]	$	2,007,647,043	(338)	$ 552,688	(43)	$ 2,008,199,731	(381)
	$\bar{x}$=	5,939,784		12,853		5,270,865	
AK Range, west of DNP[a]		101,326,368	(90)	1,140,050	(43)	102,466,418	(133)
	$\bar{x}$=	1,125,849		26,513		770,424	
Brooks Range		1,001,777,037	(164)	4,840,975	(67)	1,006,618,012	(231)
	$\bar{x}$=	610,836		72,253		4,357,654	
Chugach Mtn Range		9,517,009	(220)	110,200	(34)	9,627,209	(254)
	$\bar{x}$=	43,259		3,241		37,902	
Kenai Mtn Range		1,434,950	(108)	15,750	(6)	1,450,700	(114)
	$\bar{x}$=	13,287		2,625		12,725	
Talkeetna, Chulitna, Watana Mts		11,024,114	(151	101,350	(23)	11,125,464	(174)
	$\bar{x}$=	73,007		4,223		63,939	
Tanana-Yukon Uplands		109,700	(33)		(0)	109,700	(33)
	$\bar{x}$=	3,324				3,324	
Wrangell Mts		107,109,793	(243)	234,738	(67)	107,344,531	(310)
	$\bar{x}$=	404,781		3,504		346,273	
Unspecified Area		59,000	(5)	6,675	(3)	65,675	(8)
	$\bar{x}$=	11,800		2,225		8,209	
Total	$	3,240,005,014	(1,352)	$ 7,002,426	(286)	$ 3,247,007,440	(1,648)
	$\bar{x}$=	2,396,453		24,484		1,970,272	

[a] DNP = Denali National Park

Table 6. Total and average price (by hunt area and residency) given by the sample of Alaska's 1983 Dall sheep hunters in response to the question: "What is the lowest price you'd charge for the sale of your opportunity in 1984 to hunt Dall sheep in any mountain range in Alaska?" Area listed below based on respondents' 1983 hunt area.

Location	Residents	(n)	Nonresidents	(n)	Total	(n)
AK Range, east of DNP[a]	$ 2,015,501,635	(319)	$ 165,126	(43)	$ 2,015,666,761	(362)
	6,318,187		3,840		5,568,140	
AK Range, west of DNP[a]	100,353,992	(82)	1,197,450	(43)	101,551,442	(125)
	1,223,829		27,848		812,412	
Brooks Range	100,297,825	(154)	4,799,710	(65)	105,097,535	(219)
	651,285		73,842		479,897	
Chugach Mtn Range	18,574,060	(206)	101,385	(32)	18,675,445	(238)
	90,165		3,168		78,468	
Kenai Mtn Range	104,255,530	(113)	20,200	(6)	104,275,730	(119)
	922,615		3,367		876,267	
Talkeetna, Chulitna, Watana Mts	1,110,197,067	(141)	149,101	(22)	1,110,346,168	163
	7,873,738		6,777		6,811,940	
Tanana-Yukon Uplands	1,130,800	(31)		(0)	1,130,800	(31)
	36,477				36,477	
Wrangell Mts	1,060,929,007	(322)	248,612	(62)	1,061,177,619	(384)
	3,294,811		4,010		2,763,483	
Unspecified Area	55,000	(4)	7,500	(3)	62,500	(7)
	13,750		2,500		8,929	
Total	$ 4,511,294,916	(1,372)	$ 6,689,084	(276)	$ 4,517,984,000	(1,648)
	3,288,116		24,236		2,741,495	

[a] DNP = Denali National Park

Table 7. Total and average price (by hunt area and residency) given by the sample of Alaska's 1983 Dall sheep hunters in response to the question: "What is the <u>lowest</u> price you'd charge for the sale of all of your <u>future</u> opportunities to hunt Dall sheep <u>in your 1983 hunting area?</u>"

Location		Residents	(n)	Nonresidents	(n)	Total	(n)
AK Range, east of DNP[a]		$ 5,151,694,667	(302)	$ 1,594,088	(38)	$ 5,153,288,755	(340)
	$\bar{x}$=	17,058,592		41,950		15,156,732	
AK Range, west of DNP[a]		9,257,808	(77)	2,332,125	(40)	11,589,933	(117)
	$\bar{x}$=	120,231		58,303		99,059	
Brooks Range		2,117,697,800	(131)	37,086,800	(61)	2,154,784,600	(192)
	$\bar{x}$=	16,165,632		607,980		11,222,836	
Chugach Mtn Range		3,048,932,675	(201)	163,750	(26)	3,049,096,425	(227)
	$\bar{x}$=	15,168,819		6,298		13,432,143	
Kenai Mtn Range		8,914,300	(92)	20,500	(5)	8,934,800	(97)
	$\bar{x}$=	96,895		4,100		92,111	
Talkeetna, Chulitna, Watana Mts		517,934,083	(122)	2,726,400	(23)	520,660,483	(145)
	$\bar{x}$=	4,245,361		118,539		3,590,762	
Tanana-Yukon Uplands		2,308,825	(29)		(0)	2,308,825	(29)
		79,614				79,614	
Wrangell Mts		5,687,198,008	(301)	2,900,088	(57)	5,690,098,096	(358)
	$\bar{x}$=	18,894,346		50,879		15,894,129	
Unspecified Area		1,044,000	(6)	14,000	(3)	1,058,000	(9)
	$\bar{x}$=	174,000		4,667		117,556	
Total		$16,544,982,166	(1,261)	$ 46,837,751	(253)	$ 16,591,819,917	(1,514)
	$\bar{x}$=	13,120,525		185,129		10,958,930	

[a] DNP = Denali National Park

Table 8. Total and average price (by hunt area and residency) given by the sample of Alaska's 1983 Dall sheep hunters in response to the question: "What is the lowest price you'd charge for the sale of all of your future opportunities to hunt Dall sheep in Alaska?"

Location	Residents	(n)	Nonresidents	(n)	Total	(n)
AK Range, east of DNP[a]	$ 9,374,220,255	(277)	$ 2,640,001	(38)	$ 9,376,860,256	(315)
	$\bar{x}$= 33,841,950		$\bar{x}$= 69,474		$\bar{x}$= 29,767,810	
AK Range, west of DNP[a]	20,945,833	(70)	2,477,326	(42)	23,423,159	(112)
	$\bar{x}$= 299,226		$\bar{x}$= 58,984		$\bar{x}$= 209,135	
Brooks Range	3,135,971,525	(120)	36,575,760	(56)	3,172,547,285	(176)
	$\bar{x}$= 26,133,096		$\bar{x}$= 653,139		$\bar{x}$= 18,025,837	
Chugach Mtn Range	3,115,831,092	(170)	214,500	(25)	3,116,045,592	(195)
	$\bar{x}$= 18,328,418		$\bar{x}$= 8,500		$\bar{x}$= 15,979,721	
Kenai Mtn Range	2,017,450,290	(84)	32,800	(5)	2,017,483,090	(89)
	$\bar{x}$= 24,017,265		$\bar{x}$= 6,560		$\bar{x}$= 22,668,349	
Talkeetna, Chulitna, Watana Mts	2,040,708,322	(109)	3,798,000	(21)	2,044,506,322	(130)
	$\bar{x}$= 18,722,095		$\bar{x}$= 18,000		$\bar{x}$= 15,726,972	
Tanana-Yukon Uplands	2,995,100	(25)		(0)	2,995,100	(25)
	$\bar{x}$= 119,804				$\bar{x}$= 119,804	
Wrangell Mts	8,655,308,542	(271)	1,068,501	(50)	8,656,377,043	(321)
	$\bar{x}$= 31,938,408		$\bar{x}$= 21,370		$\bar{x}$= 26,966,907	
Unspecified Area	2,035,000	(5)	$\bar{x}$= 37,000	(3)	2,072,000	(8)
	$\bar{x}$= 407,000		12,333		$\bar{x}$= 259,000	
Total	$28,365,465,959	(1,131)	$ 46,843,888	(240)	$ 28,412,309,847	(1,371)
	$\bar{x}$= 25,079,988		$\bar{x}$= 195,183		$\bar{x}$= 20,723,785	

[a] DNP = Denali National Park

hunting is a priceless experience," "hunting is a right and can't be sold," or "I don't like these questions and I refuse to answer them." Thirty-three percent of residents and 16% of nonresidents made such comments regardless of whether they answered the questions.

DISCUSSION

So, what is sheep hunting worth? All of the values obtained in this study represent some portion of the full value of sheep hunting, sheep, and sheep habitat to hunters. It is important for those making land use decisions to remember what is being measured and whether benefits are being included as well as costs.

The value-in-exchange or expenditures method measures only hunters' costs. The $5-6 million dollar figure is impressive, especially when one remembers it is a minimum amount and is spent annually by approximately 2,600 people who harvest only 1,100 sheep. The cost per sheep for hunters responding to this survey was over $6,400 including the expenses of unsuccessful hunters. An input-output model designed for Alaska's current economy would be able to translate these expenditures into jobs and income levels. Such a model does not yet exist, although there has been some progress (J. Wettleton, University of Alaska, pers. commun.).

One must be cautious when comparing expenditure values. They are useful as "wow" figures, and may indicate the effects of resource management decisions on local employment and income levels. But they measure only costs and not benefits of particular activities or land uses.

For example, Wyoming Game and Fish estimated hunters spent $2,500 per bighorn sheep (*Ovis canadensis canadensis*) harvested in 1982, with total expenditures by hunters in the state reaching nearly $500,000 (Thorne et al. 1985). If hunters in Alaska spent at least $6,400 per Dall ram harvested, then is Dall sheep hunting more important than bighorn sheep hunting? More jobs may be supported and more income may change hands in Alaska, but value measured in terms of costs does not measure the benefits gained. Loomis et al. (1984) give examples of how misuse of expenditure information can even be detrimental to wildlife.

If the expenditure figures seem impressive, the amount hunters were willing to pay in addition to their expenditure level is even more so. The reason nonresidents were willing to pay more could be due to at least two factors. Residents tended to have lower income levels than nonresidents and were less able to pay should the price increase. In addition, nonresidents were less likely to be able to return regularly to Alaska and may have thought of their hunt as perhaps a once (or twice)-in-a-lifetime experience.

The alternative technique (what is the lowest price...?) for determining value-in-use is not affected by income restraint. This can explain part of the difference between the two value-in-use amounts.

The different results may also be due to the latter technique's tendency to provoke emotional responses especially when used for valuing a public good or an activity which has high personal value. It is difficult

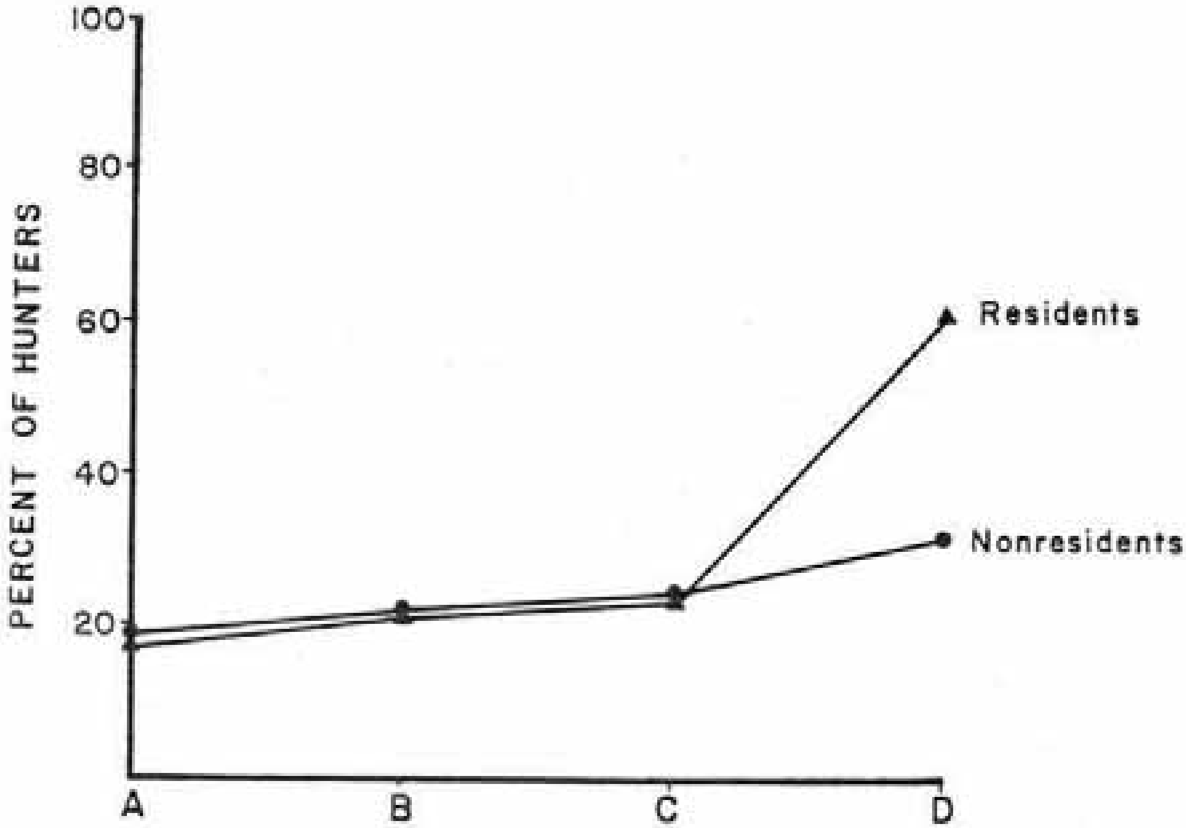


Figure 4. Percent of sample of Alaska's 1983 Dall sheep hunters who did not answer or answered "priceless" in response to the following questions:

What is the lowest price you'd charge for the sale of:

A....your opportunity to hunt Dall sheep in 1984 <u>in your 1983 hunting area</u>?

B....your opportunity in 1984 to hunt Dall sheep in <u>any</u> mountain range in Alaska?

C....<u>all</u> of your future opportunities to hunt Dall sheep <u>in your 1983 hunting area</u>?

D....<u>all</u> of your future opportunities to hunt Dall sheep <u>in Alaska</u>?

to say whether the high dollar responses were given honestly or inflated by emotion. Some degree of difficulty was reflected in the increasing number of "priceless" and nonresponses received (Fig. 4). These responses, though not usable in estimating an economic value, are an indication of the importance sheep hunters place on the activity, and should not be entirely discounted.

Is $28 billion, or $20.7 million per hunter who answered this question, a reasonable amount of compensation for the loss of all of these hunters' future sheep hunting opportunities in Alaska? If the average compensation requested for the loss of a year's opportunity to hunt sheep is $2.7 million (Table 6), then the average number of years for which hunters want to be compensated ($20.7 million ÷ $2.7 million per year) is 7.7 or 8 years. With a discount rate of 10%, the compensation would cover 12 years. If the average hunter is in his 30's or 40's (Watson, in press), 12 more years of the opportunity to go sheep hunting might approximate what these hunters would be losing in their lifetimes should they not be able to hunt sheep again.

The $2.7 million amount may seem like an inappropriate value to be placed on the loss of a year's opportunity to hunt. But this figure is not the result of a court of law's determination of an award for damages. What is being measured in economic terms are human values. Obviously, the opportunity to go sheep hunting is extremely important to hunters.

The values obtained here are minimum values. The values of all sheep hunters are not included; subsistence hunters were not surveyed and not all who were surveyed chose to respond. In addition to these values directly associated with Dall sheep hunting are those values held by nonconsumptive users. These additional values must also be considered in land use decisions.

Putting dollar values on public goods is a difficult proposition for economists, biologists, and for the general public who has to help them. As an increasing number of land use decisions are being made on an economic basis, it is important to understand the benefits and the costs of land uses. The best decisions cannot be made without both benefits and costs in mind.

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QUESTIONS AND ANSWERS

Bruce Smith, Wyoming: I'm interested in how you might be able to apply this information to benefit either hunting or conservation of wildlife?

Sarah Watson: I'm hoping to be able to apply this information and I'm hoping to get planners to apply it. Our habitat division has been working with me trying to make sure we use techniques that are going to be comparable with alternative uses, like mining or homesites. The techniques used here are being used more and more by economists. I understand there;s several studies being done in the lower 48; if anybody knows about them I would appreciate references because I would like to compare the values I've obtained, to see just how close or far off I am. Most of the values are for comparative purposes and when you compare the benefits, the one that has the higher benefits is probably the one you should invest in. Politics is not being included in this decision and that is really something I can't do anything about.

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THE MYTH OF ALASKA'S SHEEP HUNTERS: RICH, EXPERIENCED, SUCCESSFUL, AND DEDICATED?

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Abstract: A mail survey of 2,079 Dall sheep (*Ovis dalli dalli*) hunters in 1983 has provided demographic insights. Some common perceptions about sheep hunters are compared with survey results. Findings suggest sheep hunters had higher than average (for Alaska) annual household incomes and spent 5-17% of their annual income on the hunt. Hunters in low income categories spent proportionally more for their hunts. Resident hunters tended to be inexperienced and relatively new to Alaska. Success rate was higher for hunters with experience or a guide. A high level of interest was shown by most hunters in hunting sheep again in Alaska.

Who hunts sheep? Are sheep managers familiar with the characteristics and potential needs of their hunting public? Many of us probably have some general ideas about who hunts sheep in Alaska, but it is seldom that we have the ability to compare our ideas with data. It can be useful to check our perceptions to make sure we are still in touch with all of the hunting public, not just aware of the views of a vocal few. We can serve the public better if we understand their attitudes and needs.

When I first began Dall sheep (*Ovis dalli dalli*) research and management work, I had little idea who hunted sheep. But within 6 months, I acquired some general perceptions about sheep hunters. My subjective perceptions were derived largely from listening to co-workers and meeting hunters.

I thought sheep hunters must have high incomes. After all, weren't hunters who usually flew into hunting areas rich? Certainly, the amount of sheep meat obtained could not balance the cost of the hunt and the amount of effort expended climbing mountains. Therefore, I reasoned that sheep hunters *had* to be rich.

I also thought sheep hunters were likely to be successful at getting a sheep. Harvest information collected by the Alaska Department of Fish and Game (ADF&G) showed sheep hunters had higher success rates than hunters of any other common big game species such as moose, bears, or caribou. Even though sheep hunting is generally difficult, the success rate appeared to be high.

It seemed to me that sheep hunters had to be experienced to be so successful. From my time in the field, I knew sheep hunting required strength, stamina, and knowledge about sheep habits. One rarely just stumbled onto a group of legal rams. One had to spend time in the mountains to learn about sheep or go with someone, such as a guide, who had already taken the time and who had the minimum 5 years of experience required by Alaska law.

I also believed that sheep hunters were dedicated to sheep hunting. They seemed to really enjoy sheep hunting and they hunted because they couldn't stay away. Some individuals were openly enthusiastic when coming by the ADF&G office for information and help in planning a trip to the mountains. Other hunters, especially those whom I knew were experienced, had an attitude that suggested sheep hunting was an integral part of their lives. The Alaska National Interest Lands Conservation Act (ANILCA), which put 25% of the huntable sheep into unhuntable National Parks in 1980, was still fresh in many sheep hunters' minds and many were concerned about the future. Dedication was also shown by their interest in and support for good research and proper management. Some sheep hunters, such as members of the Foundation of North American Wild Sheep went so far as to put their money and time into supporting these efforts.

These ideas about income, success, experience, and dedication have been either reinforced or eroded since I began sheep work. It was not until results from the Dall sheep hunter questionnaire provided more objective insights into the characteristics of sheep hunters, that I reexamined my initial impressions.

The sheep hunter questionnaire was funded in part by the Foundation for North American Wild Sheep and the Alaska Department of Fish and Game. The editorial comments of R. Bishop, J. Brown, L. de Veuve, W. Heimer, J. Kruse, L. McManus, S. Murphy, S. Peterson, W. Regelin, R. Stephenson, B. Townsend, R. Weeden, W. Workman, and one anonymous reviewer are gratefully acknowledged. D. Reed also provided technical assistance with data analysis.

METHODS

In February 1984, ADF&G mailed a questionnaire to all of 1983's Dall sheep hunters in Alaska to determine economic values of Dall sheep hunting in Alaska (Watson 1984). The questionnaire asked hunters to provide demographic information to aid in the analysis of the economic results (Appendix 1). This information is not available from hunter harvest report forms.

RESULTS AND DISCUSSION

Income

Eighty-three percent of the year's Dall sheep hunters (82% of the residents, 89% of the nonresidents) returned completed questionnaires. The following results are based on this sample group.

Some sheep hunters do have relatively high incomes, especially some of the nonresidents (Fig. 1). This is not surprising when, by law, nonresidents must hire a guide unless hunting with a resident relative within the second degree of kindred. A professional guide generally costs at least $4,000-5,000. Twenty-one percent of the nonresident respondents said they had incomes over $140,000. However, the remaining 79% of the nonresidents had income levels similar to residents.

I compared the income levels of resident sheep hunters with the incomes of all Alaska residents. Alaska census data from 1980 lists the average income for all households in Alaska in 1979 as $29,789 (U.S. Dep. Commerce). The average income for the state was probably higher by 1983 but probably not as high as the average income for resident sheep hunters, at least $46,000.

Not all sheep hunters spent the same amount on their hunt. They spent anywhere from 25¢ (the cost of a hunting license for the head of a welfare-assisted household) to $62,400 (for one nonresident) on their sheep hunt in 1983. To determine if the amount a hunter spent was related to income, I calculated the percentage of income applied toward the hunt.

Residents spent an average of 5% of their annual household income on sheep hunting in 1983 (Table 1). Resident hunters with less than the average annual income for Alaska spent more than 5% rather than reducing their costs. Six percent of the resident hunters had incomes over $100,000 and spent only 3% of their income on their sheep hunt.

Nonresidents spent an average of 17% of their income hunting Dall sheep in Alaska. Again, those in the lower income categories spent proportionally more money on their hunt. Compared with residents, only a small (17%) percentage of the nonresidents had incomes under $30,000, but these hunters spent over a third of their incomes on their hunt. Some, especially those with incomes of less than $10,000, may have had their hunt paid for by someone else (e.g., teenagers accompanying parents). But for most, their Dall sheep hunt was probably a once-in-a-lifetime experience.

One third of the nonresidents had incomes of over $100,000. These hunters spent only about 7% of their income hunting sheep.

Success and Experience

Forty percent of those who answered the questionnaire said they killed a ram. (General harvest statistics show that only 37% of all sheep hunters in 1983 were successful, so the questionnaire data may be slightly biased in favor of those who were successful.) It is interesting to note who got a ram. Seventy percent of the nonresidents killed a ram while only 33% of the residents were successful. The most likely reason for this is that most nonresident hunters were professionally guided. The residents' 33% success rate is good compared to other types of hunting, but I would have thought residents would be more successful given my perception that sheep hunters are supposed to be experienced.

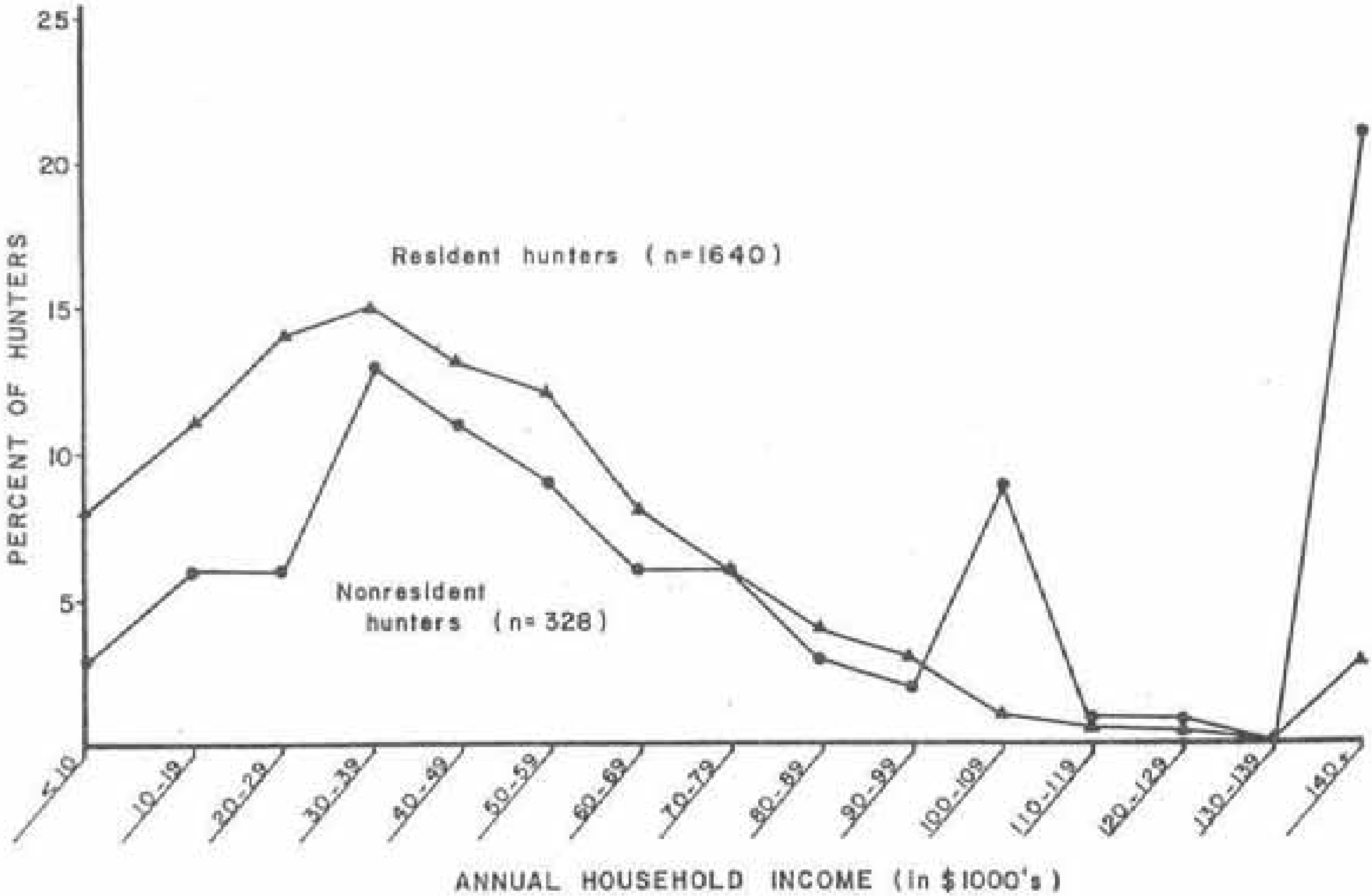


Figure 1. Percent of the sample of Alaska's 1983 Dall sheep hunters who claimed one of the above categories for annual household income.

Table 1. Percentage of annual household income spent on hunting Dall sheep in Alaska in 1983 as reported by resident and nonresident respondents to Dall sheep hunter questionnaire.

Percentage of Annual Household Income Spent on 1983 Dall Sheep Hunt		
Income (in $1000's)	Residents (n = 1613)	Nonresidents (n = 315)
<10	.16	1.01
10-19	.07	.34
20-29	.05	.30
30-39	.04	.17
40-49	.03	.17
50-59	.03	.14
60-69	.03	.12
70-79	.03	.09
80-89	.02	.12
90-99	.03	.09
100-109	.03	.08
110-119	.06	.05
120-129	.03	.07
130-139	.03	.09
≥140[a]	.03	.07
$\bar{x}$ =	.05	.17

[a] $145 was used as the midpoint.

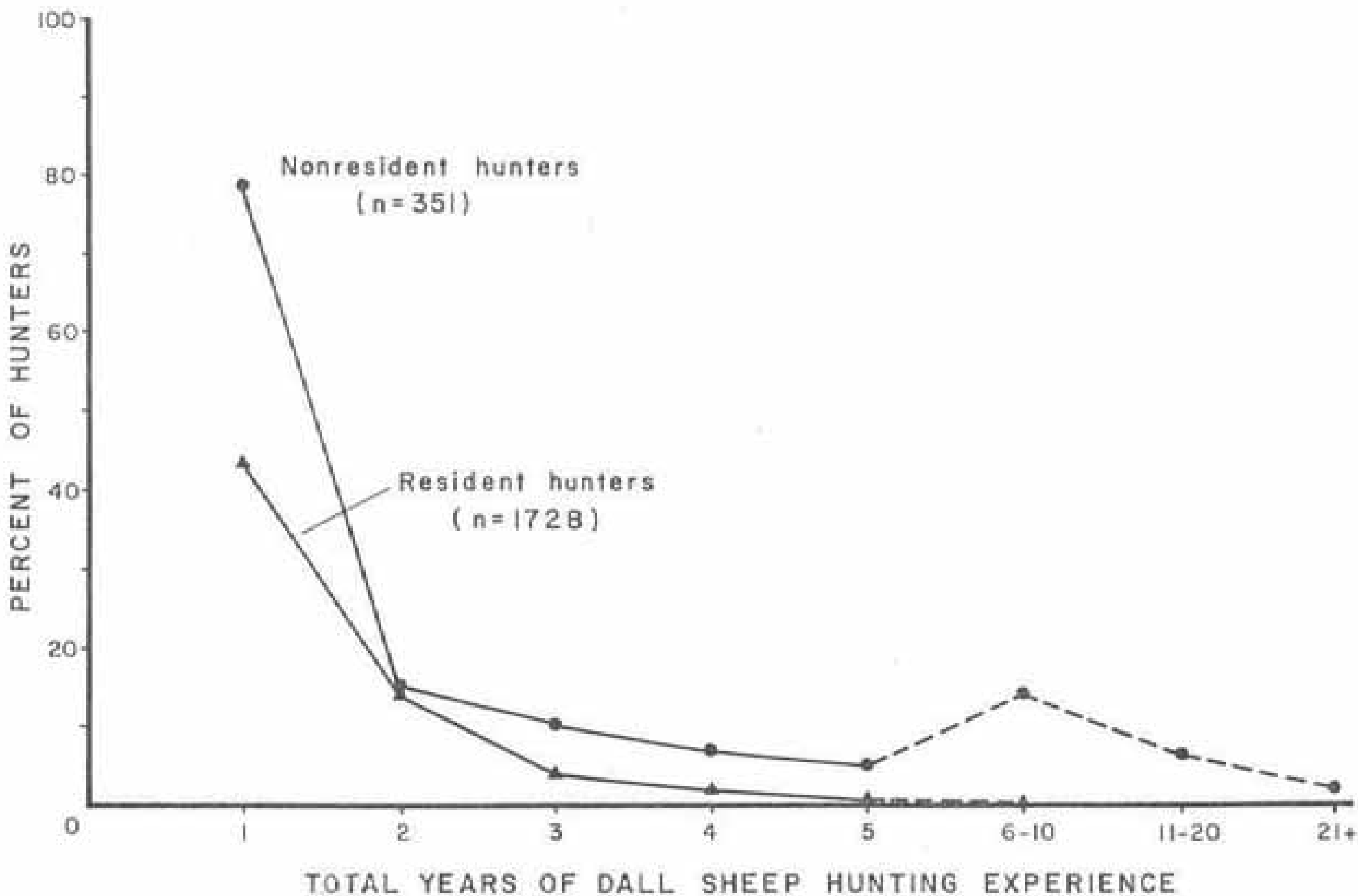


Figure 2. Number of total years of Dall sheep hunting experience of the sample of Alaska's 1983 Dall sheep resident and nonresident hunters (by percent).

The questionnaire asked hunters to list the years they had hunted sheep in Alaska. I was surprised to find that 43% of the residents were hunting Dall sheep for the first time in 1983 (Fig. 2). Another 35% had 2-5 years of Dall sheep hunting experience. Those with even more experience, including one hunter with 44 years, composed only 22% of all the resident sheep hunters.

Nonresidents had less experience (although most were hunting with an experienced guide). Seventy-eight percent were hunting Dall sheep for the first time in 1983. Given the cost and the percentage of their income they put toward their hunt, it is not surprising that many nonresidents have not made Dall sheep hunting in Alaska an annual affair. Nonresidents who had hunted in Alaska before (the maximum from this group had 6 years of experience) may have been fortunate to have hunted with a resident relative and avoided the cost of hiring a guide.

I was intrigued by the large number of resident first-time hunters. I separated residents into two groups; these included first-time hunters and those with more than 1 year of experience. On the average, first-time hunters were the same age as other hunters (30-39 years) but had lower incomes, had lived in Alaska half as long (7 years), and tended to spend less on their sheep hunt. The difference in costs can probably be attributed to fewer taxidermy bills (due to lower success rate) and cheaper transportation (due to choosing modes other than aircraft).

If a hunter had more prior sheep hunting experience, he or she was not necessarily apt to be successful in 1983. I examined the success rate of resident hunters who had more than 1 year of experience. The success rate increased as the total number of years hunted increased until experience equaled 10 years. Hunters with this much experience had a success rate in 1983 of 45%. But for hunters with more than 10 years of experience, the success rate decreased to 31%. This decrease could be due to an increase in age and/or to an increase in hunter selectivity. Success rate may not be a good indication of hunting ability.

Dedication

Is sheep hunting as important to sheep hunters as I had presumed? An indication of strong interest in sheep hunting is whether hunters planned to hunt Dall sheep in Alaska again, and, if so, how often. Ninety-five percent of the residents (including 90% of the first-time hunters) did plan to hunt sheep again, and 67% of the nonresidents were willing to again bear the cost of hiring a guide or hunting with a relative (Fig. 3). Only 1% of the residents (which were all first-time hunters) and 10% of the nonresidents did not intend to hunt sheep in Alaska again. The remainder did not know if they would hunt sheep again.

The frequency with which hunters intended to hunt sheep in the future was different for residents and nonresidents. More than half of the residents claimed they would go every year while over half of the nonresidents said "only once or twice in the future."

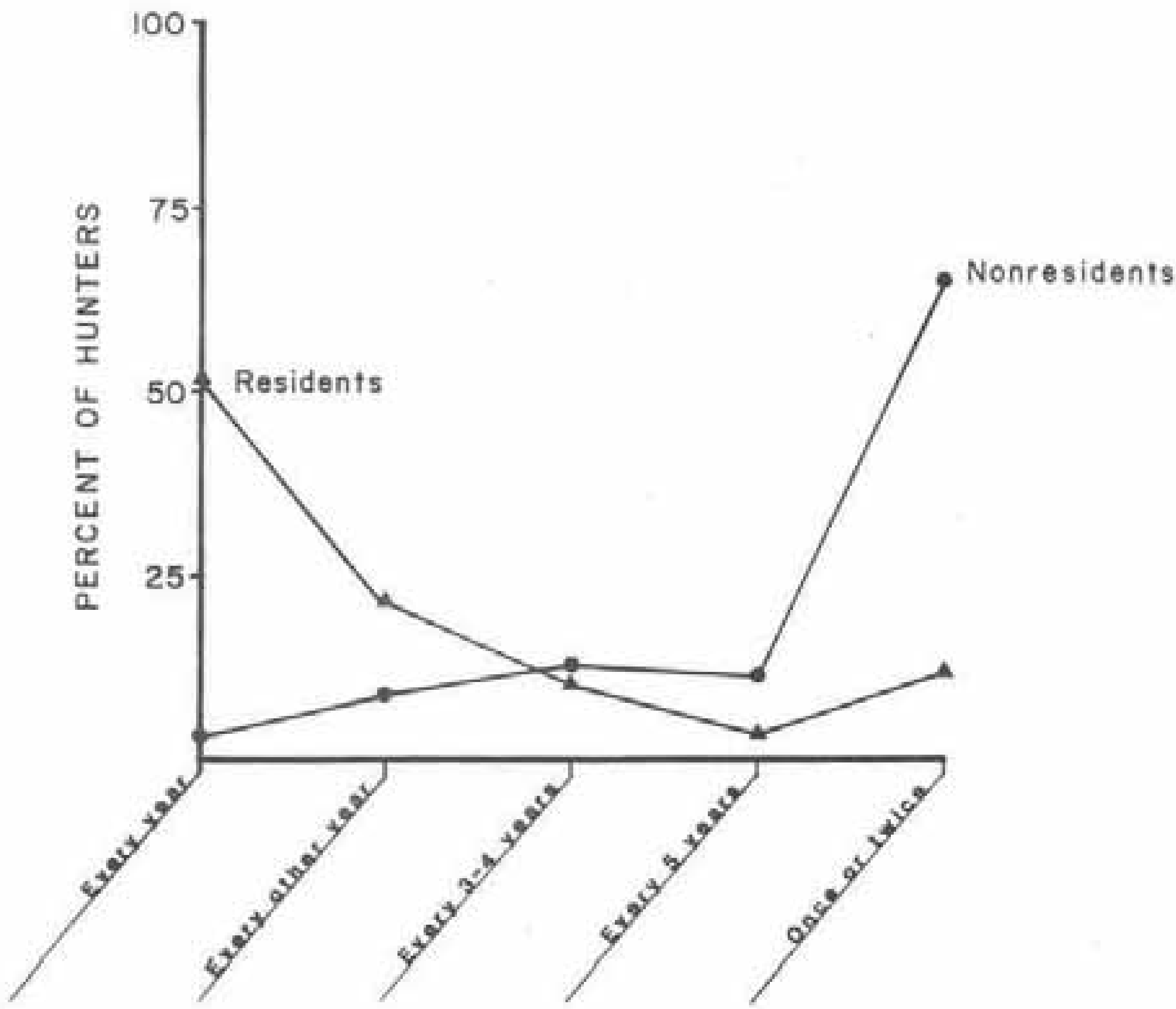
First-time resident hunters did not display as much enthusiasm as residents with even one additional year of sheep hunting experience. Only

Figure 3. The future plans for Dall sheep hunting in Alaska from the sample of Alaska's 1983 Dall sheep hunters.

PLAN FUTURE HUNTS?

	YES	NO	DON'T KNOW
RESIDENTS	1640 (95%)	12 (1%)	72 (4%)
NONRESIDENTS	235 (67%)	35 (10%)	81 (23%)

IF YES, HOW OFTEN?



34% said they would go sheep hunting annually while 60% of the hunters with more experience said they would hunt sheep annually.

Another indication of the value of sheep hunting was the economic value hunters placed on their hunt and future hunting opportunities. The results of this evaluation show that hunters only pay about 60% of what the experience is worth to them (Watson, in press).

SUMMARY

The following generalizations can be made based on the sample of Alaska's Dall sheep hunters in 1983:

Dall sheep hunters tended to have higher annual incomes than the average Alaskan. However, one-third of the resident hunters had lower than average (<$30,000) incomes. From 5 to 17% of hunters' incomes was spent on sheep hunting. Instead of significantly reducing costs, hunters in lower income categories spent a proportionally greater amount on their hunt than did hunters in higher income categories.

Dall sheep hunters, though generally more successful than other big game hunters in Alaska, nevertheless benefited from increased experience or the services of a guide. Hunter success, however, may be affected by selectivity as well as experience and general hunting ability.

Only 20% of all resident and less than 1% of the nonresident sheep hunters had hunted sheep more than five times. Nearly half (43%) of the resident and four-fifths (78%) of the nonresident Dall sheep hunters hunted sheep for the first time in 1983. First-time resident hunters had lived in Alaska an average of 7 years (or since 1977).

Most resident hunters wanted to hunt sheep every year or every other year. Nonresidents generally did not plan to return to hunt sheep in Alaska more than once or twice.

The Alaska Department of Fish and Game can use this and other available information to improve relations with and services to the public. Information and education programs can be reviewed and enhanced to better suit the needs, for example, of the high number of first-time hunters. The general public, as well as wildlife managers, may also benefit from more accurate perceptions of hunters. Informing and aiding the public can have long-term benefits such as increased cooperation and support for the conservation and careful management of sheep populations.

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Appendix 1. Questions from the 1983 Dall sheep hunter questionnaire that provided demographic information about income, success rate, experience, and continued interest in Dall sheep hunting in Alaska.

A. Which of the following categories best describes your household income before taxes in 1983? Please check one.

___under $10,000	___$50,000 - 59,999	___$100,000 - 109,999
___$10,000 - 19,999	___$60,000 - 69,999	___$110,000 - 119,999
___$20,000 - 29,999	___$70,000 - 79,999	___$120,000 - 129,999
___$30,000 - 39,999	___$80,000 - 89,999	___$130,000 - 139,999
___$40,000 - 49,999	___$90,000 -100,999	___$140,000 and higher

B. How much did your Dall sheep hunt cost? Total cost ______________.

C. If you came to Alaska for reasons other than to hunt Dall sheep, what fraction of your expenses can you attribute to your Dall sheep hunt? Circle one: 1/8 1/4 3/8 1/2 5/8 3/4 7/8 (Asked of nonresidents)

D. Please list all the years you have gone sheep hunting in Alaska: 1983,____.

E. How many times have you killed a Dall sheep in Alaska including your 1983 hunt? __________ times

F. Did you kill a Dall sheep in Alaska in 1983? _____yes _____no

G. Do you plan to hunt Dall sheep in Alaska in the future?
_____yes _____no _____don't know

H. If yes, about how often in your life do you expect to go? Check one:
_____once or twice more in my life
_____once every 5 years of my life
_____once every 3-4 years of my life
_____every other year
_____every year

I. Where do you live? ____

J. Which group below best describes your age?
_____under 20
_____20-29
_____30-39
_____40-49
_____50-59
_____60-69
_____70-79
_____80 and over

K. Where was your hunting area? Please check the mountain range location(s) where you hunted Dall sheep in 1983? The map of Alaska may help you.
_____Alaska Range, east of Denali National Park
_____Alaska Range, west of Denali National Park
_____Brooks Range
_____Chugach Mountains
_____Kenai Mountains
_____Talkeetna, Chulitna, Watana Mountains
_____Tanana Hills-White Mountains
_____Wrangell Mountains

L. How many years have you been a resident of Alaska? _____
(Asked only of residents of Alaska.)

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SUBSISTENCE SHEEP HUNTING IN ALASKA

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Abstract: Implementation of the Alaska National Interest Lands Conservation Act contributed to an ironic subsistence hunting situation. Attempts to satisfy the inconsistent mandates of the State and Federal subsistence titles resulted in establishment of subsistence hunts for trophy Dall sheep (*Ovis dalli dalli*) rams in areas previously managed for recreation. Subsistence hunting is still undefined, and situations such as these involving Dall sheep appear to be contributing to an unknown level of citizen dissatisfaction with the Alaska subsistence law. The future of nonresident hunting, the widespread subsistence use of Dall sheep, and possible management options are uncertain.

When the great oil fields on Alaska's north coast were discovered, it was apparent that a pipeline would have to be constructed to transport the oil to an ice-free port. From there oil could be transported, by tanker, to refineries on the west coast. The question of land ownership of the pipeline right-of-way was settled by passage of an act settling the aboriginal claims of Alaskan Natives. I have reviewed these occurrences and their impacts in previous transactions of this symposium (Heimer 1978, 1980, 1982, 1984).

When Congress passed the Alaska Native Claims Settlement Act there was provision for adding a minimum of 80,000,000 acres to Federal conservation systems. This land was to be included in national parks, wildlife refuges, national forests, and wild and scenic rivers. The Native claims settlement generally described how this was to be accomplished. Actual land selection and classification required another act of Congress, the Alaska National Interest Lands Conservation Act (ANILCA). This was a vigorously debated settlement, and it resulted in the present subsistence hunting situation in Alaska.

To secure passage of ANILCA, the special interests involved, Alaska Natives, Federal agencies, animal protection groups, and some environmental interests (which were generally opposed to hunting) compromised with each other. Interests seeking more Alaska land and those opposed to hunting exchanged their support for subsistence hunting for reciprocal support by Alaskan Natives of their interests in adding land to Federal conservation systems. As a result, ANILCA has a subsistence section which accords subsistence hunting and fishing the highest priority consumptive use of fish and wildlife in certain national parks and all national park monuments, and the highest priority among consumptive uses on all other Federal lands in Alaska. Because it was politically unacceptable to define subsistence on a racial basis, it was defined as customary and traditional use by rural Alaska residents.

Under the terms of ANILCA, residents of certain rural communities are allowed to hunt for subsistence in some national parks. Urban residents must be excluded whenever it is necessary to limit harvest on Federal lands.

As the law is currently interpreted, this means that urban hunters may not participate in hunting until subsistence (rural) opportunities for use have been met. That is, if nonsubsistence hunting interferes with opportunities for subsistence use, subsistence uses may not be regulated until nonsubsistence use has been eliminated. When the subsistence provisions of ANILCA were being debated in Washington, D.C., the Alaska legislature was led to believe it could preclude Congressional inclusion of a subsistence section in the Federal law by passing a State law which would do the same thing. A state subsistence law was passed in 1978, but the Alaska legislature did not include "rural" in the definition of subsistence use. The legislature clearly intended for all Alaska residents to be classified as subsistence users.

Both subsistence titles became law, and the State, to comply with Federal law, began administratively to limit access to resources on the basis of residency with regulations favoring rural users. These regulations were adopted by the Alaska Boards of Fisheries and Game, the regulatory bodies for wildlife management in Alaska.

RESULTS

Eventually, an urban resident named Madison brought suit against the regulation limiting use on the basis of residency. He asserted that the intent of the Alaska legislature was that all Alaskans were subsistence users. The Alaska Supreme Court ruled that he was correct, and, by logical extension, all Alaskans were defined as subsistence users. Discrimination among Alaskans on the basis of residence was no longer legally possible. The constitutionality of the Alaska subsistence law was not tested in this suit, only its legislative intent.

Next, a Kodiak, Alaska resident named Eluska was cited for taking Sitka black-tailed deer (Odocoileus hemionus) out of season. On Kodiak, there was a 5-deer limit, and the open season ran from 1 August through 15 December or 7 January, depending on location. Eluska's lawyer maintained his client took the deer for subsistence purposes and that the long season and liberal bag limit were not specific subsistence regulations. As such, he argued, they did not accommodate traditional subsistence use. A magistrate in Kodiak agreed. This was seen as establishing a legal precedent: the absence of specifically designated subsistence seasons (to accommodate subsistence uses) constituted a failure to provide for subsistence uses under law.

The Madison case established that all Alaskans were subsistence users, and the Eluska case established that unless specific subsistence regulations closed the season in a given area, any Alaskan could legally take game without limit whenever he or she desired to hunt for subsistence purposes. Clearly, this was likely to compromise wildlife conservation in Alaska.

To solve this problem, the Alaska Board of Game undertook establishment of specific subsistence regulations for all game species. The Alaska Department of Law advised the Game Board that subsistence hunts should be created wherever there was a "significant restriction" of subsistence hunting opportunity. As a result, all lottery permit hunts, hunts where the Department of Law determined there was a "significant restriction" of subsistence hunting opportunity, were defined as subsistence hunts.

In these subsistence hunts, only Alaska residents were allowed to participate. To discriminate among residents (i.e., subsistence users), the Game Board implemented criteria found in the State and Federal laws to determine which of the Alaskan residents desiring to participate were most qualified as subsistence users. Alaskans were ranked on the basis of points they received when a questionnaire adopted by the Board was evaluated. The criteria for ranking included: (1) area of residence, (2) economic status and availability of alternate resources (considered measures of need), and (3) past history of using the resource in question (presumably a measure of tradition). The Alaskans who ranked highest as subsistence users of the game populations in questions were allowed to participate in the subsistence hunt allocation system. They received permits according to their numerical rank. When more qualified applicants were received than the number of permits, a drawing was held.

Existing lottery permit sheep hunts in the Alaska and Chugach mountain ranges became subsistence hunts, but season and bag limits were unchanged. It is notable that participation in these ram hunts was controlled by permit for differing reasons before the subsistence controversy developed. In the Chugach Mountains, permit hunting was instituted in 1980 to assure maximum participation by hunters. The Alaska State Park system, which owns the land upon which the hunt takes place, sought to limit hunter numbers in the field. This, they thought, was necessary because the area is immediately adjacent to Anchorage, a city of more than a quarter of a million people. To provide opportunity for as many hunters as possible to have access to the sheep there, the Alaska Department of Fish and Game negotiated development of a permit system limiting the number of hunters to that defined as acceptable by Parks criteria at any time. There are three different hunt areas with two separate hunt periods, each designed to allow the maximum participation compatible with the Alaska Park system limits.

In the Alaska Range, lottery permit hunts for sheep existed to limit participation by hunters for two different reasons. In the Tok Management Area, the management goal was production of trophy rams. Participation had to be limited to achieve this goal. In the Delta Management Area, the management goal was to provide aesthetically pleasing hunting conditions. Hunter numbers were kept low (by a permit system) so the quality of hunting experience enjoyed by those fortunate enough to draw a permit would not be compromised by crowding from other hunters. In summary, while these continued restrictions limited opportunities for subsistence (local) use, the origin of the limitations had very little to do with actual resource scarcity or welfare. These restrictions were made to: (1) increase hunter participation, (2) allow for taking of unusually large and old rams; and (3) allow for a high-quality hunting experience. These management goals had been reviewed by local committees and implemented by the Board of Game. The turn-about to provide preference for local use represented a radical change in the purpose of the hunts and in permit allocation.

It should be noted that sheep hunts by Native, rural Alaskans (in the Brooks Range) were not covered by the new allocation system. These hunts continue to provide for subsistence (local) use of Dall sheep in the same management framework, season timing, access restrictions, and local registration-permit issuance, which favored local use before passage of the subsistence law.

Following the 1985 sheep season, a sheep conservation group, the Alaska Chapter of the Foundation for North American Wild Sheep (FNAWS-Alaska) with special interests in sheep hunting and conservation, polled recreational hunters and the newly defined subsistence sheep hunters. FNAWS-Alaska compared responses of these two groups of sheep hunters to questions concerning reasons for hunting sheep, time and effort expended, amount of meat retrieved, and hunter attitudes. FNAWS-Alaska provided the raw data from their poll to ADF&G.

FNAWS-Alaska sent a total of 402 questionnaires to subsistence hunters and 225 questionnaires to their membership. A total of 227 subsistence hunters (56%) returned their questionnaires while 122 FNAWS-Alaska members (assumed to represent recreational hunters) returned questionnaires. The overall return rate for the mail-in questionnaires was slightly less than 50%. FNAWS-Alaska entered all returned questionnaires in a drawing for a sheep rifle to stimulate response. A copy of the questionnaire is given in Appendix A.

I judged some questions to be ambiguous, and disregarded them in this discussion. Results showed recreational hunters had lived in Alaska longer, had more experience sheep hunting, and had taken more sheep in Alaska than the new group of designated subsistence hunters. In the past, the average sport hunter had taken as many sheep from the subsistence hunt areas in the Alaska and Chugach Ranges as the average new subsistence hunter. Recreational hunters hunted an average of 7 days, more than twice as long as subsistence hunters, and spent correspondingly more money ($823 compared with $309). Subsistence hunters most commonly used automobiles and offroad vehicles to get to the hunting area while most recreational hunters used aircraft to get into sheep country. There was no difference in size of rams harvested or average amount of meat brought home by successful hunters of both groups. However, there was a difference in the average cost of meat between groups. Recreational hunters (including unsuccessfuls) spent an average of $45 per pound of meat obtained. Subsistence hunters spent an average (also including expenditures by unsuccessful hunters) of $10 per pound of sheep meat.

Reasons for going sheep hunting were somewhat different. Recreational hunters rated the reasons for going sheep hunting in this order: first was to enjoy sheep hunting in the mountains (65%); second was to take a trophy ram (26%); third was to get sheep meat (5%); and fourth was to just be in the mountains (4%). In comparison, subsistence hunters rated the first reason, to enjoy sheep hunting in the mountains, at 45%; second was to get sheep meat (33%); third was to take a trophy ram (19%); and fourth was to just be in the mountains (3%).

Twenty-nine percent of subsistence hunters thought limiting subsistence hunting by lottery permit to those qualified by the present ranking system was necessary for good sheep management. Only 2% of the recreational hunters agreed.

Classification of the lottery permit hunts as subsistence hunts seems to have weakened public support for these programs. Both groups of hunters were supportive of these hunts before application for the drawing was restricted to qualified subsistence users (80% in favor). After restrictions were imposed on applicants, 88% of recreational hunters and 76% of subsistence hunters were opposed to these hunts. Because public support is necessary for any successful management program, this aspect of subsistence hunting, as it is currently defined and practiced, could have serious detrimental effects on management programs designed to meet goals other than maximum game harvest. It is possible that the options of wildlife users and managers are legally limited to this one management goal by these laws.

Most respondents who wrote additional comments on the questionnaire were opposed to classification of Dall sheep for subsistence uses. These Alaskans typically stated that the small size of Dall sheep, the difficulty of obtaining them, and the costs involved should preclude subsistence as the primary use of this species. These Alaskans apparently consider getting meat to eat as the major component of subsistence. However, definition of subsistence use on the basis of residence, as in ANILCA, greatly broadens the concept of subsistence, though it remains legally undefined with respect to specifics such as need, lifestyle, etc.

Of the 227 subsistence hunters who responded, 211 wrote extra comments on the questionnaire. Seventy-nine (37%) of these hunters specifically stated Dall sheep should not be a subsistence animal. Among recreational hunters, 102 of 122 respondents made extra comments. Forty-seven percent of these individuals made the same comment. Of the 313 Alaskans who made extra comments, only 3 spoke in favor of retaining Dall sheep on the subsistence list. That is, the ratio of those opposed to those in favor of Dall sheep as a subsistence animal was 43 to 1.

Subsistence hunters most frequently used transportation types other than aircraft. This is expected of local residents. Their preference for offroad or all-terrain vehicles was notable. The environmental impacts of this type of mechanized ground transport in the Alaskan alpine environment may become an issue if this is a developing trend.

The administration of a subsistence law continues to be a divisive, emotionally charged issue in Alaska. Federal law (ANILCA) states that the Federal government must take control of fish and wildlife management on Federal lands in Alaska if the State does not comply with the ANILCA subsistence title. The State of Alaska, even with the complicated mechanism for identifying subsistence users, was declared (after a review requested by the Alaska Federation of Natives) to be out of compliance with the subsistence title in ANILCA in fall 1985. Following its review, the U.S. Department of the Interior ruled that if the State does not comply before 1 June 1986, the Federal government must, under the terms of ANILCA, assume management of resident species on Federal lands. If that occurs, it will, of course, preclude Alaska's ability to manage that resident wildlife. Of course, compliance with the Federal law restricts the State's management options as well. The defined legal objective of the Federal management is to provide for subsistence use. What that means is not certain, but Alaskans appear to regard this as an unacceptable alternative. Consequently, the Alaska legislature is currently considering a bill which may bring the State into compliance with Federal law. Under provisions of the proposed legislation, the word "rural" would be inserted into the Alaska law. Differing versions of the bill would also allow the Board of Game to designate which species would be identified for subsistence use on State lands. Should this occur, there is certain to be an effort to remove Dall sheep from the subsistence list. One other thing is certain, the subsistence issue in Alaska will not be easily resolved. Alaskans react to the issue along racial and philosophical grounds, and the controversy is certain to continue.

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THE USE OF TRANSPLANTING TO EXPAND BIGHORN SHEEP RANGE

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Abstract: In March 1977, 20 bighorn sheep (*Ovis canadensis canadensis*) were transplanted from a migratory herd in the Tarryall Canyon near Pikes Peak to the east side of Rocky Mountain National Park, Colorado. The objectives of the project were to expand the winter range of the native sheep population from primarily alpine tundra ranges to historically used low elevation sites that had been abandoned, and to re-establish historic annual migration between the two range areas. In 1982, since it was believed the introduced sheep had established their movement patterns, a study was initiated using radio telemetry to document the movements and range use of these sheep. Observations from 1982 to 1985 indicate that the introduced sheep do winter primarily on relatively low elevation ponderosa pine (*Pinus ponderosa*)/shrub sites along Fall River, Black Canyon and Cow Creek (the release site). Annual movements from these areas were made generally in July to the alpine tundra summer range areas in the vicinity of Mummy Mountain. The adult males summered separately from the ewes and lambs, generally on alpine range in the Desolation Peaks. Return to the winter range was made in September or October. Since the objectives were met, the project was considered a success.

INTRODUCTION

Transplanting of bighorn sheep has become a popular method for extending sheep distribution (Bear 1976, Kopec 1982). However, few studies have been made of transplanted populations after they have stabilized their range use patterns.

A bighorn sheep transplant to abandoned historic range areas was included as part of the 1976 Management Plan for bighorn in Rocky Mountain National Park (Stevens 1982). This plan was initiated in response to studies showing that the native sheep population wintered primarily on quite restricted areas on the alpine tundra (Baumann 1978), and that no use was being made by sheep of most of the low elevation historic winter range (Contor 1958). Sheep populations on restricted ranges may be vulnerable to severe mortality as a result of stress, pneumonia complex or lungworm infections (Post 1976) and be rapidly decimated (Moser 1962, Thorne 1971, and Simmons 1982). A transplant was proposed to alleviate this situation. In cooperation with the Colorado Division of Wildlife 20 bighorn sheep were transferred from the Pike's Peak Area to the east side of Rocky Mountain National Park.

The objectives of the reintroduction were to expand the range used by restoring bighorn sheep to historic low elevation winter ranges and to redevelop migration routes between alpine tundra summer range and low elevation wintering areas.

Initial observations on the sheep indicated that they had established patterns of movement and range use by 1981.

A study utilizing radio telemetry was initiated in 1982 to test the hypothesis that the objectives of the transplant had been achieved.

STUDY AREA

The study area was in the northeast section of Rocky Mountain National Park east of the Continental Divide. It covered an area of about 30,000 hectares, including the Mummy Range of mountains (Figure 1). Elevations ranged from 2329 meters to 4133 meters.

The mountains were formed by precambrian metamorphic schists and gneiss intruded by large masses of granite and pegmatite (Richmond 1974). Present physiography demonstrated the extent of alteration by pleistocene glaciation. The soils were relatively infertile and low in essential elements, being very sandy with poor development from decomposed granitic substrates.

The climate was typical of the central Rocky Mountains. At lower elevations, annual precipitation was 41 cm, with a mean annual temperature of 6°C. Precipitation increases with elevation to as much as 66 cm on the alpine tundra, while mean temperatures decrease. Highest precipitation occured in late March and April, with heavy wet snows. In winter, the precipitation fell as snow, but severe winds blew many areas free and deposited the snow in drifts, especially in the alpine.

Vegetation of the study area represented three climax regions (Marr 1961), all of which are utilized by bighorn sheep. The upper montane climax region occurred from 2300 to 2740 m elevation. Dominant vegetation types were the ponderosa pine (Pinus ponderosa)/shrub savannah, closed canopy Douglas fir (Pseudotsuga menziesii)/ponderosa pine forest, and a lodgepole pine (Pinus contorta) forest. Interspersed in the bottom areas and more mesic sites were grassland, meadow, and willow (Salix spp.) types. Aspen (Populus tremuloides) was present in small stands. Above the montane, from 2740 to 3500 m, was the subalpine forest region. It was characterized by an Engelmann spruce/subalpine fir forest, interspersed with lodgepole pine and limber pine (Pinus flexilis) stands. In the openings were willow and herbaceous meadow types. Above the forest at about 3500 m was the alpine tundra. Vegetation of the alpine was a complex mosaic of types related to numerous environmental factors, interspersed with rock outcrops and talus slopes (Willard 1979).

Ungulates that shared the park ranges with bighorn sheep were elk (Cervus elaphus nelsoni) and mule deer (Odocoileus hemionus). The elk, a dominant ungulate in the park, with a population of over 3,000, utilized most of the vegetation types in the summer. Although most moved to the upper montane in winter, some remained on the alpine tundra. About 200-300 deer, a portion of a much larger summering population, remained in the park to winter.

HISTORY OF SHEEP POPULATION

Bighorn sheep were very common in the vicinity of Estes Park when the first settlers arrived. However, when the National Park was established in 1915 the population had declined to an estimate of 1,000 (Packard 1946). After a brief recovery the decline in numbers continued and in 1935 Potts estimated only 192 sheep left in the park. An intensive study covering more of the park was initiated by Packard in 1939. His total count was 318. Packard still found sheep on low elevation ranges on McGregor Mountain, Cow Creek, Black Canyon and Castle Mountain. By 1958 when Contor made his count, the sheep had abandoned the use of these areas except for possibly a few on

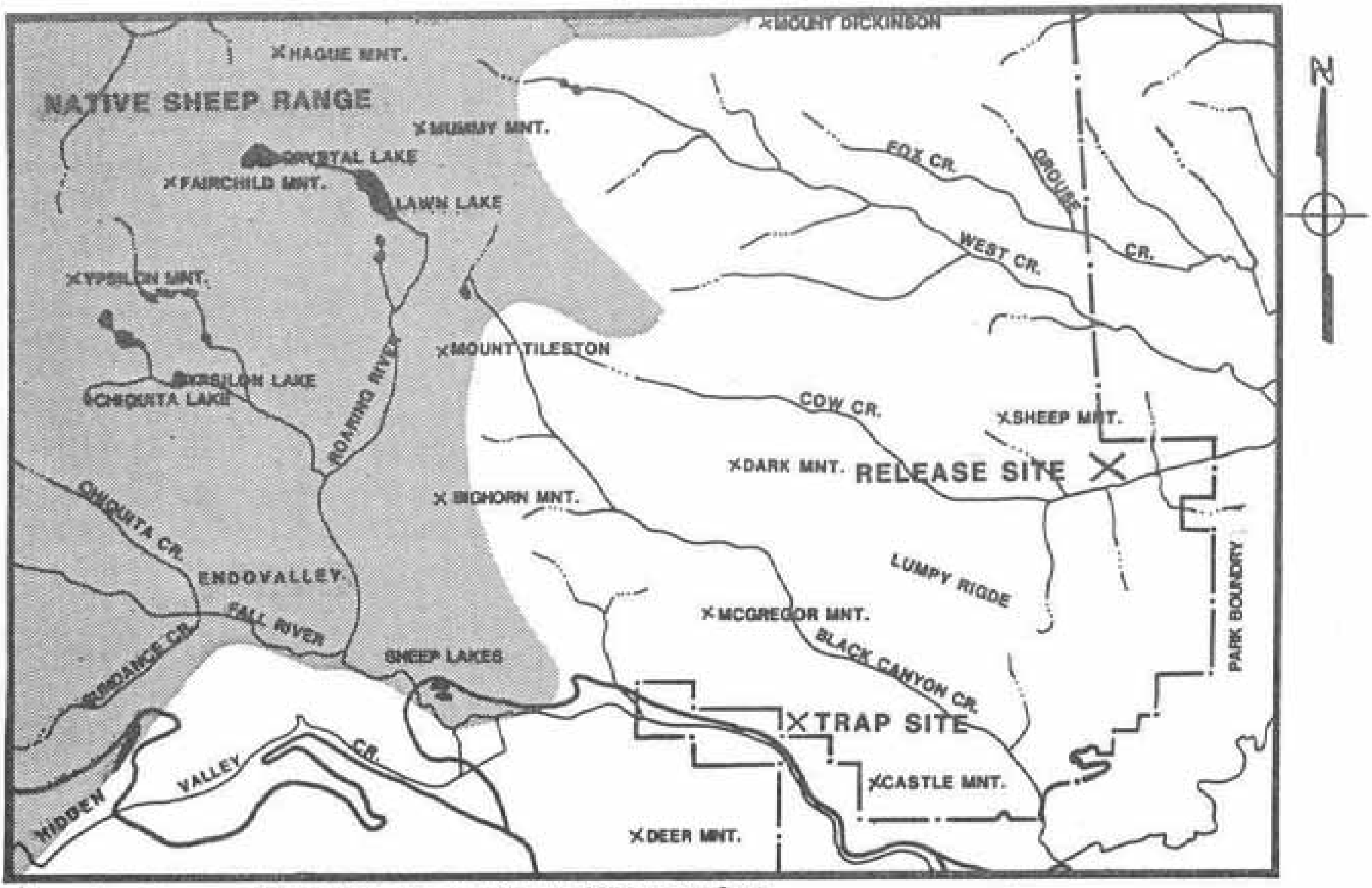

Figure 1. Range used by native sheep prior to 1977 transplant.

Cow Creek. He estimated the total population to be only 36 sheep in the total Mummy Range area. This was probably the low point for the population. If this count was correct by the time Goodson (1978) did her study, the population had increased in the intervening years to an estimated 81 sheep.

Reasons for decline in the population have been hypothesized by numerous investigators. In the early days the first decline was probably the result of market hunting, livestock competition for forage and scabies introduced by domestic sheep. Later, although range competition with livestock was still important, competition with increasing elk and deer populations was becoming a factor. Also the presence of lungworm and pnuemonia along with possible mineral deficiencies were considered to be contributing factors.

With the abandonment of the low elevation areas, the Mummy range sheep spent most of the time from late fall to spring on the alpine tundra (Baumann 1978 (Figure 1). Of those observed in the low elevation, most were associated with the natural mineral licks in Horseshoe Park. Although sheep also used south exposures along Upper Fall River above Endovalley, they did not remain on them all winter. Increased use of these areas was made in the spring with the appearance of new green vegetation (Goodson 1978).

Although Goodson (1978) believed the population to be increasing slowly in 1975-76, long term observations indicated a more stagnant situation. Perhaps because of their use of the mineral deficient high elevation range, sheep appeared to nutritionally require the natural licks in Horseshoe Park (Stevens 1982). This demand is believed to cause stress in the native herd due to high visitor use of the area. Also, depending on the alpine for winter range meant a very restricted range availability and the possibility of a major loss as a result of abnormal deep snow conditions, stress or disease. The carrying capacity of these ranges was probably near maximum which would also account for the lack of population increase.

The management solution, supported by the 1976 Master Plan for the park, was to restore bighorn use of the abandoned low elevation ranges.

The most suitable area was on Cow Creek above the McGraw Ranch. An area of 393 acres inside the park had been purchased by the Park Service in 1964 with a 10-year livestock grazing permit that had expired in 1974. After 3 years of rest and the low elk use in that area, the range appeared to be in good condition and available for use.

The transplant was conducted on March 17, 1977. Twenty bighorn were trapped by drop net in Tarryall Canyon near Pikes Peak and released at the park boundary above the McGraw Ranch on Cow Creek (Figure 1). The adult sheep were marked with white neck bands and black numbers while 5 lambs had white ear tags. All released sheep were treated for lungworm infection.

The sheep immediately dispersed. The first observation was made on April 6 when a collared sheep was observed about 4 km east of the release site outside the park headed in an easterly direction. On April 21, five sheep returned to the vicinity of the release site. Further observations on marked sheep were made on the Roaring River Trail and Fall River in May. By October use of the lower Fall River area was common. As also reported by Bear (1976) for other transplants, the movements of the transplanted sheep were extremely variable. In November, the females had attracted 2 males from the native herd for breeding. This was the first record of native sheep on this part of Fall River in recent years.

METHODS

On January 19, 1982 radio collars were placed on 9 sheep at a trap site on Fall River (Figure 1). The sheep were captured by the use of a 21 m square drop net baited with applemash with the assistance of the Colorado Division of Wildlife (Schmidt 1978). A total of 15 sheep were trapped. Three mature females from the original transplant and two yearling females were fixed with radio collars. Two 4-year old and two 2-year old males were also radioed. The remainder of the sheep were just ear tagged with easily readable white tags. All were released at the trap site. In another trapping operation, April 19, 1983 the following year at the same site, the final radio was fixed to a mature female.

The radio telemetry system utilized was the Telonics Model TTR-1 receiver and MK-IV transmitters. The antenna utilized was the RA-2A hand held H-shaped dipole which has excellent direction finding capabilities and is easily back-packable. The transmitters were packaged in a large Model MK-IIIB hermetically sealed enclosure embedded in urethane. They were prepackaged at the factory and attached to a collar of white butyl rubber over cotton webbing. The ribbon antenna was placed inside the collar.

The system operated on frequencies of 164.4375 to 164.6625. Using a B-2A Lithium battery, life expectancy of the transmitter was estimated at 4 years. Each collar weighed from 500 to 650 grams.

Data were recorded both by direct observation and by triangulation of radio signals. Since the terrain was very rugged, signal bounce was a problem, so generally signals from three observation points were required before an observation was recorded.

RESULTS

Of the original 5 females marked, 3 were radio monitored the entire study period. The radio on one of the older transplanted females malfunctioned the first summer. One of the yearlings was killed by a poacher near the release site in 1983. The remaining four females, counting the female marked in 1983, provided most of the information on range use and movement. A total of 238 accurate relocations were made.

In May and June, female groups were generally in the vicinity of lambing areas in the Upper Montane Zone composed of rock outcrops on steep south exposures. The groups consisted of adult females, yearling males and females, and often 2-year old males. Considerable movement between Fall River area, Black Canyon and Cow Creek, a distance of 5.5 km, was observed. Lambing by radio collared sheep occurred on all 3 areas. Following lambing, movements by these groups were rather unpredictable. This was probably related to weather and phenology of vegetation. Movements to the alpine were often made followed by a rapid return to lower elevations and back up again, a distance of about 8 km each way.

Generally by mid-July (mean of July 16) most of the female groups were in the Mummy Mountain summering area (Figure 2). This is an area of 4000 hectares encompassing Mummy Mountain, Mt. Dickinson, Hagues Peak and Fairchild Mountain. The area used is primarily alpine and above 3350 m elevation. About 1/3 of this area is steep cliffs and talus with rock outcrops and tundra

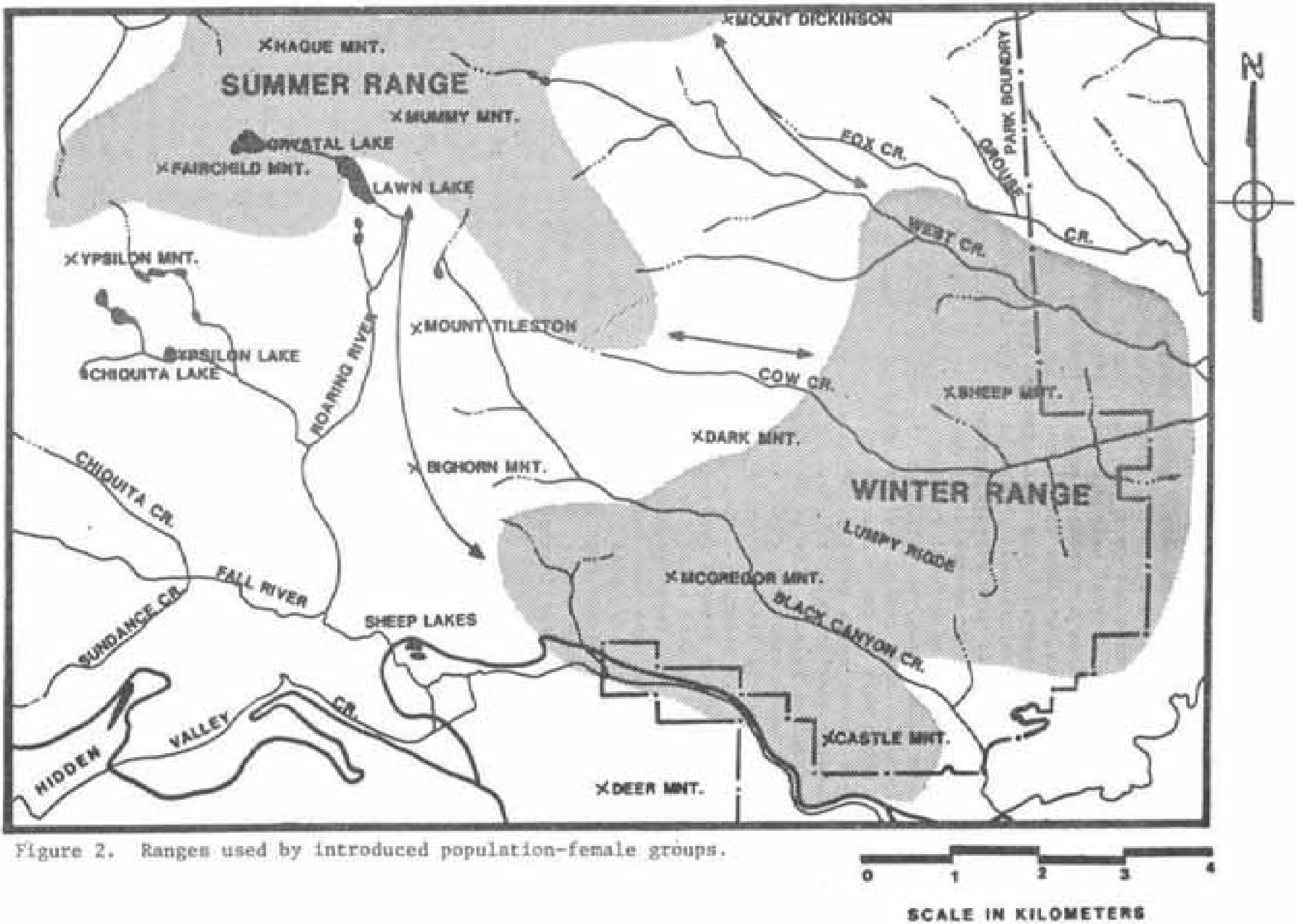

Figure 2. Ranges used by introduced population-female groups.

interspersed. The remainder is fairly gently rolling alpine tundra meadows and fellfields. The sheep utilize the steep rocky areas for escape, resting and feeding, but often move out on to the open tundra to feed. Except for the trail from Lawn Lake to Crystal Lake and the saddle between Fairchild and Hagues Peak, the area does not receive much visitor impact.

This summering area overlaps the summer range used by the native sheep. Some interchange was observed but a separation of the two herds of ewes and lambs did appear to be maintained. Movement of the introduced sheep back to the low elevation is even more erratic probably in response to weather conditions. Early downward movements in August were often followed by a return to summer range and a final movement down in October. In 1984, a relatively late fall, sheep were still on the alpine until late September, while in 1985 early snows caused downward movement in August. The mean for the day that sheep were on the winter range to stay was October 18.

The female winter range consists of an area of 5100 hectares along the east park boundary just north of the Town of Estes Park (Figure 2). It includes the original release site on Cow Creek, McGregor Mountain and Castle Mountain and the south exposures along Fall River east of the park entrance. The rock pinnacles along Black Canyon, Sheep Mountain and the cliff areas just north of West Creek are included. Open ponderosa pine/shrub and grass/shrub vegetation types are the primary feeding areas and are limited to about 600 hectares. However, the more expansive open canopy ponderosa pine and Douglas fir stands also provide a considerable amount of forage.

Although the sheep have been using this winter range for 8 years they continue to pioneer into new areas. The use of Castle Mountain was initiated for the first time in 1983 and West Creek in 1984 as determined by the locations of radio collared sheep. However, a few other areas that were used originally by the sheep after transplant no longer appear to be used by the reintroduced animals. Upper Fall River and the aspen stands along Fall River west of Sheep Lakes were used the first few years. No radio collared sheep used these areas and no other marked sheep have been seen there in recent years. One marked sheep also was observed near Sheep Lakes in 1977 and 1978 with the native sheep. Marked sheep were not observed in this area during the present study.

Since the introduced sheep do utilize the lower elevation ranges it is believed that their mineral requirements are being met by their forage and salt blocks set out by local residents. There is no apparent physiological need to visit the natural mineral licks.

Although four radios were placed on male sheep during the trapping operations, only a total of 56 relocations were made. One of the radios went out in 1982, two in 1983, and one in 1984. As a result, the range use and movement of the rams are not so well documented (Figure 3).

In the spring radio collared males were on Fall River or Cow Creek winter range. During late May and June they did move to higher elevations utilizing the moraine north of Fall River and Upper Fall River enroute a distance at 14 cm for up to two-week periods. By mid-July they were on the primary summering areas (Figure 3). It appears that the male sheep associated with the introduced population summer primarily in the Desolation Peaks-Fairchild Mountain area. This area is west of the female group summering area with some overlap on the west side of Fairchild. The area consists of about 717 hectares

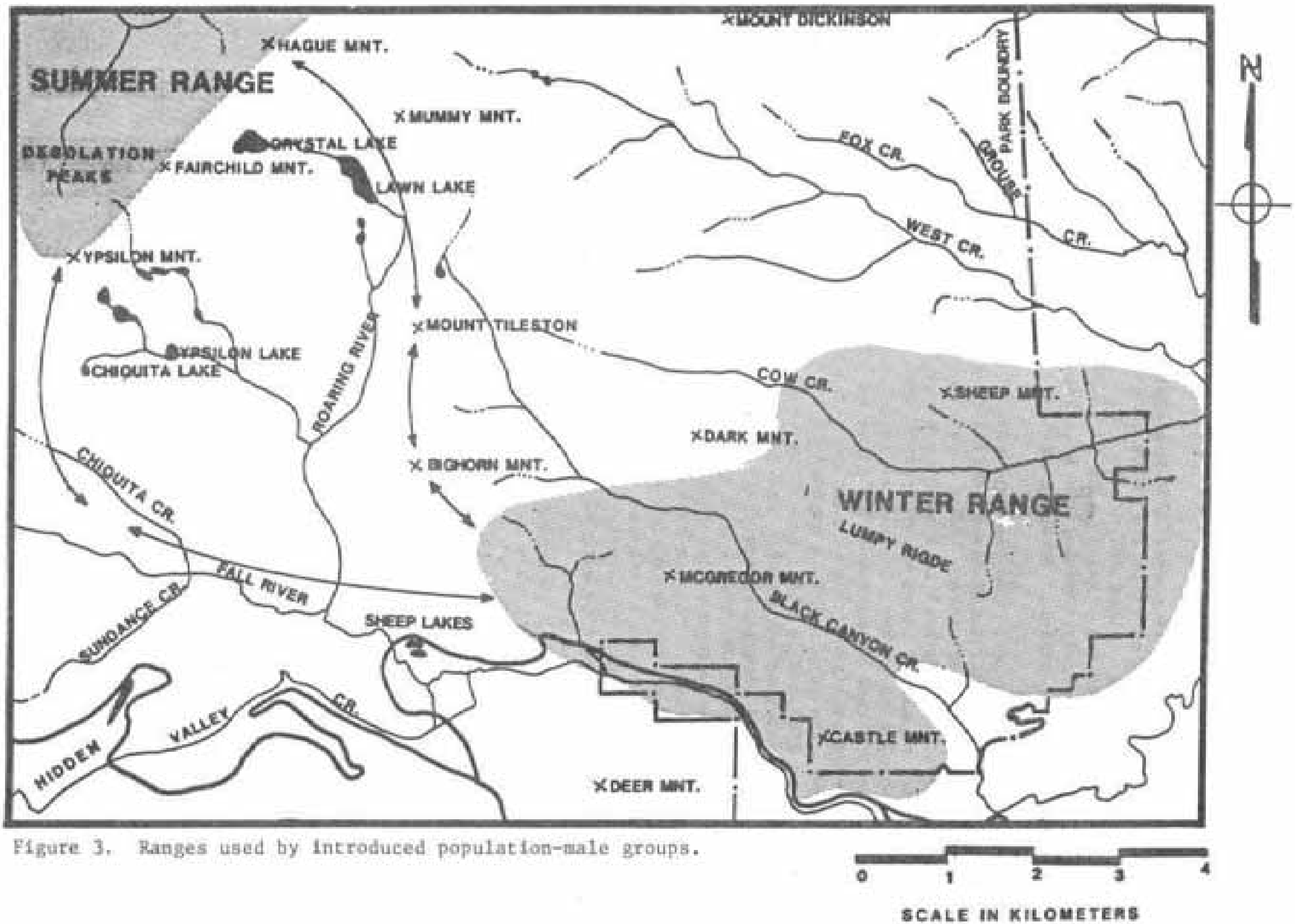

Figure 3. Ranges used by introduced population-male groups.

of very rugged alpine terrain over 3350 m elevation. Topography is mostly steep cliffs, with rock outcrops and talus slopes. Tundra turf is in small patches on these sites. About 30% of the area is open tundra meadow and bogs.

The return to the low elevations is also not well documented for the males. Generally by early November the breeding males were back on the Fall River range with the females. Breeding activity was noted through November and December.

From what we can tell from the relocations made, males that are associated with the introduced sheep generally remain in the low elevation winter range through the winter, but are very mobile. Some may accompany the native rams as they move back to wintering areas in the North Fork and at Rock Cut. However, no marked sheep were observed with these groups.

Total population numbers in the introduced herd were difficult to obtain even with the presence of marked animals due to the vegetation density and size of the area utilized. The erratic movement also complicated such determination. The population is apparently increasing with high counts of 43 in 1982, 59 in 1983, 72 in 1984, and 70 in 1985. This is after the removal of 19 sheep for transplant purposes by the Colorado Division of Wildlife in 1983.

Through ground counts reproduction in the population was indicated by lamb/ewe ratios of 69/100, 68/100 and 52/100 in 1983, 1984, and 1985, respectively. These were made in the fall on the winter range so summer mortality is considered. The native herd appeared to have lower reproductive success with counts of 38/100, 60/100 and 41/100 in the same three years.

Kopec (1982) reported a lamb/ewe ratio of 57/100 in the 1979 Cut Off transplanted population 2 years after introduction in Montana. Similar ratios of 56/100, 53/100, and 49/100 were reported on a native herd in 1982, 1983, and 1984 respectively, on Trout Peak in Wyoming (Irwin and Hurley 1985). Considerably lower ratios were reported for the 1958 to 1977 period with an average of 34/100 for the Whiskey Mountain herds in Wyoming (Thorne et al 1979).

CONCLUSIONS

The results of this study indicate that the original hypothesis may be accepted. The introduced sheep have established a reproducing population that is wintering on the low elevation ranges which had been historic bighorn habitat but not used in recent years. They migrate annually to the high elevation alpine ranges where they spend a portion of the summer sympatrically with the native sheep. The return to the winter range is usually complete by October. The objectives of the 1977 transplant have therefore been met.

The erratic movements to and from the high elevation ranges, and fairly recent pioneering to Castle Mountain may mean, however, that the movement patterns are not absolutely set and new movement behavior still may develop.

The appearance of the native rams on the fall range of the introduced females during the breeding season suggests that interbreeding of the two populations exists. This, of course, could improve the genetic variability and reduce any deleterious effects of inbreeding in the Mummy Range population.

The results of this transplant effort indicate that transplanting even in the close vicinity of a native herd can be used successfully to expand the range use of a population. This can perhaps alleviate some of the problems of bighorn that have been reduced to a small portion of historic range and may be vulnerable to die-off conditions.

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CIRCADIAN ACTIVITY RHYTHMS OF CHAMOIS IN NORTHERN TYROL, AUSTRIA

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Abstract: Circadian activity of chamois (Rupicapra rupicapra) was studied both by direct observation and by radio-tracking. Activity rhythms were characterized by two main peaks which coincided with the crepuscular intervals. Secondary peaks were apparent at mid-morning, mid-afternoon and midway through the nocturnal period. Individual activity patterns varied within a herd during most of the diurnal period but were highly synchronized at dawn and dusk. On the average, chamois were active between 13.6 and 14.5 hours per solar period throughout the year. General activity was highest in late fall and winter and lowest during the spring and early summer. During the snow-free months, feeding bouts/24-hour period were more numerous and of shorter durations than during winter. The length of activity bouts varied from 10 minutes to over 10 hours in the course of the year (mean: 2½ hours). Resting periods were considerably shorter than feeding bouts and ranged from 7 minutes to 5 hours (mean: 1½ hours). The pattern of resting and feeding shown by an individual varied from one day to another. Nocturnal activity was substantial (up to 5½ hours/night) especially in the fall. Nocturnal feeding bouts were significantly shorter than diurnal bouts. Clouds, fog and light to moderate rainfall had no effect on chamois activity rhythms. Chamois sought shelter and became inactive during thunderstorms and blizzards accompanied by high velocity winds. Very high (21°C to 30°C) temperatures, deep or heavy, coarse snow as well as non-supporting crust reduced chamois activity.

Activity rhythms of a species may be influenced by season, habitat type, disturbances, social interactions or climatic conditions. Changes in feeding and resting rhythms reflect the energy requirements of an animal at different times of the year.

The chamois, being an ungulate endemic to the alpine and subalpine zones, feeds mostly in treeless, open habitat. Resting periods on the other hand, are spent primarily in deep, cool gullies or creek beds, underneath cliffs or in the shade of trees. Chamois are thus easier to census and to hunt when active.

Studies of the activity rhythms of free-ranging chamois have been limited to observations during the daylight period and to a particular season (Briedermann 1967, Daenzer 1978, Pachlatko 1980). Zuber (1977) observed activity rhythms of captive chamois in a large enclosure for one year. He used an infrared night-viewing device and reported extensive nocturnal activity, especially in fall and winter. Daenzer (1978) noted that free-ranging chamois grazed before sunrise and after sunset during wither. None-the-less, the existing literature on chamois life history presents the species as an almost exclusively diurnal ungulate (Fuschlberger and Nerl 1969, Knaus and Schroeder 1975, Briedermann 1976).

The present study investigated activity rhythms of free-ranging chamois on a year-round basis both by direct observation and by radio-tracking. To establish the extent of nocturnal activity, one animal was monitored continuously through all seasons using an activity sensitive radio collar and an automatic event recorder.

STUDY AREA

The study area measured roughly 30 km^2 and was part of the Karwendel Mountain Range in Northern Tyrol, Austria. Elevations ranged from 920 to 2060 meters. Forest, composed mainly of fir, spruce and beech comprised 60 to 65 percent of the study area. Extensive alpine pastures above elevations of about 1600 meters were rarely interrupted by patches of mountain alder or dwarf pine. Precipituous cliffs, screes and fellfields with locally extensive growth of dwarf pine occupied the highest elevations. Mean annual precipitation in the study area varied between 1450 and 1850 millimeters.

Summer and winter temperature extremes were measured at +32°C and -25°C respectively with an average of +5.5°C during three years of study. Yearly snow accumulation reached about 400 centimeters. Continuous snow cover was present from mid December to mid April.

Chamois in the study area were subjected to a number of disturbances. A system of hiking trails allowed tourist access to all elevational zones during the snow-free period. Hikers frequented the region from early June until late September. An alpine ski-resort comprised about 20 percent of the study area. Skiers frequented the study area from late December until early April. Use of habitat by livestock was intensive both above and below timberline from July to September. Logging was practiced year-round. Chamois hunting season lasted from August 1 to December 31 each year.

METHODS

Field Observations

The studied population (approximately 350 to 400 animals) included 12 individuals with ear-tag radio-transmitters (powered by solar energy) as well as 26 animals with numbered plastic ear-tags and 27 naturally recognizable individuals (broken horns, pelage anomalies). Telemetry and visual surveys of known chamois were conducted 2 to 6 times per week from 1981 to 1983. Surveillance routes and times were altered from one session to the next. The activity of each known animal was recorded upon location. If on its feet, the chamois was considered active. All recumbent animals were considered as resting. Wherever the focal individual was sighted in association with other chamois, both the predominant activity and the degree of activity synchronization in the group was recorded. Activity rhythms of known chamois were observed for extended periods and comparisons were made between simultaneously observed animals. During late summer, when female chamois formed large herds (up to 90 individuals), the numbers of active and resting animals in a herd were recorded at 15 minute intervals throughout the diurnal period. Checks or nocturnal activity were made whenever light conditions allowed.

Event Recording

A Burchard and Reinchenbach, type 294078-A radio collar with a mercury activity switch was used. Activity was monitored and recorded by a B. and R. receiver, type 287178, connected to a Metrawatt recorder, type Miniscript-D. The unit was weather-proofed, equipped with a whip antenna positioned 5 meters above ground and installed in the test animal's home range. Activity records were printed on a calibrated carbon paper ribbon which was replaced every 11 days.

To calibrate the equipment, a captive, ten-year-old female was initially fitted with the activity collar. She was fed supplements regularly, but also consumed natural food available in the enclosure. The activity rhythms of this female were recorded simultaneously by the event recorder and by an observer for 48 hours. A 95 percent correspondence was found between visual and mechanical records.

The event recorder distinguished three distinct behavioral modes. A continuous movement of the mercury switch was apparent when the animal was feeding and moving around (Figure 1a). Field observations revealed that undisturbed chamois grazed almost continuously even during long-range, goal-oriented movements. When no activation of the mercury switch took place, the test animal was resting. This was the case whenever the neck was held upright during rumination or surveillance of the environs in a sternally recumbent position (Figure 1b). The recorder could also identify sleep with the head down whenever the animal lay flat on its side or on the sternum (Figure 1c). Both the sleep (head down) and rumination (head up) modes were pooled and treated as rest for data analysis.

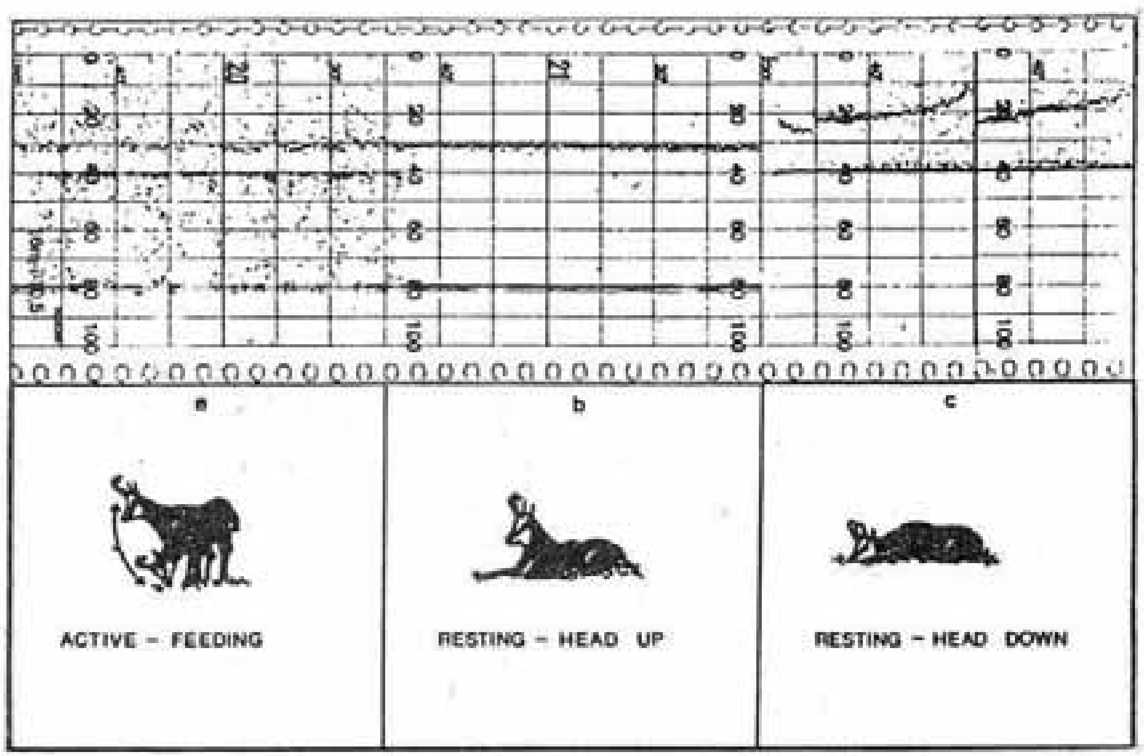

Figure 1. Three behavioral modes distinguished by the event recorder: a. activity, b. rest-rumination, c. rest-sleep. Horizontal number sequences on carbon paper ribbon indicate signal frequency; vertical number sequence indicates time.

A possible source of error arose whenever the test animal browsed or fed on cliff vegetation. In such cases, the neck remained upright, thus preventing switch activation. Since chamois in the study area clearly preferred ground vegetation to other food throughout the year (Perle and Hamr 1985), the chance of error occurrence was presumably very small. Nevertheless, the mechanical records may somewhat under estimate actual activity totals. This would be the case especially during winter when chamois preferred steep, snow-shedding cliffs and when thick snow crust induced browsing.

A free-ranging yearling male was fitted with the activity collar in the beginning of August 1983. The animal was darted with a Tel-inject-Vario 2 air gun and narcotized by a mixture of Rompun (Xylazine) and Vetalar (Ketamine). The yearling was monitored for almost 10 months. During this period, continuous recording of activity rhythms was attempted. Reception was usually interrupted whenever the test animal moved more than 1 km away from the recorder. Depending on the accessibility of the new location and on the snow conditions, up to one month elapsed before recording could be continued. Signal reception was also sporadically subject to disturbances by planes vehicles and by portable radio-transmissions. Twenty-four hour records with interruptions amounting to more than 72 minutes (5 percent) were not used for data analysis. The yearling was periodically located during daylight and observed continuously for up to 7 hours. His activity was compared to that of simultaneously observed animals belonging to the same herd.

Climatic Influences on Activity

Weather records (daily temperature, duration and amount of precipitation, snow depth) were obtained for the 1981 to 1984 period from a meteorological station located in the study area. In addition, a number of weather data were recorded with each field observation: wind speed (0-3), fog density (0-3), snowfall or rainfall intensity (0-3), cloud cover (0-¼-½-3/4-1), depth of snow (cm), quality of snow (5 categories).

Data Analysis

Data was examined for solar period as well as seasonal and climatic influences on several chamois activity parameters. Analysis of field observations was performed by utilizing SPSS programs (Nie et al. 1975). The numbers of "active" and "resting" records were cross-tabulated with respect to each temporal or climatic factor. Raw chi-square was used to test for significance. Seasonal differences in activity rhythms obtained by the event recorder were tested by Kruskal-Wallis one-way analysis of variance (Siegel 1956). In all tests, a significance at p 0.05 was accepted. Mechanical recordings of activity were chronologically charted and tallied by computer using a program developed during the study (Mayr 1984).

RESULTS

Field Observations

A total of 1239 activity records were compiled by observations during 2.5 years. The diurnal data produced a biomodal activity curve. The main peaks coincided with the crepuscular periods. Two secondary peaks were apparent at mid-morning and mid-afternoon.

Seasonal differences in the frequencies of active chamois sightings were significant. Activity was observed more frequently during winter than during the other seasons (Table 1). The highest percentages of active records were registered in February, March and April (84, 82.5 and 86 percent, respectively). Chamois activity decreased in late spring and early summer. In May, June and July, the sightings of active animals comprised 74.5, 67 and 71 percent respectively. A marked increase in the frequency of active chamois sightings was registered again in September (78.5 percent).

Table 1. Seasonal differences in the proportion of "active" to "resting" field records.

Records	Winter	Spring	Summer	Fall	Totals
active	328	78	259	295	960
resting	67	32	87	93	279
% active	83	71	75	76	p .005

Continuous observation of individual chamois revealed an activity pattern composed of feeding bouts alternating with resting periods typical for most ungulates. The length of 62 diurnal feeding bouts recorded mostly during the snow-free period varied from 9 minutes to 2.5 hours (mean: 73 minutes). Activity bouts tended to be shorter from mid-morning to mid-afternoon (9-90 minutes) and rather extended just after sunrise and before sunset (45-150 minutes). The length of 35 recorded resting periods varied between 7 minutes and 1.7 hours (mean: 47 minutes).

The activity of individuals within a herd was heterogeneous during most of the day but became highly synchronized at dawn and at dusk (Figure 2). Uniform group activity was seen less frequently from late spring to late fall than during the winter. This was apparently due to the break-up of large summer-fall herds on winter ranges. The smaller the group the greater were the chances of observing uniform behavior of all its members.

Nocturnal data collected by observation were of a highly anecdotal nature. Several records of chamois activity were made during late summer and fall in open terrain on clear, full-moon nights. Feeding activity could also be monitored in total darkness by listening to the sounds of falling rocks, released by chamois grazing on steep slopes. Nocturnal rutting activity was apparent from courtship vocalizations of males competing for mating rights.

Event Recording

The yearling male covered an area of approximately 6 km^2 while his activity was monitored. The event recorder had to be relocated five times.

Although several gaps occurred in the recording, distinct seasonal and daily activity patterns are apparent. The test animal was active at night throughout the year. The onset of diurnal activity correlated with relatively high light intensity during or just after sunrise. Evening activity on the other hand, usually continued until well after sunset. The longest feeding bouts usually occurred at the start and at the end of the day. The pattern of feeding and resting bouts produced by the test animal on successive days was at times very similar but never identical.

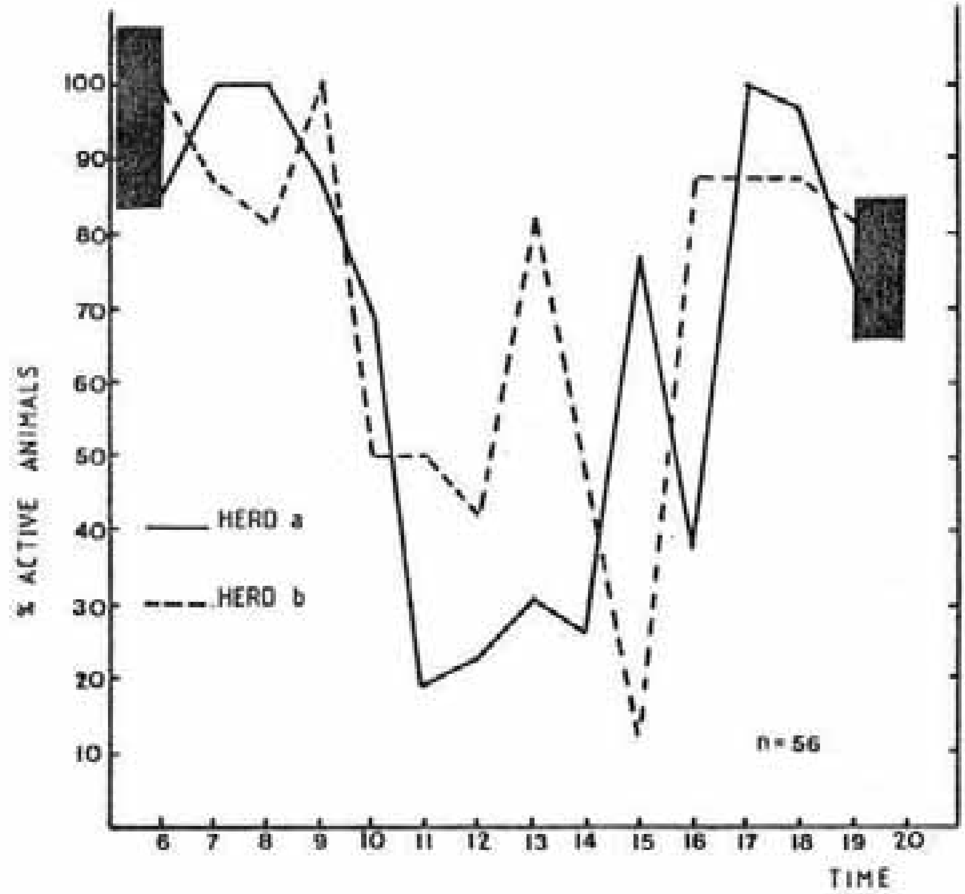

Figure 2. Diurnal variability in activity synchronization among the members of two female herds observed simultaneously in late summer. There were 26 chamois in herd a and 16 in herd b. The number of active animals in each herd was recorded every 15 minutes from dawn to dusk. Data were pooled for each hour. Shaded regions represent crepuscular periods.

The bidmodal nature of chamois activity rhythms was confirmed by the yearling's 24-hour activity cycles both in the winter and in the snow-free period. The diurnal portion of both curves corresponded closely to the activity cycle obtained by field observations (Figure 3). The overall degree of diurnal activity (measured by the percentage of active records at a particular time of day) shown by the yearling was somewhat higher during the winter than in the snow-free period. This was also in accordance with field observation data. The peak in nocturnal activity was shifted from around midnight during the snow-free period to around 02:00 hours during winter.

Seasonal differences in activity parameters between four time periods characterized by several close to perfect 24-hour records were tested for significance. These periods corresponded to: a. late summer - early fall b. early winter c. later winter - early spring d. late spring. Although a slight increase was apparent from early fall to early winter, the circadian activity totals remained more-or-less constant throughout the year at about 14 hours per solar phase. The daily and nightly activity totals for the yearling correlated with the length of daylight and darkness respectively. The number of activity bouts per 24 hours was significantly higher during the snow-free period than during the winter. The number of activity bouts per diurnal period during

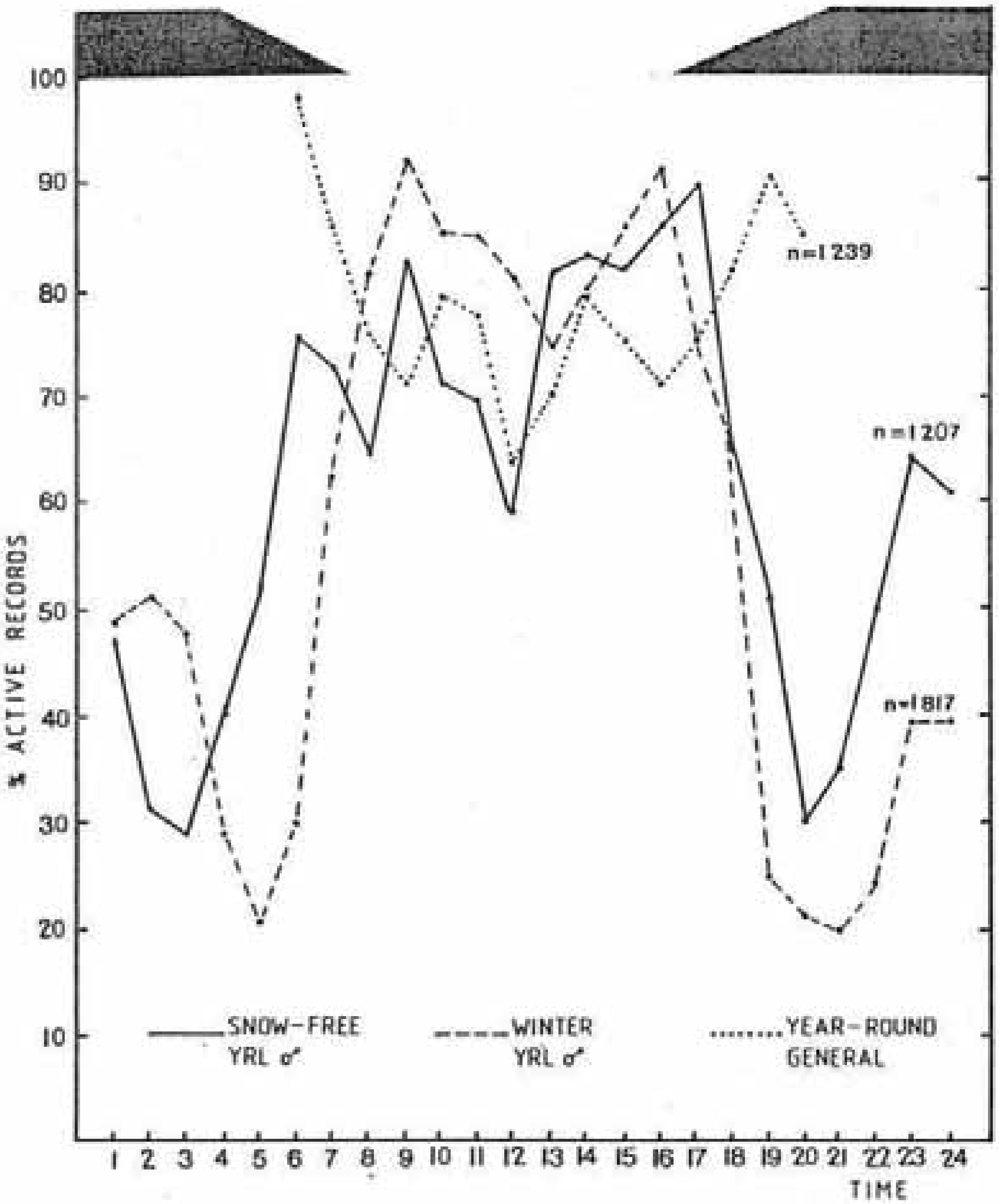

Figure 3. Daily activity rhythms of the studied chamois. Dotted curve represents pooled data obtained by year-round field observations of diurnal activity. Solid curve represents circadian activity data from the snow-free period recorded mechanically for the yearling male. Dashed line shows the yearling's winter activity rhythm. The curves were constructed by computing the percentage of "active" records for each hour of the solar phase. Shaded regions represent the duration of darkness at different times of the year.

spring was more than double that in early winter. Also the difference in the length of diurnal activity bouts between these two seasons was striking (Table 2).

The highest number of activity bouts per night was recorded in early fall (mean: 4.36). This number gradually decreased in the course of the winter until it was reduced by ½ in late spring. Diurnal activity bouts lasted two to three times the length of nocturnal activity bouts regardless of season. The duration of nocturnal feeding bouts remained relatively constant throughout the year (Table 2).

Sporadic visual comparisons of the yearling's activity rhythms to those of other chamois revealed no major differences. As expected, adult females were somewhat less active than the physically and socially developing male. Even though individual differences in the distribution of activity bouts were apparent, the total amount of activity shown over an extended period varied only little from one animal to another within a herd.

Table 2. Seasonal differences in the activity rhythms of a yearling male chamois.

	SEASON								
	a. Late summer-early fall		b. Early winter		c. Late winter-early spring		d. Late spring		
Parameter	N	$\bar{x}$	N	$\bar{x}$	N	$\bar{x}$	N	$\bar{x}$	p
total activity/ 24 hrs.	8	14.53	8	14.14	23	13.65	16	14.01	0.3
total activity/ day (hrs)	8	9.78	8	8.43	23	10.75	16	11.71	.001
total activity/ night (hrs)	8	4.47	8	5.53	23	2.68	16	2.16	.001
no. of activity bouts/24 hrs	8	8.13	8	5.38	23	4.79	16	8.11	.001
no. of activity bouts/day	8	4.58	8	2.45	23	3.32	16	6.39	.001
no. of activity bouts/night	8	4.36	8	3.56	23	2.31	16	2.25	.001
length of diurnal bouts (hrs)	38	2.22	20	4.39	73	3.57	101	1.93	.001
length of nocturnal bouts (hrs)	27	1.09	23	1.61	37	1.23	30	1.01	.05

Climatic Factors

Cloud cover, fog density and rainfall intensity did not alter chamois activity rhythms. Low to moderate snowfall seemed to stimulate chamois activity (Table 3). Chamois sought shelter and reduced feeding activity during extreme weather fluctuations (thunderstorms, blizzards) accompanied by strong winds.

The frequency of sightings of active chamois was indirectly proportional to temperature (Table 3). On extremely hot days (temperatures: 28°C to 32°C) diurnal feeding activity was virtually limited to early mornings and late afternoons. At mid-day, chamois rested in shady, cool locations. Although there was some evidence that chamois reduced feeding activity during extremely cold winter nights (temperatures below -15°C), sufficient data could not be obtained to prove this.

Table 3. The effects of climatic factors on chamois activity.

Climatic factor	Intensity	Resting records	Active records	% Active records	p
cloud cover	0	69	279	80	
	¼	61	197	76	
	½	35	126	78	0.55
	3/4	27	88	76	
	1	89	266	75	
fog	0	248	852	77	
	1	2	13	87	
	2	23	76	77	0.44
	3	8	15	65	
rainfall	0	238	842	78	
	1	20	45	69	
	2	22	68	76	0.29
	3	1	1	50	
snowfall	0	248	834	77	
	1	18	48	72	
	2	11	70	86	0.04
	3	4	4	50	
wind speed	0	182	708	74	
	1	35	105	75	
	2	43	101	70	0.02
	3	21	42	67	
temperature (°C)	-10- 0	46	200	81	
	+1-10	73	267	78	
	+11-20	126	412	77	0.049
	+21-30	36	78	68	

The depth and the quality of snow significantly influenced chamois feeding activity. The frequency of activity chamois sightings decreased with increasing snow depth. Coarse, heavy late winter snow and non-supporting crust also decreased chamois activity. On the other hand, compact or dry, light snow as well as a supporting crust favored foraging activity. A marked increase of chamois activity was noted whenever snow was shed off steep, south-facing slopes (Table 4).

Table 4. The effects of snow conditions on chamois activity.

		Resting records	Active records	% Active records	p
snow depth (cm)	0	144	476	77	
	1-20	26	103	80	
	21-50	27	92	77	
	51-100	16	40	71	0.001
	101+	2	1	33	
	shed	20	167	89	
snow quality	dry	25	109	81	
	wet	47	169	78	
	non-support. crust	17	53	76	0.005
	coarse	29	41	59	
	support. crust or compact	16	80	83	

DISCUSSION

The present investigation confirmed and enhanced the results obtained in previous studies of chamois diurnal activity rhythms. It also showed that free-ranging chamois are active at night throughout the year.

Feeding activity of ungulates is not uniformly distributed over the 24-hour period. The characteristic bimodal pattern with overt peaks at dawn and dusk was shown by chamois in different parts of their domain (Briedermann 1967, Daenzer 1978, Pachlatko 1980) and in captivity (Zuber 1977). Such activity rhythm is also typical for red deer (Cervus elaphus) (Georgii 1980), roe deer (Capreolus c.) (Turner 1980) as well as the mountain goat (Oreamnos americanus) (Fox 1978). These results suggest that the crepuscular periods serve as cues ("Zeitgeber") for the synchronization of these species' activity rhythms. In accordance with the results of the present study, both Briedermann (1967) and Zuber (1977) noticed that sunrise was much more effective as an initiator of chamois feeding activity than sunset was as an activity terminator.

Turner (1978) suggested that de-synchronization of activity during the day is due to the variable digestion times of foods selected by the individual animals. There is also some evidence that food intake of subordinate chamois in a group is less efficient than that of more dominant animals due to social stress (Lovari and Rosto 1985). Nutritional requirements and therefore food intake presumably differ between sexes, age classes and barren as opposed to nursing or pregnant females. These factors further contribute to activity de-synchronization within a population. De-synchronization of individual activity rhythms within a chamois group seems to function as a method of danger detection. Resting animals usually survey the surroundings and alarm feeding group members if danger approaches. This was especially apparent from mid-morning to mid-afternoon during the snow-free period when the highest numbers of human intruders frequented the study area.

Considering how little quantitative data has been obtained on chamois nocturnal activity, it is surprising how many authors labeled the ungulate as entirely diurnal (Knaus 1960, Christie 1967, Briedermann 1967, Pachlatko and Nievergelt 1985). Briedermann (1967) cited several reports by incidental observers on chamois activity during full-moon nights but considered these cases unusual. He correctly estimated the total duration of chamois diurnal activity at 10 to 10½ hours in summer and compared this figure to the activity budgets reported for roe deer and red deer by Bubenik (1959 and 1960). Since the estimate of total diurnal activity for chamois already exceeded the 24-hour activity totals for both cervids, Briedermann (1967) concluded that any additional chamois activity would not be possible during the night at the expense of rumination and sleep.

Ungulate circadian activity budgets differ from one species to another and the direct application of results obtained for the member of one taxonomic group to another is highly questionable. For example, ibex (Capra ibex) are active predominantly during daylight (Georgii 1978, Daenzer 1978), whereas red deer feed mostly at night and during the crepuscular intervals (Georgii 1980, Georgii and Schroeder 1983). The two species also show differences in the length, number per unit time and temporal location of feeding bouts.

A herd of 9 captive chamois was night-active on the average 51 minutes during summer and 4.5 hours during winter (Zuber 1977). Diurnal activity totals varied from 6.5 to 8.5 hours in the course of the year. Generally lower activity would be expected in animals fed ad-libitum year-round and restricted in movement as compared to those in the wild. However, all seasonal activity trends shown by the captive chamois were remarkably similar to those found in the present study. The captive chamois also gradually increased their general activity from a low during the summer to a high in winter. The changes in circadian activity totals were not as pronounced in the course of the seasons as the changes in diurnal and nocturnal activity which varied with the length of each respective solar phase. The marked similarities among activity rhythms shown by captive as well as free-ranging chamois in different habitats suggest that the activity pattern is endogenous to the species. Unless extreme, environmental factors probably have only a minor effect on activity budgeting.

The present results showed that chamois interrupted normal feeding activity cycles only at very high temperatures or during periods of high velocity winds and extreme precipitation. Chamois in the Elbe Sandstone Range (Czechoslovakia) also decreased their activity during intense rainfall and thunderstorms. Cases of chamois summer mortality due to lightning are frequently reported by game wardens in the Alps. Turner (1980) found that winds of high speed negatively influenced the activity of roe deer and hypothesized disruption of scent-localizing abilities important in predator avoidance.

Chamois in the Alps seem to increase feeding time during winter in order to compensate for the decline in forage quality and availability. The same strategy was observed in red deer on the island of Rhum (Clutton-Brock et al. 1982). However, when snow conditions are adverse, energy losses incurred by locating widely spaced, not readily attainable forage probably override the gain represented by ingested food and chamois remain stationary. In the spring, chamois slowly recover from the hardships of the winter. Still in winter pelage, they avoid heat stress by reducing activity and rest in the shade of trees or on the remaining snow patches. The new vegetation is abundant, attainable with minimal effort and of high nutritional quality. As summer progresses, days become shorter, temperatures gradually drop and the quality as well as palatability of forage worsen. These changes induce chamois to feed longer and to rest less. A high level of activity is reached by the rutting season in late fall. The about two week long rut represents the yearly activity peak especially for mature bucks.

Although the present study did not consider differences in activity rhythms among chamois sexes or age classes, some variations are likely. In bands of ibex, yearlings fed over 1 hour longer and rested about 2 hours less during daylight than six-year-old males (Schaerer 1977). Briedermann (1976) observed old chamois males resting and feeding in longer spurts than younger animals thus producing fewer activity bouts per day. Zuber (1977) compared the seasonal activity rhythms of three age classes of captive chamois: mature females, yearlings and kids. The year-round activity of yearlings was higher than that of mature females and slightly higher or equal to that of kids. This would be expected since neither kids or yearlings have completed body-growth and thus have higher nutritional requirements than adult animals. These findings can be used in the present study as a reference for relating the activity rhythms of the radio-tracked yearling to the rest of the population.

Although frequent, human induced disturbances had limited effect on chamois activity. It was expected that diurnal activity cycles would be disrupted during the period of most frequent human intrusions into chamois ranges (June-September). However diurnal activity showed no unusual fluctuations during these months. This suggests that chamois in the present study area were strongly habituated to the presence of humans in their environment. In view of the alarming increase of year-round recreational activities inside preferred chamois ranges during the last two decades, further investigation of human influences on chamois behavior is necessary.

The present study answers only some of the questions important to efficient chamois management. It is intended as an impulse to initiate a larger scale, more detailed study of those factors which influence chamois activity rhythms. Thorough knowledge of how a game species' behavior is affected by man-induced changes to the environment should allow the wildlife manager to adjust management practices according to the objectives of both the public and the animal concerned.

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QUESTIONS AND ANSWERS

Mike Scott, Idaho: I'm curious to know how long those animals were on a lichen diet and what their general condition was in the spring time?

Joseph Hamr: They were never on a purely lichen diet. That was only after periods of very intensive snow fall. Sometimes there would be up to 1 or 1 1/2 meters of snow dumped within 3 or 4 days. During these periods they would take primarily lichen off branches and tree trunks. But generally they would feed on grass through the winter that they pawed up, or as soon as bare patches appeared on south facing slopes they would go to those. Even so, there's quite a bit of winter mortality every year, especially during severe winters because chamois will not accept supplementary feed during the winter. Except for a few males that will pop up at deer feeding stations, you can't feed them. Winter mortality was quite high in some years...up to 50 or 60 animals within that study area, and those were just the ones that were found. The dead were mostly kids and males seven years old and older. Most dead chamois were usually found in April.

No Name: I was wondering why they don't winter above the tree line? Are there open slopes above tree line? Ecologically they seem similar to our sheep during the summer, but very different during the winter.

Hamr: Yes, generally above the tree line there's a lot of snow and a very high danger of avalanches. Chamois tend to move into the forest because they find more food there. There's no food above the tree line. There is a lot of snow, and perhaps the ski resort in my study area was a factor in pushing chamois into the forest. But there are ibex in the study area that stay on the highest ridges throughout the winter.

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TRACE ELEMENT LEVELS IN MONTANA BIGHORN SHEEP HORNS

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Abstract: In an effort to develop a tool for law enforcement use, multi-element scans were done on 112 bighorn sheep horn samples from 21 Montana hunting districts. The hunting districts were grouped into 8 geological regions for comparison. A total of 16 different elements were recorded from the samples. The mineral contents of individual samples were not specific enough to allow definite pinpointing of their area of origin. However, a key was developed which allowed samples from hunting areas having an unlimited number of permits to be separated from districts having limited numbers of permits with a 99.2% efficiency. A comparison of the element data with published horn size data for the areas gave a significant inverse correlation between magnesium levels and horn size as well as with the combined aluminum and magnesium levels. Grass tetany, atmospheric acid deposition ("acid rain"), soil infertility and bound phosphorus appear to be hypotheses tenable with this horn size and mineral relationship.

Mineral analysis of hair samples from a variety of big game mammals gave rise to the hypothesis that it might be possible to analyze samples from sheep horns for trace minerals and identify the area from which the animal came. Similar analysis of feathers from waterfowl has enabled researchers to identify their areas of geographical origin. It was hoped that this would serve as an aid in law enforcement and in the control of bighorn sheep harvest.

The authors wish to express their appreciation to the many Montana Fish, Wildlife and Parks personnel who collected the samples; to Jodie Canfield and Bert Harting, who assisted in the preparation of the samples; and for the financial support of the North American Wild Sheep Foundation.

METHODS

Montana law requires that all bighorn sheep ram heads taken in Montana be registered and marked with a metal plug. The drill shavings were collected from most sheep hunting areas in Montana during the 1984 hunting season.

A standard 250 mg aliquot was weighed out from each sample. Any obvious contamination was removed and the sample was submitted for analysis.

Originally it was felt that the small size of samples would only permit the use of the very sensitive and expensive neutron activation analysis technique. However, after the samples had been obtained, it was found that they were large enough to permit multiple element scans by an atomic emission spectrum technique. This much cheaper technique permitted a ten fold increase in the number of samples that could be analyzed.

Spectra Inc. of San Diego, CA. analyzed the samples. They were charred, vaporized and their atomic emission spectra was photographically recorded. This technique permits small samples to be scanned simultaneously for the presence of 45 separate elements. The concentrations measured were accurate to within a factor of two.

The results were grouped according to the hunting area of origin. These were then grouped on the basis of the geology of the region of the state in which the hunting area was located.

RESULTS

A total of 112 samples from 21 hunting districts were analyzed (Fig. 1). These were grouped into 8 geological regions for comparison. Six to 12 different elements were identified in individual samples with 8 being the most common number. A total of 16 different elements were recorded from the samples (Al,Bo, Ca,Cr,Cu,Fe,Mg,Mn,Mo,Na,Ni,P,Pb,Si,Ti,Zn).

The concentrations of Ca and Na were too high to be used for comparisons while still obtaining adequate information about less abundant elements using this atomic emission technique. Seven elements had a high enough frequency of occurrence to allow meaningful comparisons (Al,Cu,Fe,Mg,P,Si,Zn). Table 1 summarizes the analytical results from this study.

The mineral contents of individual samples were not specific enough to allow definite pinpointing of their area of origin. However, the composite data indicates that various areas do tend to have distinctive tendencies in their element contents.

Rank comparisons for the means of the seven commonly occurring elements indicated that the Prairie-Breaks (hunting districts 620 and 760) tended to have the lowest overall concentrations of minerals. Six (Al,Cu,Fe,Mg,Si,Zn) of the seven common elements were recorded for the area and one (P) was not found. The mean levels of iron and zinc were the lowest of any of the areas. No trace elements other than these common ones were found in the samples. Since only four samples were

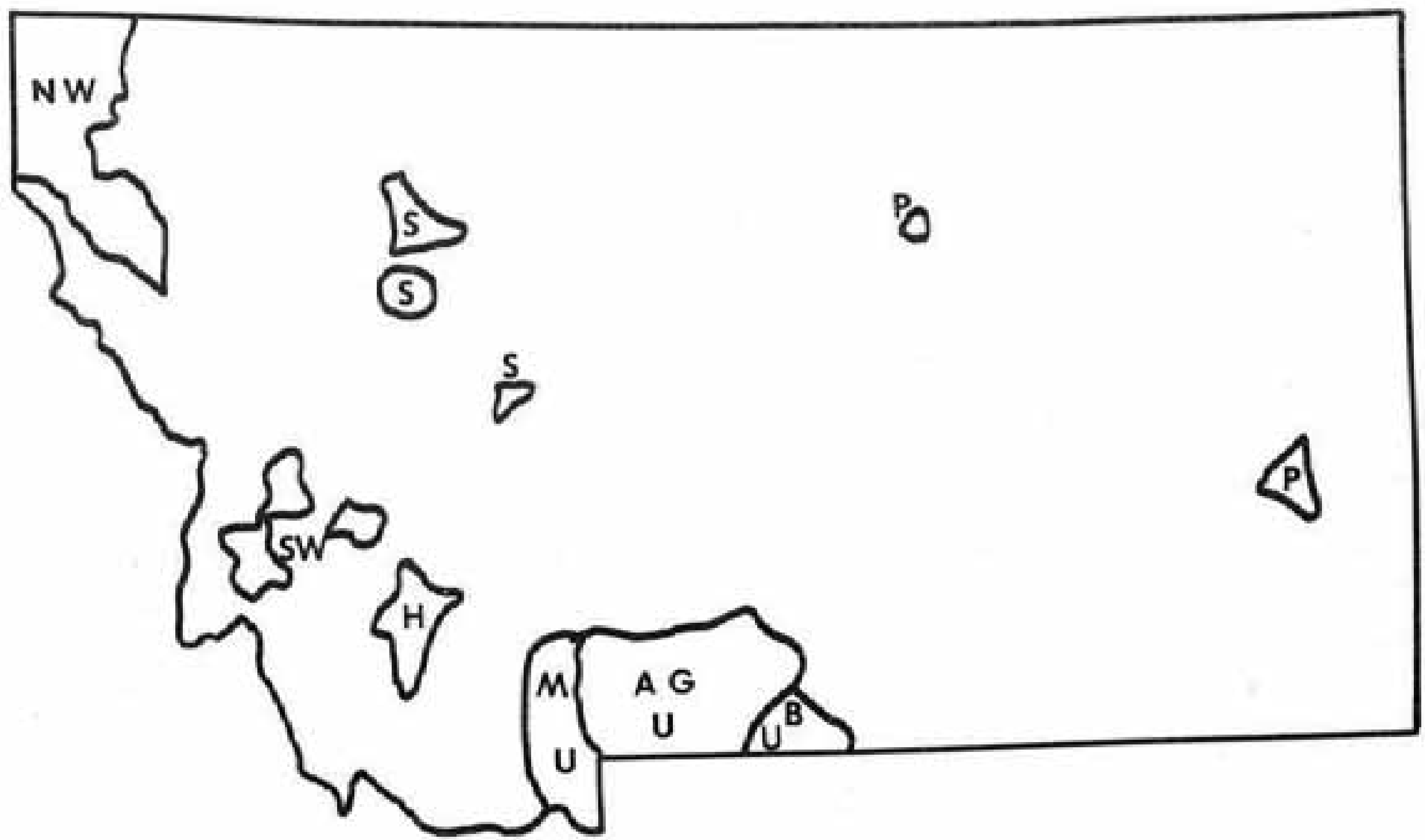

Fig. 1. A map of Montana showing the bighorn sheep hunting areas from which samples were obtained. All areas had a limited number of hunting permits except those designated for unlimited. P = prairie-breaks; S = Sun River-Belts; NW = Northwest; SW = Southwest; H = Highland; M = Madison; AB = Absaroka-Gallatin; B = Beartooth.

Table 1. A summary of the trace elements found in Montana bighorn sheep horns by region.

	Mean Concentrations in Parts per Million							
AREAS	North west	South west	Highland	Madison	Absaroka Gallatin	Sun River	Bear tooth	Prairie Breaks
n	17	18	12	12	25	17	7	4
ELEMENTS								
Al	9	20	71	65	77	5	80	15
Ca	All samples had over 1000 ppm							
Cu	4	6	4	6	4	3	6	4
Fe	36	12	14	25	20	26	14	11
Mg	17	172	35	179	156	79	279	138
Na	All samples had over 1000 ppm							
P	94	194	188	292	210	44	179	0
Si	113	51	30	73	121	19	48	39
Zn	112	325	346	254	300	79	279	38
OTHER ELEMENTS								
Freg.	59%	61%	17%	8%	32%	12%	29%	0%
	Bo	Bo	Bo	Pb	Bo	Ti	Pb	none
	Mo	Mn	Ni		Mn	Cr		
	Ti	Ni			Ni			
		Pb			Pb			
HORN VOLUME (as calculated from Stewart and Butts 1982)								
	198	196	192	135	161	174	125	---

available from these small hunting districts, the results should be interpeted with caution.

The Sun River-Belts area (hunting districts 421,424,441,455) was ranked second lowest in the overall abundance of the seven common elements. The levels of Cu and Si were the lowest of any of the areas. The mean levels of phosphorus were quite low and the area has sometimes been regarded as having soils low in this element. All seven common elements were present in samples from the area. Only 12% of the samples contained elements (Cr, Ti) other than the common ones.

While the Prairie-Breaks and Sun River-Belts areas were really fairly similar in overall mineral content, there was a substantial jump in the mineral contents of the next lowest area (Northwest Montana) over these two low ranked areas.

The third lowest ranked area in the mean concentration levels of the major seven elements was Northwest Montana (100 numbered hunting districts). All seven elements were found. These districts ranked lower than any other area in mean level of Al and Mg but highest in iron and second highest in silicon. Other elements were frequent (Bo,Mn,Mo,Ti) in these samples, occurring in 59% of the samples.

The Highland (hunting district 340) was the fourth ranked area. All common elements were present. The area ranked second lowest in mean silicon and magnesium levels and highest in the level of zinc. Other elements (Bo,Ni) were found in 17% of the samples.

The southwestern Montana area (200 numbered hunting districts) fell in fifth place in overall mean element abundance. The area ranked second lowest in iron levels and second highest in zinc levels. Other elements were found with greater frequency than in any other area (61%; Bo,Mn,Ni,Pb).

The sixth ranked area (Beartooth, hunting district 502) had the highest mean levels of Al and Mg and the second highest level of Cu. None of the seven common elements were particularly low. Other elements had a 29% frequency of occurrence (Pb).

The Absaroka-Gallatin area (hunting districts 300,303,500, 501) had the second highest mean levels of the more common elements. It showed the highest mean levels of silicon and the second highest of aluminum and phosphorus. Only iron was relatively low (3rd ranked). The frequency of occurrence of other elements was 32% (Bo,Mn,Ni,Pb).

The Madison area (hunting districts 301 and 302) showed the highest mean levels of the common elements. It ranked highest in phosphorus and second highest in copper, iron and magnesium. Only the Prairie-Breaks ranked lower in the occurrence of other elements (8%;Pb).

A binary key of the type often used for the identification of biological materials was developed and is presented in table 2. This key was developed to permit the separation of samples obtained in hunting areas having an unlimited number of bighorn permits (Beartooth, Absaroka-Gallatin, Madison) from all areas having a limited number of permits. One sample was found not to be correctly classified by using this key giving a classification efficiency of 99.1%.

DISCUSSION

The areas of the state which included geological substrates of primarily sedimentary origins tended to have the lowest occurrences of mineral elements in the horn samples. These included the Prairie-Breaks, the Sun River - Big Belts, and Northwest Montana (Alt and Hyndman 1972). Northwest Montana does have some mineral deposits of sedimentary origin and includes some mineralized areas on the edge of the Idaho batholith. It also includes the site of the largest silver producing mine in North America.

Areas whose geological substrates which include igneous base materials tended to have higher mineral levels. Many of these have had metal mining operations in them historically. These include the Southwest Montana, Highland and the Absaroka-Gallatin areas. The Beartooth area contains very old igneous rock. Mineralized zones are present but it should be noted that some of these sheep herds migrate to summer ranges in the Absaroka mountains (Martin 1985; Stewart 1975).

The Madison range contains primarily metamorphic and sedimentary rocks. Some igneous rocks are found in the portion of the range adjacent to Yellowstone Park. Little in the way of economic minerals have been found in the area. The element levels recorded for this area were quite similar to those for adjacent Absaroka-Gallatin region.

Comparison of the ranking of the areas according to overall mineral levels with the data for horn volumes of 3 year old rams (Stewart and Butts 1982) did not reveal a significant relation ($r=.57$, $n=7$). The two areas with the largest horns also had the highest mineral levels.

When horn size was compared with the levels of individual elements a significant negative correlation was found with Mg levels ($r=-.790$, $P=.025$). Combined aluminum and magnesium levels were also negatively correlated with horn size ($r=-.831$; $P=.015$). Magnesium imbalances, particularly low levels are associated with the "grass tetany" syndrome (Robbins 1983; Jones and Hanson 1985). This condition is encouraged by cool weather and reduced food intake (Church 1972). Its effects are pictured as producing episodes of illness and malnutrition during the spring periods critical for horn growth. Magnesium imbalance is also associated with eclampsia which could cause a loss of the fetus and mother with no effect upon horn growth. Magnesium and

Table 2. A key for classifying bighorn sheep horn samples as to their origin from unlimited permit hunting areas (Beartooth, Absaroka-Gallatin, Madison) or from limited permit hunting areas based upon mineral composition.

A. Have Mg levels of 500 ppm or more	-- 1	
Have Mg levels under 500 ppm	-- B	
1. Al level or Si level at or over 50 ppm		-- Unlimited
Al or Si level under 50 ppm		-- Limited
B. Have Si level at or over 250 ppm	-- 2	
Have Si level under 250 ppm	-- C	
2. Al level at or over 50 ppm		-- Unlimited
Al level under 50 ppm		-- Limited
C. Al level at or over 250 ppm	-- 3	
Al level under 250 ppm	-- D	
3. Zn level under 500 ppm		-- Limited
Zn level at or over 500 ppm	-- 4	
4. Fe level 50 ppm or more		-- Unlimited
Fe level below 50 ppm		-- Limited
D. Zn level 500 ppm or over	-- 5	
Zn level under 500 ppm	-- E	
5. Al level 100 ppm or more		-- Limited
Al level under 100 ppm	-- 6	
6. Si level under 50 ppm		-- Limited
Si level 50 ppm or over	-- 7	
7. Cu level of 10 ppm or over		-- Limited
Cu level under 10 ppm	-- 8	
8. Al level of 10 ppm or over		-- Limited
Al level under 10 ppm		-- Unlimited
E. Cu level of 0		-- Limited
Cu level not 0	-- F	
F. Fe level of 0	-- 9	
Fe level not 0	-- G	
9. Si level of 50 ppm or more		-- Limited
Si level of under 50 ppm	-- 10	

Table 2 continued.

10.	Al level 25 ppm or more		-- Unlimited
	Al level under 25 ppm	-- 11	
11.	Ni present		-- Unlimited
	Ni absent		-- Limited
G.	Zn level of 0	-- 12	
	Zn level not 0	-- H	
12.	Cu level under 10 ppm		-- Limited
	Cu level of 10 ppm or more	-- 13	
13.	Mg level under 100 ppm		-- Limited
	Mg level 100 ppm or over	-- 14	
14.	Fe level under 10 ppm		-- Unlimited
	Fe 10 ppm or over	-- 15	
15.	Pb present		-- Unlimited
	Pb absent		-- May be either limited or unlimited.
H.	Zn level 250 ppm or more	-- 16	
	Zn level under 250 ppm	-- I	
16.	Cu level 3 ppm or more	-- 17	
	Cu level under 3 ppm	-- 21	
17.	Al level under 50 ppm		-- Limited
	Al level 50 ppm or over	-- 18	
18.	Fe under 10 ppm		-- Unlimited
	Fe 10 ppm or over	-- 19	
19.	Si 50 ppm or over		-- Limited
	Si under 50 ppm	-- 20	
20.	Fe 25 ppm		-- Unlimited
	Fe 10 ppm		-- Limited
21.	Al under 10 ppm		-- Limited
	Al 10 ppm or over	-- 22	
22.	Fe level over 5 ppm		-- Limited
	Fe level 5 ppm or under	-- 23	
23.	Al over 50 ppm; Mg under 100 ppm		-- Unlimited
	Al at 50 ppm; Mg at 100 ppm		-- Limited

Table 2. Concluded.

I. Al level of 5 ppm	-- 24	
Al level over 5 ppm	-- J	
24. Si level is 0	-- 25	
Si level is not 0	-- 27	
25. Fe level under 50 ppm		-- Limited
Fe level 50 ppm or over	-- 26	
26. Fe level of 250 ppm		-- Limited
Fe level not 250 ppm		-- Unlimited
27. Si level of 5 ppm		-- Limited
Si level not 5 ppm	-- 28	
28. Zn level of 100 ppm		-- Limited
Zn Level not 100 ppm	-- 29	
29. Mg level of 100 ppm		-- Limited
Mg level not 100 ppm		-- Unlimited
J. Si level under 10 ppm	-- 30	
Si level 10 ppm or over		-- Limited
30. Fe 5 ppm or over		-- Limited
Fe under 5 ppm	-- 31	
31. Cu 3 ppm or over.		-- Unlimited
Cu under 3 ppm	-- 32	
32. Al at or over 100 ppm		-- Unlimited
Al under 100 ppm		-- Limited

aluminum are often the last elements leached from soils. High altitude soils are often heavily leached by snowpack melt. It also been noted that magnesium, aluminum and iron often form insoluble complexes with phosphorus and thus limit its availability (Robbins 1983). Phosphorus deficiency is a world wide problem and most of the forage that ungulates consume is of marginal adequacy (Church 1972). Phosphatases are important in cellular energy transfer and in the synthesis of keratin (Fraser et al 1972). It should also be noted that atmospheric acid deposition tends to mobilize Al and Mg to the point of toxicity to plants. Thus it is reasonably possible to hypothesize an involvement of "acid rain" in the horn size of bighorn sheep in Montana. It is uncertain at the present time which of these four hypotheses (grass tetany, acid rain, soil infertility, bound phosphorus) represent the best explanation for this negative correlation. The last three, separately or in combination, are the most likely. Management strategies ranging from range manipulation to provision of mineral supplements probably could be developed to counter these nutritional problems if it can be shown that they exist.

An unlimited number of bighorn sheep permits are sold for certain hunting areas in southern Montana (Beartooth, Absaroka-Gallatin, Madison). It is important to prevent hunters from killing an animal in a limited area under a permit for an unlimited area. This could result in a decrease in hunting opportunity and, in some situations, an overharvest in a limited area. The key (table 2), based upon grouping the unlimited areas together and then all limited areas together had good discrimination. The primary difficulty in its development was in distinguishing the Highland and Southwest Montana areas from the unlimited ones. It is important to test the key using another similar set of samples before it can be considered validated.

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QUESTIONS AND ANSWERS

Wayne Heimer, Alaska: I'm interested in arsenic. We've been working with the mineral industry in our country which is interested in gold. Gold and arsenic are chemically similar. They found some arsenic in some of our sensitive areas, and it wasn't in the places we thought it would be. We have, maybe, an interesting correlation between arsenic concentration and mineral licks and horn size. Arsenic, of course, is related to hair coat in low amounts. Did you find any arsenic?

Picton: No, the problem is that this particular method of analysis cannot identify arsenic. Arsenic is quite volatile, so when you run the sample it boils off before the other elements, so you have the choice of running for arsenic or running for the other elements. As a matter of fact, I've had some interest in arsenic too, but to run it you have to have enough material for duplicate samples, and the same thing would apply to mercury. Now there are some areas, for example, Yellowstone Park where you could conceivably have mercury influencing small horn size in some of these unlimited areas. But the problem is you can't test for mercury at the same time you test for these other elements. It would require a separate analysis and there are some areas in which mercury reaches levels which could be toxic.

No Name: Is there any correlation between the abundance, or presence or absence of mineral licks in some of these regions showing a relationship between magnesium and low horn size?

Picton: I'm not sure, that's something I haven't really looked at. Its an interesting question. My impression (now this is strictly off the cuff) is that there's almost a negative correlation, in that some of the areas that had relatively larger horns and low concentrations of minerals, had quite a number of licks in them. But in these southern unlimited permit areas, which are the areas that tend toward the small horns, we don't find much in the way of mineral licks. Very few in the Yellowstone area quite frankly. Dick Knight and I have spent a lot of time flying, and a lot of time trying to see evidence of licks in these areas. There are some, but they don't seem to be very extensive.

Jim Ford: Are you planning a study to show a correlation between the minerals and horn size?

Picton: I guess Charlie and I haven't really talked about it yet. I think that's the obvious thing to do, and I really would like to investigate it further. We had not prepared a proposal, but we have talked about it, and we'd like to do some actual soil fertility measurements and a few things like that to go along with this work.

Parasites and Disease

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EXPERIMENTAL PASTEURELLA PNEUMONIA IN BIGHORN SHEEP

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ABSTRACT: Pasteurella hemolytica biotype T non hemolytic variant, isolated from sick bighorn sheep (Ovis canadensis canadensis) during a die-off from pneumonia in Southern Alberta was used for pathogenicity studies in bighorn sheep (BHS) as well as domestic sheep. 10^{11} viable organisms were inoculated intratracheally into BHS and 10^{12} organisms into domestic sheep. Ten days later Pasteurella could not be recovered from tonsils or lungs of domestic sheep while the BHS had developed a lobar fibrinous bronchopneumonia from which the same Pasteurella variant was reisolated. Sham inoculated sheep remained without lesions and negative for Pasteurella.

Pasteurella hemolytica biotype T isolated from tonsils of healthy slaughtered domestic sheep was inoculated I.T. at a level of 10^{12} viable organisms into two BHS and caused mortality from pneumonia in 16 and 42 hours respectively. Pasteurella hemolytica type A, modified as a cattle vaccine, caused mortality from pneumonia and septicemia in five BHS three days after intradermal inoculation. Pasteurellosis can be reproduced in BHS without concurrent predisposing viral infection. Domestic sheep are refractory to the BHS pathogen while bighorns are susceptible to the BHS isolates and highly susceptible to domestic animal strains.

QUESTIONS AND ANSWERS

DeForge: Have you had serological survey work that might indicate that viruses have been present?

Onderka: There's a money restraint, of course, of how much we can do, and also the availability of serum from sheep that are found dead. We thought an isolate would be more meaningful than demonstrating the possible experience with the virus, but now we're getting interested in a serologic survey.

Kim Keating, Montana: I would like to make a comment regarding the pattern of the disease in Glacier National Park. Looking at strictly demographic indicators in Many Glacier or the northern portion of the park, we were seeing pretty much what Canada saw. Almost no lambs coming on the rutting ground following the disease, very low lamb/ewe ratio. In the southern part of the Park there was absolutely no indication that the disease ever hit, which leaves a very large block of country in there between where we know the disease was and the Sun River area, but apparently that population as near as we can tell was not affected.

Onderka: Thank you. We also see a very low recovery as far as lamb recruitment in those areas now. It seems to be probably two years or more before we see recovery on these herds. I'm not sure why that is.

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USE OF IVERMECTIN TO INCREASE LAMB SURVIVAL IN A HERD OF ROCKY MOUNTAIN BIGHORN SHEEP

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ABSTRACT

Population growth of a Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) herd is believed to be limited due to lungworm (*Muellerius capillaris*) induced mortality of lambs. Thirty-five of 93 ewes were treated with ivermectin during a preliminary study to decrease lungworm loads in ewes and to increase lamb survival. Treatments were administered orally (ivermectin mixed with a bait) or by subcutaneous injection. Oral treatment of free-ranging sheep was done by spraying the drug dose onto alfalfa hay. Oral treatments, at doses similar to those recommended for injection, were efficacious against *Muellerius*. Effects of treatment on marked ewes were analyzed by ewe group (comparisons among the east end (EE), west end (WE), and Grace Coolidge (GC) ewe groups) and by treatment group (injection, oral, or no treatment). No differences in larval counts among the ewe groups were found. No differences were found in the proportion of ewes lambing for either ewe groups or treatment groups, or in lamb survival among the treatment groups. There were also no differences in lamb survival among 2 ewe groups (partial treatment), but lamb survival in the third ewe group (untreated) was significantly lower ($P < 0.05$). Although treatment results from this preliminary study are not conclusive, ivermectin appeared to be efficacious against *Muellerius*, to reduce lungworm levels in bighorn sheep ewes, and to increase lamb survival. Advantages of using ivermectin over Cambendazole and Fenbendazole to treat bighorn sheep for lungworms are discussed.

INTRODUCTION

Habitat has been considered to be the most important criterion in selecting areas for reintroductions of Rocky Mountain bighorn sheep, with most reintroductions having been relatively successful (Geist

1974). However, factors other than habitat may also contribute to the success or failure of reintroduction programs. One such factor is the effect lungworms may have on survival and maintenance of a herd, particularly the survival of lambs.

Audubon's bighorn sheep (O. c. canadensis) were indigenous to the Badlands and Black Hills areas of South Dakota prior to European settlement in the 1800's but were extinct by 1916 (Buechner 1960). A herd of approximately 22 Rocky Mountain bighorn sheep from Wyoming were introduced into the Black Hills in Custer State Park (CSP), South Dakota (Fig. 1) in 1965 and subsequently increased to a level estimated between 100-150 animals in 1975 (Trefethen 1975). Although this introduction established a resident herd, now estimated to be approximately 90 animals, population growth between 1975-1985 has been virtually zero. Since natural mortality in yearlings and adults is believed to be minimal (Geist 1971), changes in the structure of the population are directly related to reproductive success and, especially, lamb survival. At best, recruitment of lambs in CSP bighorn sheep is thought to be only enough to maintain the herd at its present level.

Disease related mortality is responsible for a decline in the growth or size of many bighorn sheep herds. Epidemics attributed to the lungworm-pneumonia complex can be particularly severe on the lamb cohort (Forrester 1971, Hibler et al. 1972). Lungworms have been shown to predispose bighorn sheep to bacterial pneumonias, primarily caused by Pasteurella spp., which can be highly pathogenic (Forrester 1971, Post 1971, Hibler et al. 1972). Of particular importance is the effect of lungworm infection on the reproductive potential of bighorn sheep. Lungworms can adversely affect lamb survival both directly through heavy infections and indirectly by predisposing the lamb to secondary bacterial infections (Forrester et al. 1966, Woodard et al. 1974). Hibler et al. (1974) reported 95-98% lamb mortality within 3 months of birth in one herd of bighorn sheep they studied, with pneumonia cited as the major cause of mortality. With such deleterious lamb losses and resultant low recruitment, it is easy to visualize how lungworms could be detrimental to population growth of a bighorn sheep herd, regardless of how suitable habitat conditions may be.

The Muellerius lungworm is found to be ubiquitous among adult sheep in CSP (Pybus and Shave 1984, McCabe et al. 1985) and is suspected to be the major cause of lamb mortality. With 100% infection of the herd at high levels (as high as 15,000 larvae/gram feces [lgf, herein] in one ewe) in CSP bighorn sheep (McCabe et al. 1985), the possibility that most lambs in CSP are infected at birth is also very high. A significant reduction in lungworm burdens of pregnant ewes should reduce the possibility of fetal infection, resulting in a greater proportion of uninfected lambs being born. Absence of lungworms at birth would increase a lamb's chance of survival and ultimately increase recruitment to the population. Schmidt et al. (1979) reported that lamb survival

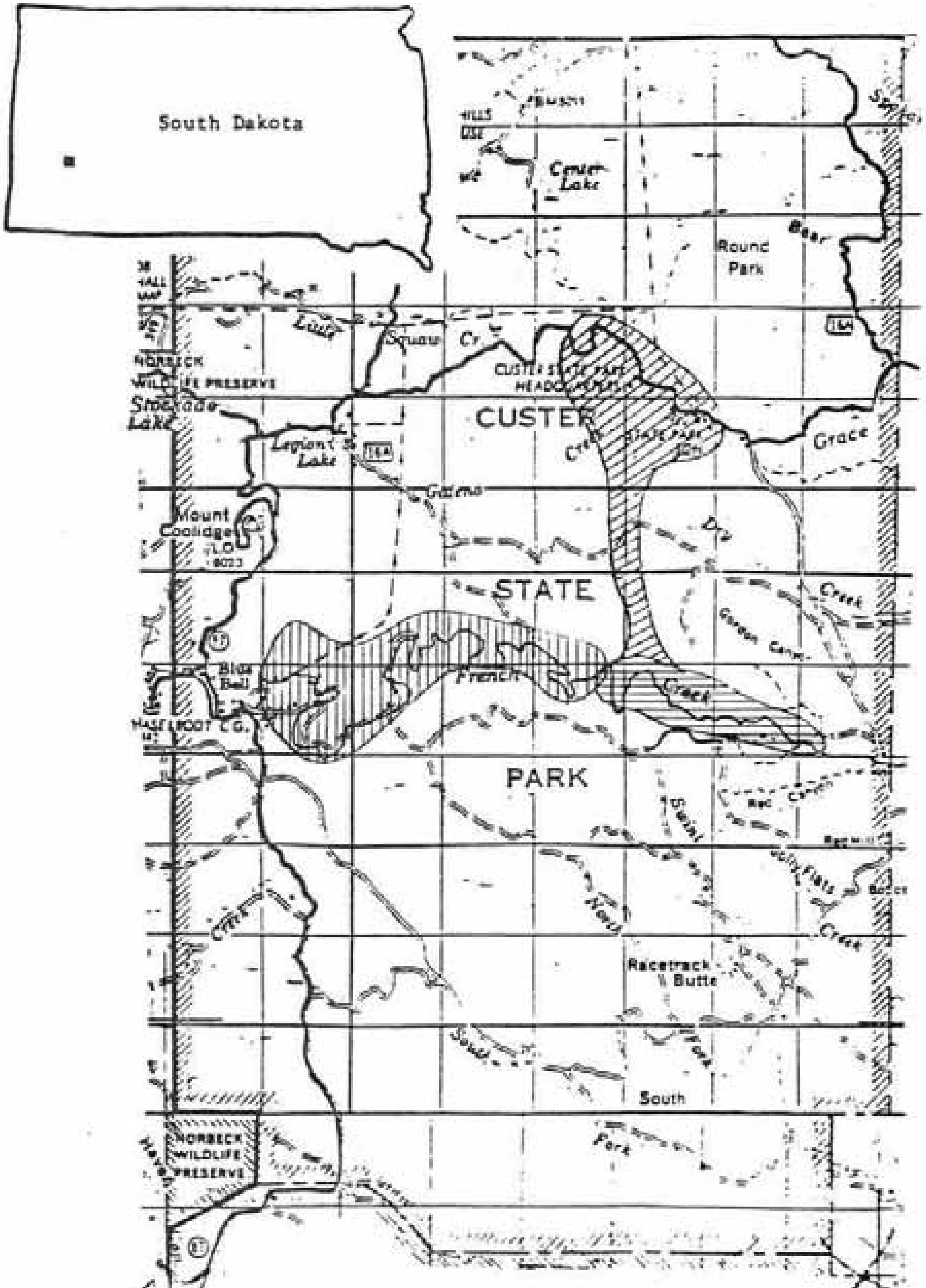

Figure 1. Location of French Creek Canyon and ewe groups in Custer State Park, South Dakota. Ewe groups: [hatched] Grace Coolidge, [horizontal lines] East End, [vertical lines] West End.

treated with anthelmintic drugs, indicating a causal relationship between bighorn lamb mortality and lungworm infection in ewes.

Objectives of this preliminary study were to evaluate the effectiveness of a relatively new nematocide, ivermectin, in reducing lungworm levels of *Muellerius* in adult Rocky Mountain bighorn sheep and to compare the lamb survival of a treated ewe group with that of an untreated group. This study is part of a larger research effort to investigate causes which have limited growth of the CSP bighorn sheep herd over the past 10 years and to provide recommendations for increasing herd size.

We wish to extend appreciation to Wayne Winter, Rollie Noem, and Warren Jackson of Custer State Park for their continued support of this study. Sincere thanks is extended to Hazel Shave for critical review of the manuscript. The enthusiasm of many undergraduate and graduate students in the Department of Wildlife and Fisheries Sciences at South Dakota State University is acknowledged. Funding was provided by a grant from the Foundation for North American Wild Sheep, Custer State Park, and the South Dakota Department of Game, Fish, and Parks. Reference to trade names does not imply endorsement of commercial products by the authors.

METHODS AND MATERIALS

STUDY AREA

Research was conducted in Custer State Park, South Dakota, which is located in the southeast corner of the Black Hills approximately 65 km southwest of Rapid City. Bighorn sheep ewes primarily inhabit French Creek Canyon, located in the central portion of the Park (Fig. 1). French Creek Canyon is approximately 19 km long and ranges from 140 to 270 m in depth. Elevations within CSP bighorn sheep range vary between 1160 to 1580 m. French Creek Canyon is characterized by steep, rugged walls with adjacent rolling meadows and Ponderosa pine (*Pinus ponderosa*) forests.

LAMBING SUCCESS AND SURVIVAL

Lamb:ewe ratios were calculated from ewe group counts made over 10 day intervals during the summer and fall of 1985 to determine an overall index of lambing success and lamb survival. The number of lambs and the number of ewes for each group observed were used. The number of each age class counted over the 10 day interval was summed and expressed as lamb:100 ewe ratios.

FECAL SAMPLES

Fecal samples were collected whenever fresh pellet groups were found. These included samples from marked, unmarked, and unidentified individuals. An effort was made to observe marked sheep long enough to collect a fresh, identifiable sample. Fecal samples were frozen and delivered to H. Shave at the Veterinary Diagnostic Laboratory, South Dakota State University, for analysis. Larval counts were determined using a modified procedure of the Baermann technique (Baermann 1917) where a Buchner funnel was not used.

Mean larval counts were calculated for each month from June through September 1985, for each age group (lambs and ewes), and for each ewe group. Means were compared using analysis of variance.

TREATMENT

CSP bighorn sheep ewes have segregated into 3 distinct groups, the Grace Coolidge (GC), east end (EE), and west end (WE) ewe groups (Fig. 1). All GC sheep captured in January 1985 were injected with ivermectin. Injections were made subcutaneously in the front shoulder region at a rate of 200 μg/kg body weight as recommended by the manufacturers. At this rate, dosages for ewes and lambs were calculated to be 200 μg and 100 μg ivermectin, respectively (McCabe et al. 1985). Ivermectin is known to have a safety margin of up to 20x normal dosage in domestic sheep, therefore accurate estimates of dosages were not critical (Campbell and Benz 1984).

In early March 1985, individuals in the EE group were treated orally with ivermectin. All sheep of each age class (ewe or lamb) present at the EE feeding site were counted and a total volume of ivermectin was calculated at rates of 300 μg ivermectin/ewe, and 200 μg ivermectin/lamb. This volume was poured into a hand spray bottle and sprayed onto approximately 20 kg of alfalfa hay which had previously been spread out. Treatment was repeated again after 2 days to insure that as many sheep as possible from this ewe group received an adequate dosage. The WE ewe group was used as the control. Comparisons were made among the 3 treatment groups (oral, injection, no treatment) and among the 3 ewe groups (GC, EE, WE groups) for proportion lambing and lamb survival using chi-square tests of independence. Only marked ewes were used in these comparisons. Also, comparisons of lamb:ewe ratios for lamb survival among the ewe groups, including marked and unmarked ewes, were made using a chi-square test of independence.

In December 1985, EE ewes were again treated orally with ivermectin. Fecal samples from this group were collected and analyzed for lungworm levels in order to monitor any significant changes in levels and assess whether ivermectin was efficacious against Muellerius when administered orally at the dosages prescribed above. Comparison of larval counts were made using analysis of variance.

RESULTS AND DISCUSSION

LARVAL COUNTS

Comparisons Among Months

A total of 310 fecal samples were collected between 1 June and 30 September 1985. Of the 310 samples, 262 were from ewes and 48 from lambs. Lungworm counts for ewes were highest in June with a mean of 887 lgf (n = 57). Counts decreased by about half this number in July (491, n = 74) and were even lower in August (201, n = 100) and September (228, n = 31). The distribution of these counts are comparable to previous years (1983 and 1984) when counts decreased over the summer (McCabe et al. 1985).

For lambs, fecal counts were lower in June (3 lgf, n = 6) and July (6, n = 13) than in August which had a mean of 20 lgf (n = 16). In September, counts dropped to 6 lgf (n = 13); these levels were comparable to June and July levels.

Although the means were not different (P > 0.70), the fluctation seen in lamb fecal counts might be expected since lambs which were born in early June would be producing larvae by mid- to late August whether they were infected as fetuses or not. The drop in counts during September would likely be due to loss of lambs with high counts. Lambs born infected with the parasite (high counts) would begin dying at this time leaving mostly lambs which had not been infected at birth but were becoming infected through grazing and were in the process of building levels (low counts).

Comparisons Among Ewe Groups

Mean lungworm levels for ewes among groups from June-September 1985 were 233 lgf (n = 36) for the GC group, 496 lgf (n = 102) for the EE group, and 444 lgf (n = 124) for the WE group. Although, there were no statistical differences in counts among groups (P > 0.09), the probability of no difference is relatively low.

Since approximately half of the EE group had been treated, a lower fecal count of lungworms was expected. Ivermectin has been shown to retain anthelmintic activity against *Dictyocaulus viviparus*, a cattle lungworm, for about 21 days (Armour et al. 1985). Since these ewes were treated in March, there was sufficient time for the ivermectin to be metabolized and lungworm levels to build back to pretreatment levels by late spring-early summer, thus the reason for no difference between the EE and WE groups. Levels for the GC group tentatively support lowered lungworm counts due to treatment.

Mean levels for lambs in the EE and WE ewe groups were 15 lgf (n = 23) and 7 lgf (n = 24), respectively. No differences were found between lamb larval counts from the EE and WE groups (P > 0.76).

Effectiveness of Oral Treatments on Larval Counts

Figure 2 depicts the levels of fecal larval counts for collection days at the EE feeding site. There was a great reduction in levels of fecal larval counts between pre- and post-treatment counts. High counts, which were persistent for at least 17 days after the last treatment (19 December), were probably due to the amount of time it took for the effects of treatment to be seen in larval counts. All December counts were higher than the 5 January count ($P < 0.01$), indicating that ivermectin was efficacious against Muellerius in bighorn sheep.

Similar results of oral treatment using ivermectin were found for Oestrus ovis, a parasite which occurs in domestic sheep and goats, European ibex (Capra ibex), and bighorn sheep (Roncalli 1984). When a group of Corriedale sheep were treated orally at a rate of 200 μg/kg body weight, ivermectin was found to be 100% effective against all 3 larval stages of the nematode. Apparently, ivermectin may be administered orally at rates similar to those recommeded for injection, with comparable results.

LAMBING SUCCESS AND SURVIVAL

Tables 1 and 2 list the number of ewes found in each category for treatment types and ewe groups. Four out of 9 ewes from the GC group were treated by injection with only 2 of the treated ewes producing lambs. One ewe from the EE group moved to the WE group after oral treatment in March. Thus, all 3 ewe groups contained both treated and untreated, marked ewes. However, location of ewes after treatment should have had no effect on treatment results.

No differences were found in the proportion of ewes lambing for either treatment groups or ewe groups (Table 1), or in lamb survival among treatment groups (Table 2). There was also no difference in lamb survival between the EE and GC ewe groups ($P > 0.40$); however, lamb survival in the WE group was significantly lower than either the EE or GC groups ($P < 0.01$, Table 2).

Lamb:ewe ratios in 1985 exhibited a bimodal distribution (Fig. 3) indicating some ewes had not conceived until their second estrus. Bimodality in 1985 follows the general trend seen in 1984. Sheep were not observed prior to 1 July 1983, thus the onset of lambing in 1983 is not known. If the peak of lambing for 1983 (Fig. 3) is assumed to be the second peak of lambing, it would correspond exactly to the second peak of lambing in 1984. What is most important from the curves in Fig. 3 is that troughs occur 30-40 days after peaks, the approximate amount of time lungworm loads could have fatal effects on lambs if transplacental transmission of larvae had occurred (Hibler et al. 1974). Also, lamb production and survival for the EE group (half of the ewes treated) was higher than that for the WE group (only 1 treated ewe present, Fig. 4). These results suggest that ivermectin treatment had a positive effect on lamb survival. Reasons explaining the 100% survival rate for the GC ewe group are unknown but may reflect both individual and annual variation associated with such a small sample size.

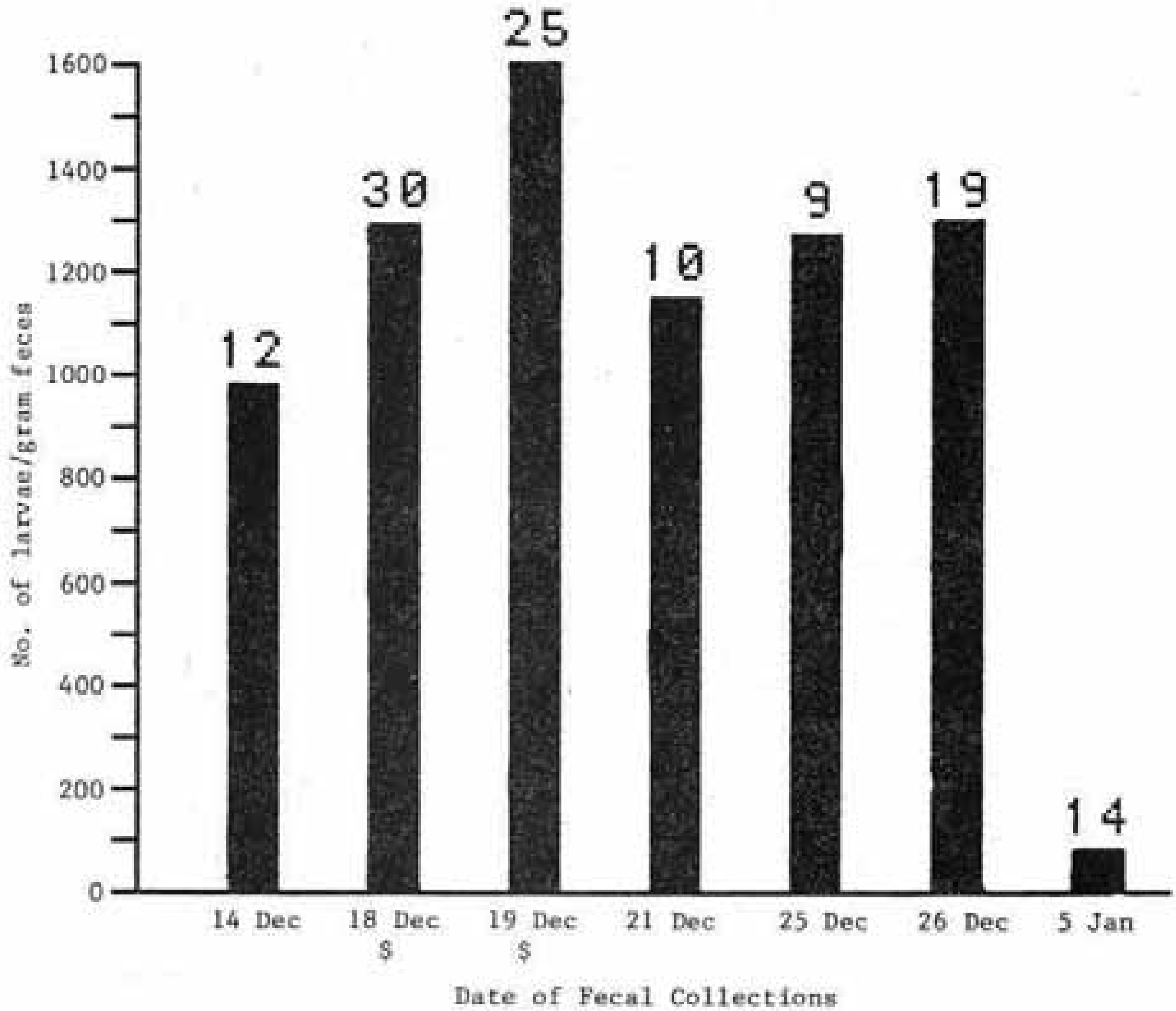

Figure 2. Mean lungworm levels for the east end ewe group treated with Ivermectin during December 1985 in Custer State Park, SD. Numbers on top of bars represent the number of pellet groups collected. ($) denotes day of treatment.

Table 1. Chi-square test of independence comparisons for proportion of ewes lambing among treatment groups and among Grace Coolidge (GC), east end (EE), and west end (WE) ewe groups in Custer State Park, 1985. Critical value for all tests = 3.841 at the 0.05 level of significance.

TREATMENT COMPARISONS

Treatment Type	No. ewes lambed	No. ewes not lambed	
oral	8	1	$x^2 = 2.359$
injection	2	2	$P > 0.20$
oral	8	1	$x^2 = 1.365$
control	13	6	$P > 0.35$
injection	2	2	$x^2 = 0.494$
control	13	6	$P > 0.45$

EWE GROUP COMPARISONS

Ewe Group	No. ewes lambed	No. ewes not lambed	
WE	8	3	$x^2 = 1.222$
EE	10	1	$P > 0.35$
WE	8	3	$x^2 = 0.642$
GC	5	4	$P > 0.40$
EE	10	1	$x^2 = 3.300$
CG	5	4	$P > 0.08$

Table 2. Chi-square test of independence comparisons for lamb survival among treatment groups and among Grace Coolidge (GC), east end (EE), and west end (WE) ewe groups in Custer State Park bighorn sheep, 1985. Critical value for all tests = 3.841 at 0.05 level of significance.

TREATMENT COMPARISONS

Treatment type	No. lambs alive	No. lambs dead	
oral	6	2	$X^2 = 0.621$
injection	2	0	$P > 0.40$
oral	6	2	$X^2 = 0.404$
control	8	5	$P > 0.50$
injection	2	0	$X^2 = 0.200$
control	8	5	$P > 0.20$

EWE GROUP COMPARISONS

Ewe Group	No. lambs alive	No. lambs dead	
WE	2	6	$X^2 = 7.901$
EE	9	1	$P < 0.01$
WE	2	6	$X^2 = 6.964$
GC	5	0	$P < 0.01$
EE	9	1	$X^2 = 0.536$
GC	5	0	$P > 0.40$

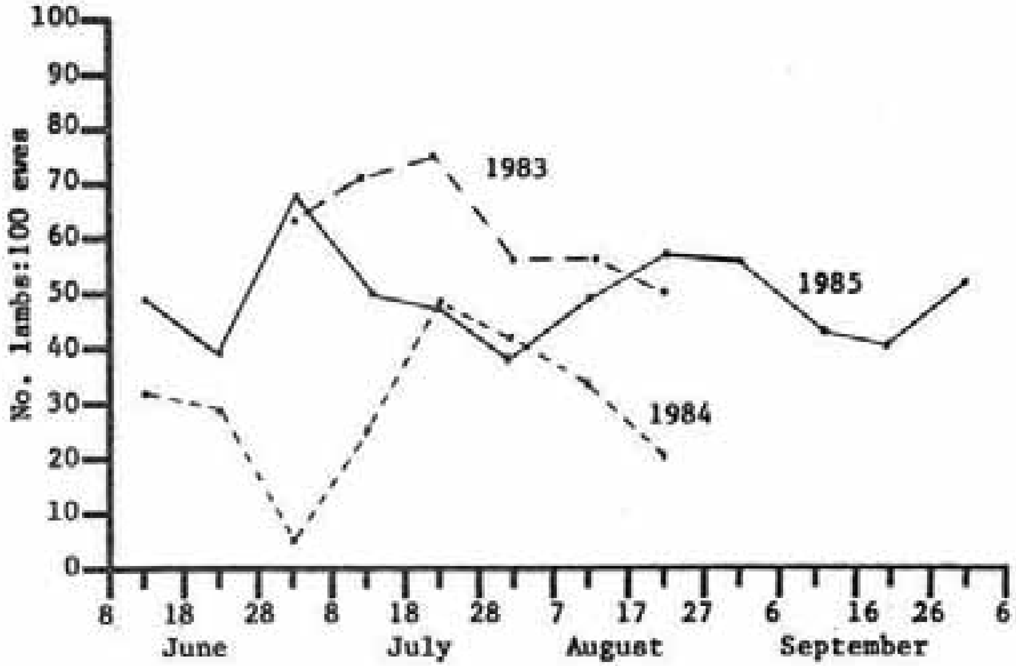

Figure 3. Lamb:ewe ratios in Custer State Park bighorn sheep for 1983, 1984, 1985.

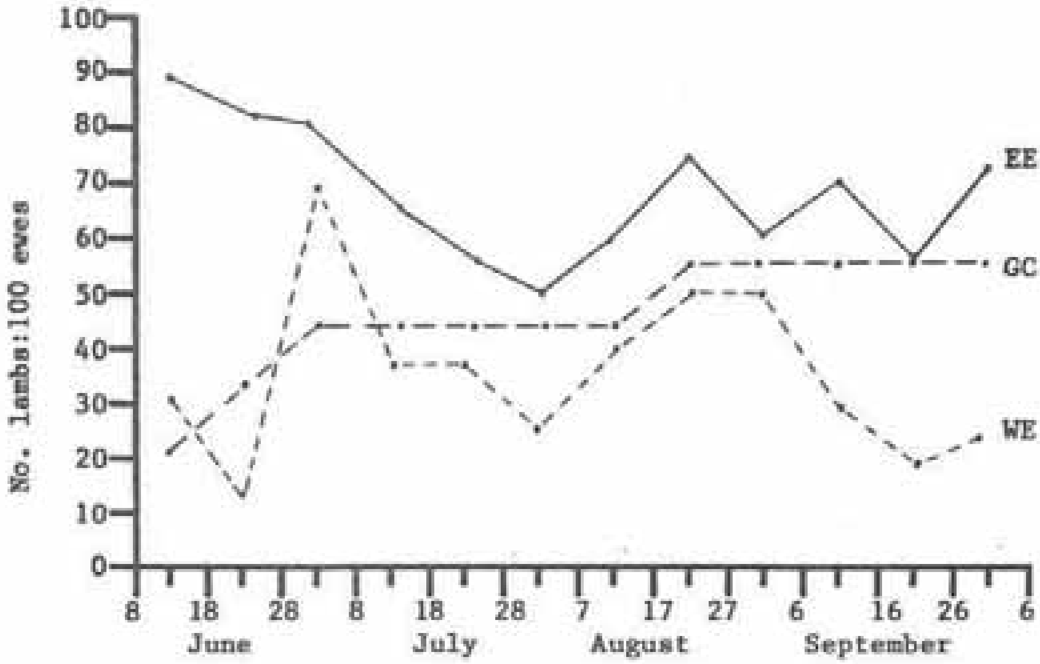

Figure 4. Lamb:ewe ratios in Custer State Park bighorn sheep for the Grace Coolidge (GC), east end (EE), and west end (WE) ewe groups in 1985.

Similar results were found by Schmidt et al. (1974) for treatment against Protostrongylus spp. lungworms to increase lamb survival in a herd of bighorn sheep in Colorado, where several other nematocides were used. There were no differences in lamb survival among treatments, but a significant difference in lamb survival between treated and untreated ewes was found. Cambendazole had the greatest effect for increasing lamb survival, but was only efficacious against 3rd stage infective larvae. Fenbendazole had low efficacy against larvae, but was effective against the adult stage. These 2 drugs together were recommended for treatment against Protostrongylus to increase lamb survival and reduce the number of available larvae in the environment.

CONCLUSIONS

Lungworms appear to be a causative mortality factor in CSP bighorn lambs. Either method of ivermectin administration (injection or oral) at similar dosages will apparently yield similar results in reducing lungworm levels in bighorn sheep. The main advantages to using ivermectin over Cambendazole and Fenbendazole to treat bighorn sheep for lungworms are its specificity, wide therapeutic index, ease of application, and effectiveness against several life stages of lungworms.

The main disadvantage of ivermectin is its environmental instability. Water renders ivermectin inactive over a short period of time. Ivermectin also readily binds to soil, becoming inactive over time. Like Cambendazole and Fenbendazole, ivermectin should be administered orally only when sheep to be treated are present and ingestion of treated bait will be immediate.

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QUESTIONS AND ANSWERS

No Name: You're on to something very interesting, Larry. I don't know my literature real well, but I don't know of any other herd of bighorns in North America from which this genus of nematode (muellerius) has been reported in the lungs, so I guess we can assume it didn't come in with the transplant from Wyoming, or the worm would have found Tom Thorn a long time ago in which case the obvious question: Where do you think the parasite came from?

Layne: I don't know. Again the sheep were transplanted from Wyoming, and I have no doubt that at least one individual of these was infected, and if they were infected, they should have had Protostrongylus. Yet, Muellerius appears to be indigenous to the Black Hills region. There is another lungworm which was found in Alberta which is similar to Muellerius, but they haven't decided if its the same species, or why any Protostrongylus don't occur in the Park, maybe in tandem with Muellerius. Who know, there may be competition between the two, but again, there's no speculation of origin of Muellerius capillaris.

No Name: Since Muellerius capillaris is typically a domestic sheep and goat worm. Is there evidence there of transplacental transmission?

Layne: I mean, I don't know the literature on that one. It would be interesting to know.

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LONG-TERM EFFECT OF FENBENDAZOLE ON LUNGWORM INFECTIONS IN TRANSPLANTED BIGHORN SHEEP

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ABSTRACT

The use of fenbendazole (Panacur) in transplanted bighorns to reduce parasite-related stresses associated with shipping and prevent contamination of ranges was tested in two experiments. In the first trial, 27 sheep from the Sun River Game Range were drenched with fenbendazole before they were moved to the Brandon Butte area of the Missouri Breaks in northeastern Montana. Twenty-nine untreated animals from the same holding pen were released simultaneously in the Chimney Butte area about 75 miles to the west. Both ranges are similar in terms of grazing potential and terrain. Neither area had resident bighorn populations, although both had been inhabited historically by *Ovis canadensis auduboni*.

Fecal lungworm larval counts in the two transplanted herds were compared over a six-year period. Results indicated that the level of larval output in the untreated sheep remained two- to three-fold higher than in the treated herd, except for one year midway in the study when counts tended to equalize.

In the second experiment, alfalfa pellets containing 0.5% fenbendazole were fed free-choice to two bighorn ewes moved from the Sun River Game Range to the Montana State University Veterinary Research Laboratory. Both animals were shedding low to moderate numbers of lungworm larvae and various gastrointestinal nematode ova prior to treatment. After exposure to medicated pellets for two days, normal feeding was resumed. The effect on parasite levels was monitored by comparing periodic fecal larval counts over an eight-week period and again after one year. Results indicated that passage of larval lungworms decreased to barely detectable levels by day 7 and ceased completely by day 21 post-treatment. Both ewes remained negative through day 58, but subsequently resumed low-level excretion of larvae. Both sheep were completely cleared of gastrointestinal nematodes by the free-choice regimen used.

INTRODUCTION

The role of protostrongylid lungworms (*Protostrongylus stilesi*, *P. rushi*) as contributors to chronic or subacute respiratory disease problems in Rocky Mountain bighorn sheep (*Ovis c. canadensis*) has been recognized for many years (Marsh, 1938; Buechner, 1960; Forrester, 1971). Although disagreement exists over the relative importance of the various microbial pathogens in field outbreaks of pneumonia, lungworms appear to be one of the constant stressors associated with lack of productivity and/or increased mortality in free-ranging bighorn populations (Spraker et al., 1984). As a result, efforts to develop effective control measures for *Protostrongylus* infections have received continuing emphasis. Recent development of a new "generation" of antiparasitic drugs for use in domestic livestock has made available a variety of new compounds having potential activity against lungworms in wild sheep (Enigk and Dey-Hazra, 1976; Kelly et al., 1975). Schmidt et al. (1979) reported greatly increased lamb survival when bighorn ewes were treated to control lungworms. They reported that while treatment with fenbendazole (Panacur[R]) was not as effective as cambendazole in reducing lamb mortality, fenbendazole had the advantage of killing adult lungworms, which left sheep parasite-free for a longer time. Since the sheep in the transplant study were being transplanted onto ranges that had not had resident bighorn populations since the early 1900's, it afforded an opportunity to evaluate the use of fenbendazole for lungworm control prior to relocation, in an attempt to maintain lungworm-free ranges. In a second study, the objective was to test the palatability and effectiveness of a pelleted formulation of fenbendazole when fed free-choice to penned bighorns naturally infected with lungworms and various gastrointestinal nematodes.

METHODS

TRANSPLANT STUDY

The Missouri Breaks consist of steep, eroding drainages of the Missouri River in east-central Montana. Average annual precipitation in the area is approximately 12 in. Most soils are clay derived from Bearpaw shale. Many ridges and buttes in the area where sheep were transplanted are capped with sandstone, providing small cliffs and broken rock faces.

Vegetation consists of a highly dissected mosaic of prairie and timber. The ridge tops and surrounding plateau are dominated mainly by big sagebrush, western wheatgrass, and bluebunch wheatgrass. Most slopes are dominated by ponderosa pine or Rocky Mountain juniper with grass or shrub understories. Some steep northfacing slopes are dominated by Douglas fir. Many steep, xeric slopes are barren except for very sparse stands of greasewood and longleaf sagebrush. A more detailed description of the vegetation was published by Mackie (1970).

Fifty-six Rocky Mountain bighorn sheep were live-trapped on the Sun River Game Range, Lewis and Clark County, MT, by personnel of the Montana Department of Fish, Wildlife and Parks in March, 1980. Twenty-nine animals from this group were relocated in the Chimney Butte area of the Missouri Breaks north of Winifred, Fergus County, by the Bureau of Land Management. The 27 remaining sheep were given a single dose of fenbendazole suspension at the rate of approximately 5 mg drug/kg body weight, prorated as follows: adults, 30 ml; yearlings, 20 ml; lambs, 10 ml. Baseline lungworm larval counts for both groups were calculated from pellets collected in the common holding pen used by the sheep prior to relocation. Penicillin was administered intramuscularly as a preventive agent to suppress bacterial respiratory infections (Blunt and Thorne, personal communication, 1980). The treated sheep were released the following day at Brandon Butte on the C.M. Russell National Wildlife Refuge south of Malta, Phillips County, Montana. The two release sites were approximately 75 miles apart and on opposite sides of the Missouri River.

Lungworm larval output in the two herds was monitored from fecal samples collected annually, usually in August or September. Lungworm surveillance continued from 1980 to 1985 except for one year (1984) when no samples were taken. Ten to 12 pellet groups were collected from both herds at each sampling interval. They were air-dried in paper sacks and sent to the Veterinary Research Lab. at Montana State University for analysis. The standard Baermann test was used to obtain quantitative counts of *Protostrongylus* larvae per gram of feces.

Another herd, the result of a 1958 transplant, occupies the Two Calf Creek area of the C.M. Russell National Wildlife Refuge. This area is approximately 20 miles east of the Chimney Butte control herd. Pellet samples were also collected from this herd during the same period for evidence of fluctuations in lungworm prevalence and intensity in an established bighorn herd exposed to habitat and climatic conditions similar to the test herds.

PENNED SHEEP STUDY

Two mature bighorn ewes live-trapped at the Sun River Game Range were moved to the Montana State University Veterinary Research Lab. Following confirmation of active lungworm infections in both animals with the Baermann technique, a commercial feed preparation containing 0.5% fenbendazole on a pelleted alfalfa carrier was fed over a 30-hour period in lieu of hay. Two and one-half pounds of pellets were administered to permit a desired drug intake of 5 mg/kg body weight, the dose used for domestic ruminants. Feed consumption was monitored periodically to estimate the palatability of the mixture and to measure the approximate rate of drug intake. Observations were made during initial exposure of the ewes to medicated pellets to evaluate their response to the preparation. The sensitivity of lungworms to the levels of fenbendazole ingested via free-choice feeding was measured by periodic fecal examinations during the two-month period post-treatment and again approximately 15 months later. The response of gastrointestinal nematodes to the medicated ration also was noted as an additional indication of the efficacy of the test formulation.

RESULTS

TRANSPLANT STUDY

No adverse effects of treatment or negative impacts due to relocation were observed in either group of sheep at the time of release. Animals released in the Chimney Butte area separated into several groups and colonized a 10- to 15-mile area, including one group that crossed the Missouri River. Two groups in the release area were sampled for this study. The sheep released at Brandon Butte were basically in two groups; the group that was sampled is located on Brandon and Mickey Buttes. The other group is located approximately 12 miles NE of the release site.

Lungworm prevalence data in the treated and control herds are summarized in Table 1.

Table 1. Long-term effect of fenbendazole on protostrongylid larval output by bighorn sheep moved to clean ranges.

Herd	Date Sampled					
	March 1980	July 1980	1981	1982	1983	1985
Chimney Butte (control)	126 lpg (100%+)	*	30 lpg (100%+)	43 lpg (87%+)	27 lpg (90%+)	79 lpg (85%+)
Brandon Butte[1] (treated)	126 lpg (100%+)	47 lpg (6%+)	16 lpg (55%+)	14 lpg (92%+)	41 lpg (100%+)	36 lpg (100%+)
Two Calf[2] (established herd on adjoining range	*	13 lpg (94%+)	*	10 lpg (82%+)	8 lpg (90%+)	4 lpg (91%+)

[1]Treated with fenbendazole drench following March fecal examination.
[2]Data included for purposes of comparison
*No samples available
Numbers in parentheses = percentage of sampled animals positive for Protostrongylus

PENNED SHEEP STUDY

The effect of feeding fenbendazole-medicated pellets on Protostrongylus larval output in bighorn sheep in shown in Table 2.

Table 2. Responses of protostrongylid lungworm infections in bighorn sheep to treatment with fenbendazole-medicated pellets*

	Day post-treatment								
Sheep No.	-45	-18	7	14	21	30	44	58	478
A 1661	92	278	0.4	0.2	0	0	0	0	39
G 986	101	6	0.6	0.1	0	0	0	0	0.4

*Expressed as larvae/gm. feces

Both animals were shedding low to moderate numbers of lungworm larvae (6-278 larvae/gm feces) and various gastrointestinal nematode ova prior to treatment. By day 7 post-medication, larval counts in feces were reduced 98.8% to 99.8%. Low level excretion of lungworm larvae continued through day 14 but ceased completely by the 21st day after treatment. Both ewes remained negative through day 58 but subsequently resumed low-level larval production. Both sheep apparently were completely cleared of gastrointestinal nematodes, including _Marshallagia marshalli_ and _Nematodirus_ sp. which were present in moderate numbers in both animals. No evidence was seen of side effects resulting from the levels of drug ingested during the 30-hour treatment period, or at any time during the post-treatment observation period.

DISCUSSION

Schmidt et al. (_loc. cit._) reported no recurrence of lungworm larval excretion in bighorn sheep up to six months after treatment with two doses of fenbendazole. Their interpretation was that both larval and adult lungworms had been killed. In the present field study, 47% of the sheep were passing _Protostrongylus_ larvae within five months after a single drench with fenbendazole. Residual infections apparently persisted in some animals in spite of an overall reduction of 95% in larval output following one treatment. These sheep were transplanted onto historic Audubon bighorn range that had not had resident sheep since the turn of the century. Hence, although the objective of complete parasite clearance was not accomplished, the level of range contamination was reduced significantly. Additional benefits in terms of increased vigor of the relocated herd may also have resulted from the overall reduction of total worm burdens.

Productivity data for the transplanted sheep are available only from incidental air and ground observations by agency personnel. They indicate that little difference exists between the two test herds. Lamb-ewe ratios tend to be slightly higher in the control group, ranging from 50 to 60%. Actual counts have been slightly higher in the treated herd, which consisted of 82 animals in 1985.

Additional data (Huschle and Worley, unpublished) on parasite patterns in sheep on dry prairie ranges have been collected from the Two Calf herd, which occupies an area on the C.M. Russell National Wildlife Range approximately 20 miles east of the Chimney Butte control herd. Lungworm prevalence and intensity in this herd, the result of a 1958 transplant, have consistently been the lowest in the state, averaging about nine larvae/gm. of feces. Lungworm larval output in the Brandon Butte sheep has increased following medication to a higher level than the Two Calf sheep and is approaching that of the control herd. One factor contributing to this trend may be the somewhat higher concentrations of the Brandon Butte sheep in comparison with the control herd. The decrease in lungworm output observed in the control herd to a level similar to the Two Calf herd may indicate that transmission of protostrongylid lungworms is severely limited on dry prairie ranges due to a probable scarcity of snail intermediate hosts. For this reason, benefits from reducing or eliminating lungworms probably would be minimal under the circumstances.

Use of a pelleted fenbendazole ration in a free-choice regimen was designed to test the palatability and rate of consumption by bighorns under controlled conditions. Although there are obvious differences between a confinement setting and field use of the material, the rate of feed intake was adequate to achieve the desired drug intake in about 30 hours. The response in the test ewes suggested that sufficient drug was ingested during this time interval to reduce lungworm levels significantly and completely eliminate gastrointestinal worm infections with Marshallagia and Nematodirus. However, complete eradication of lungworms was not accomplished with the short-term feeding schedule tested. The inability to eliminate all adult lungworms was predictable in view of the partial effect reported by Schmidt et al. (1979) with the use of a single dose of fenbendazole fed in apple pomace.

Rate of feed consumption as indicated by observations at two- to four-hour intervals suggested that some exploratory "testing" of the medicated ration occurred within two hoursafter the initial feeding. One ewe ate continuously for three to four minutes after tentatively nibbling at the material. An estimated one-third of the total ration was eaten during the first 18 hours. By 24 hours, 50 to 60% had been consumed. Approximately 30 hours was required for the full fenbendazole dose to be eaten. The composition of the commercial preparation apparently was sufficiently palatable to the sheep that it was not necessary to "precondition" them to a pelleted formulation or withhold feed to induce them to eat. On the other hand, lack of access to other feed in a confinement situation such as this may indicate that administration of the material in the field is more likely to be successful during the winter range period when alternative feed sources are not readily available.

The practical advantage of a commercial anthelmintic preparation that is not dependent on the availability of apple pomace and does not require additional formulating are considerable. Further evaluation of fenbendazole-medicated pellets administered over a longer period or at two or more separate feedings, is needed to determine the ultimate usefulness of the compound in parasite control programs for bighorn sheep.

ACKNOWLEDGEMENTS

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QUESTIONS AND ANSWERS

Bill Samuel, Alberta: This statement in the abstract, where you reduce the larval lungworm counts to barely detectable levels, reminds me of the young lady who came home and told her father on a Saturday night that she had a problem but not a big problem because she was just a wee bit pregnant. So, I'd like to ask, and anybody can answer, have we now decided that we should treat during transplant just to reduce the larval levels to give the transplanted sheep a better start even though treatment doesn't eradicate anything?

Gary Huschle: That is what possibly could have happened if we would have had severe winter in the first year or two, but that didn't occur.

Samuel: Then the second question is, were there significant differences between your treated and your controlled herds over the years with the lungworm larvae per gram? In the different years are they statistically different? They look pretty close to me.

Huschle: We didn't run a statistical analysis on it. In the first three years I believe they would be. You're looking at only half the animals being infected on the treated group and all 100% still infected on the control group.

Peter Davidson, BC: I've treated with Fenbendazole and have managed to reduce levels down to barely detectible levels, and had the odd sheep with high levels still transplanted probably because it was missed. I generally tried to treat three times at the sites using Schmidt's method with fermented ethyl mash. What we found is the levels, well most of the sheep had 0 levels, the odd had low levels, like Bill was saying barely detectable, but within 4 - 6 months we were back up to normal levels on the source herd, 600-800 larvae per gram which is on very poor winter range. On the transplanted herd we were up around 30 larvae per gram, anywhere from 5 - 30 larvae per gram. So we didn't stop the problem. We just changed level of infestation. The other big difference was the lamb survival did dramatically increase in the source herd, we probably increased the lamb survival by 30-45%. That's judging by pretreatment lamb survival over a period of years vs. post treatment over a period of 2 - 3 years. We did find a very similar experience to Schmidt down in Colorado.

Wayne Winter, South Dakota: I was wondering if you or anybody else in the room ever attempted to offer pelletized hay to sheep that were not captive free choice. In Custer State Park, we'd have to do that. We didn't get very good acceptance to it, but we had used alfalfa hay without apple mash and got excellent acceptance of that. I was just wondering if anyone tried to offer free choice to Montana sheep.

(Comment from back of room)

Winter: That was our experience. We couldn't get them to take it very readily and we had a lot better luck with our regular alfalfa hay.

(Comment from back of room)

Winter: We had used that for a number of years, but we felt we didn't have to mess with the mash anymore. They took plain alfalfa hay just as readily as they did alfalfa hay with mash. We just decided to discontinue using the mash.

A COMPARATIVE STUDY OF BIGHORN SHEEP HERDS IN SOUTHEASTERN BRITISH COLUMBIA

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Abstract:

Three herds of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) in southeastern British Columbia were evaluated for health status during 1983 and 1984. Each herd was of similar size but varied in disease occurrence and herd dynamics, both historically and over the period of study. Samples taken from six sheep in each herd were examined for nutritional condition, microbiological, virological and serological status, general and pulmonary parasite loads, blood chemistry and trace mineral levels, as well as gross and histological pathology lesions. A low elevation wintering herd at high density on poor quality range was demonstrated to have high levels of lungworm infection, low total serum protein, fecal nitrogen and liver selenium levels. Higher total serum protein, fecal nitrogen, liver selenium levels and lower lungworm levels were present in bighorns from a lower density high elevation wintering herd. Adrenal glands were larger and clinical and subclinical diseases were common in adults and lambs from a low elevation wintering herd 2 years after an all-age dieoff. Parameters were discussed for relevance in describing the herd status and usefulness to the wildlife manager. The first herd was treated with trace minerals and an anthelmintic after the 1983 collection. Lungworm larvae output was less in four sheep examined in the following year, but no change was seen in trace mineral levels.

The Rocky Mountain bighorn sheep populations of North America have markedly decreased in number and distribution since the human settlement of their native habitat (Buechner 1960). The factors responsible for the decline are suggested to include heavy hunting pressures, the introduction of domestic animal diseases and, especially in this century, the widespread reduction of available and suitable ranges (Buechner 1960, Stelfox 1971).

More recently, bighorn sheep have suffered epizootic dieoffs in captive and wild situations in Canada and the U.S.A.. The sheep have nearly always succumbed to pneumonia caused by opportunistic bacteria with varying degrees of lungworm involvement (Forrester 1971). Reports of sheep dieoffs have outlined a large number of environmental and animal related factors which have been present before dieoffs and are believed to predispose sheep to disease. For example, Spraker et al. (1984) described a series of conditions preceeding a dieoff at Waterton Canyon in Colorado. They included increased levels of vehicular traffic, noise, human harassment, high animal density and a reduction in forage quality and quantity. Reports of other dieoffs have included factors such as low trace mineral levels, inclement weather, habitat deterioration and loss, the presence of domestic sheep, concurrent infectious diseases and high lungworm or other parasite levels (Buechner 1960, Lange et al. 1980, Foreyt and Jessup 1982, Thorne et al. 1982, Schwantje 1983, Onderka and Wishart 1984).

Such factors are believed to function through direct and indirect mechanisms, their presence and effect varying with each situation. Chronic exposure to some of these conditions may act cumulatively to impair protective immune functions. The collective influence is believed to create a state of chronic stress (Spraker et al. 1984). The physiological responses of individual animals to chronic stress include adrenal gland enlargement and increased levels of adrenal corticosteroids (Feldman 1983). Long term maintenance of high levels of corticosteroids in other species is associated with an inhibition of immune responses and increased susceptibility to bacterial infections, particularly of the respiratory tract (Hunningshake and Fauci 1977, Kelley 1980). Studies in man and domestic animals have shown that concurrent viral respiratory infections (Yates 1982), malnutrition (Scrimshaw et al. 1968) and low tissue levels of selenium and copper (Chandra 1983) are associated with, and can directly cause depressed immune responses.

The proper function of immune systems is closely related to the overall nutrition of an animal (Chandra and Newberne 1977). Many of the factors discussed as influencing bighorn sheep herds play important roles in their nutritional condition. Forage quality and quantity have obvious direct influences. Other factors, such as intra and interspecific competition, harassment and high gastrointestinal parasite burdens may indirectly reduce the amount and type of feed consumed and utilized. Indices of nutritional status have been examined in controlled (Kirkpatrick et al. 1975, Seal et al. 1978, Bahnak et al. 1979, Warren et al. 1982) and free-ranging studies of white-tailed deer, pronghorn and wild sheep (Franzmann 1972, White and Cook 1974, Seal and Hoskinson 1978, Hebert et al. 1984, Spraker et al. 1984). The levels of total serum protein (TP), blood urea nitrogen (BUN), fecal nitrogen (FN) and body condition scores varied with season, habitat and physical condition in white-tailed deer and bighorns (Franzmann 1972, Seal et al. 1978, Hebert et al. 1984). These parameters were the most frequently used in these studies and were easily available from live animals.

Depressed blood proteins have long been accepted as occurring with protein-energy malnutrition in man (Sauberlich 1983), and studies have demonstrated reductions in TP with starvation in wildlife species (Hebert 1973, Bahnak et al. 1979, Warren et al. 1982). Blood urea nitrogen levels were proportional to protein consumption in cattle (Biddle and Evans 1973), domestic sheep (Preston et al. 1965), white-tailed deer (Seal et al. 1972, Kirkpatrick et al. 1975) and pronghorn antelope (Seal and Hoskinson 1978). Franzmann (1972) felt that the nutritional status of bighorn sheep was best estimated by BUN and suggested that values below 15 mg/dl indicated low protein intakes.

The comparison of fecal nitrogen content with feed nitrogen content has been investigated to determine the protein status of wildlife populations. Species examined include free-ranging elk (Gates and Hudson 1979), East African ungulates (Arman et al. 1975) and wild and captive bighorns (Hebert 1973, Hebert et al. 1984). In most cases, studies have followed seasonal trends in FN and related these to environmental changes (Seip and Bunnell 1985), feed quality and animal weight (Mould and Robbins 198). Hebert et al. (1984) showed changes in animal condition between seasons and years in captive, supplementary fed, free-ranging and non-migratory free-ranging California bighorn sheep. He advised the use of FN determination over time to assess the effect of changes in population density and grazing on sheep ranges and herds. Bahnak et al. (1979) suggested that periodic monitoring of all nutritional indices was more valuable than conclusions drawn from samples taken at a single point in time.

The definition of trace mineral deficiencies requires the association of clinical signs of deficiency with low mineral concentrations in animal tissues, diet and soil. Deficiency syndromes are often subclinical and may be difficult to identify due to interactions and imbalances between individual minerals and the protein-energy content of the diet. Studies related to two of the more commonly recognized deficiencies, selenium and copper, are limited in free-ranging wild species; however, both minerals have been extensively reviewed for domestic cattle and sheep (Hidiroglou 1979, Underwood 1977, Van Vleet 1980).

Subtle or marked syndromes of muscle degeneration, ill thrift, neonatal weakness and infertility are responsive to the addition of selenium and vitamin E (Se/E) to the diets of ruminants (MacDonald et al. 1976, Maas 1983). In addition, suppressed cell mediated immune functions are restored (Sheffy 1979). An acute stress induced muscle degeneration (capture myopathy) has been well recognized in wild ungulates and is associated with Se/E deficiency (Hebert and Cowan 1971). The other livestock syndromes are not well defined in wild species.

Copper deficiency in domestic sheep is also often subclinical but can reduce growth rate, reproductive performance and haircoat pigmentation (Ward 1978, Hidiroglou 1979) . Studies in Alaskan moose and Idaho mule deer suggested reductions in fertility and abnormal hoof keratinization (Flynn et al. 1977, Dunbar and Foreyt 1985). Low copper levels are also associated with decreased immune responses and an increased susceptibility to parasitism (Chandra 1983). A possibility of interaction between copper and selenium has been proposed because of a lack of response to supplementation until both elements were provided to domestic livestock (Blood et al. 1983).

Investigations into all-age dieoffs of bighorn sheep in the East Kootenay (E.K.) region of British Columbia in the 1960s and 1980s determined that these dieoffs were preceeded by high population densities, heavy interspecific competition for forage, contact with domestic sheep, severe winter weather, high lungworm levels and low copper and selenium levels in some sheep (Stelfox 1971, Davidson 1982, Schwantje 1983). It was concluded that the herds in which dieoffs occurred were predisposed to pneumonia by chronic stress conditions caused and complicated by high animal density, poor nutrition, parasitism and trace mineral deficiencies. The presence of concurrent or subclinical diseases was unknown (Schwantje 1983).

Sheep herds wintering at high elevations were not affected by either E.K. dieoff. This suggested that the absence of some of the previously mentioned factors allowed the high elevation sheep herds to be maintained in better overall health than those which suffer from dieoffs, and that they have thus avoided health disease epizootics.

A definitive study was required to evaluate the presence of these factors in E.K. herds with and without the history of dieoffs. The following project surveyed three herds of similar size which differed in herd dynamics and disease occurrence. Samples were compared and evaluated to describe the presence and influence of predisposing factors and to describe the overall health of each herd.

STUDY HERDS

The three herds selected for this project are designated by their winter ranges; Columbia Lake (CL), Wigwam (WW) and Ewin Ridge (ER) (Figure 1).

CL and WW sheep graze summer pastures at elevations up to and over 2170 metres. In the fall they migrate to low elevation, predominantly seral ranges along the eastern boundary of the Rocky Mountain Trench (Bandy 1968). Arrival on winter range is followed by the rut in November to December. Both of these herds have been affected by all age dieoffs previously.

Vehicular access to both winter ranges is possible until December 1. The roads tend to be heavily travelled for recreational and hunting use. The CL range is adjacent to a small community and shares a portion of the range with a growing residential subdivision. A lumber mill and small community are located across a river from a portion of the WW range, but most of the range is out of visual and acoustic contact from these developments.

The CL range consists of alluvial fans, parkland areas and rocky bluffs on the eastern shore of Columbia Lake. The quality of this range has been considered poor since at least 1970 (Demarchi 1970, Davidson pers. commun.). Exclosures erected in 1983 showed obvious differences in forage growth by 1984. Forest succession is very prominent around most meadows. Livestock have been absent from the range for over 20 years, however, mule deer and particularly elk are abundant.

The CL herd suffered a dieoff in 1966, reaching a low of 28 from approximately 100 animals (Bandy 1968, Demarchi 1970). At present the herd numbers approximately 150 animals. Annual lamb:ewe ratios were considered to be gradually decreasing (Davidson pers. commun.) and were 40-50% in 1983.

The WW range is made up of fire formed grasslands, some natural parkland and thickly forested areas between the Elk and Wigwam Rivers. The range condition appears to improve following reductions in the wildlife stocking rate, as was seen after a 1965 sheep dieoff and subsequent increases in elk harvests (Demarchi 1970). It is presently considered to be improving after a 1981 sheep dieoff. Livestock are not permitted on the range but mule deer and elk are abundant.

An all-age dieoff in 1965 removed 40-50% of the WW herd. By 1981 the 150 animals remaining had increased to at least 424, the highest density ever reported for the range. At this time elk and mule deer numbers were considered high, similar to levels prior to the 1965 dieoff.

Another all-age dieoff began in December 1981 and reduced the population to less than 150 bighorns. Animals in poor condition and/or coughing are still occasionally reported at this time. The herd now numbers approximately 100-150 sheep with lamb:ewe ratios of less than 5% in 1983.

ER sheep winter on virtually inaccessible, windswept subalpine and alpine ridges up to 2700 metres in elevation (Schuerholz 1984). The high elevation allows an approximately one month earlier onset of the rut and winter conditions. This herd has never been reported to suffer large scale mortality although, because of the location, we can only rely on evidence that aircraft classified counts have remained stable at 100-150 sheep since 1971 (Warkentin, Schuerholz pers. commun., 1984). Lamb:ewe ratios have averaged 55% since 1971 and were 78% in 1984. An open pit coal mine is present on ram summer range but the winter range common to both sexes is undisturbed. Extensive range studies demonstrate excellent quality and a lack of competition from elk or mule deer. The amount of available range is reduced with heavy snowfalls or the late arrival of spring. With these conditions intraspecific competition decreases the quantity of forage for overwintering sheep (Schuerholz 1983).

MATERIALS AND METHODS

In 1983 and 1984, the CL and WW herds were observed and counted from the ground (foot and automobile). ER population data were supplied by Crowsnest Resources and Transamerica Environmental Science Consultants (TAESCO) as well as minimal direct observation during early winter. Fixed wing or helicopter classified counts were performed routinely on all herds in January or February by B.C. Wildlife Branch personnel.

From late October to early December 1983 observations of major CL and WW groups were made, usually from a vehicle. The animals were observed for 0.5 to 1 hour before an individual was collected for sampling. Disturbance was considered minimal before collection. ER animals were observed from helicopter and collected after hazing towards a ground based hunter during late October and early November 1984.

Six sheep were collected from each herd. Selection criteria were designed to select for those animals which were of less than the average body condition or demonstrated symptoms of disease so that they appeared different from other sheep in the group. Criteria included body condition grading and clinical symptoms of disease or signs stated by wildlife biologists or experienced observers as indicative of poor condition or subclinical disease. The signs ranged from isolation behaviour to pale or rough haircoats, loss of muscle mass, contagious ecthyma lesions and mild to obvious respiratory symptoms. Animals were also selected from three age classes; lambs of the year, yearlings and adult ewes. The ER collections used only these criteria. Four additional sheep from CL were examined in 1984. Three were shot and a fourth poached carcass was examined.

Sheep were shot in the caudal skull or anterior cervical region. Blood was collected immediately, chilled and harvested for serum on the following day. Each animal was weighed and a necropsy was performed. Carcasses were evaluated subjectively for body condition on the basis of body fat deposits and muscling for a total body score of 100. Major organ systems were examined and representative portions were preserved in 10% neutral buffered formalin. The lungs were removed intact and photographed. Lesions were drawn and 2 cm slices of each lobe were preserved. Portions of anterior or grossly affected lobes, as well as a retropharyngeal lymph node and main stem bronchial swabs, were obtained for bacterial and viral culture. These tissues were frozen and chilled respectively and transported to the Alberta Agriculture Laboratory, Edmonton, Alberta for culture.

Kidney, liver and sera were frozen and assayed for trace minerals at the British Columbia Veterinary Pathology Laboratory, Abbotsford, B.C.. Serum was frozen and analyzed later for antibodies to infectious bovine rhinotracheitis (IBR), parainfluenza 3 virus (PI3), bovine virus diarrhea (BVD) and bovine respiratory syncytial virus (RSV) and levels of blood urea nitrogen, glucose and total serum protein at the Western College of Veterinary Medicine, Saskatoon, Saskatchewan. Cortisol levels in serum and urine were assayed by the T.R. Spraker laboratory at the College of Veterinary Medicine, Fort Collins, Colorado. Serological evaluations for bovine lymphosarcoma virus (WW4), bluetongue (BT), epizootic-hemorrhagic disease (EHD), maedi/visna viruses and Johne's disease (*Mycobacterium pseudotuberculosis*) were performed by the Canadian Animal Disease Research Institute, Nepean, Ontario.

Samples of feces were frozen and analysed for nitrogen content by the Soil, Feed and Tissue Testing Laboratory, Kelowna, B.C. Gastrointestinal parasite ova counts were done with fecal flotations by A. Gajadhar, W.C.V.M.. Fecal lungworm larvae counts were performed on air dried feces by the W.M. Samuel laboratory, University of Alberta, Edmonton, Alberta, using a Baermann technique (Samuel and Gray 1982).

Microscopic tissues were mounted in paraffin, sectioned at 5 um thickness and stained with hematoxylin-eosin. Special stains (Masson's trichrome, PTAH, PAS, Grocott, Brown and Brenn) were used as required. Three microscopic sections were taken from each lung slice as well as any additional lesions. Histopathological findings were noted in all organs. Pulmonary changes were categorized on the basis of microscopic changes. The left kidney and adrenal from each animal were preserved, weighed and photographed. The thoracic thymus was collected where identifiable, photographed and sectioned.

RESULTS

1. CLINICAL EVALUATION

Columbia Lake

The sheep in this herd were usually seen in groups of 40 to 65 animals. They could be approached to within 50 feet and remained in the immediate area during all procedures. On clinical inspection individual sheep appeared in good to excellent body condition. The pelage was occasionally long and/or pale or yellow. Three sheep (CL 1,4,5) were selected for these haircoat changes. One ewe was selected because of a mild dry cough (CL 6). This was the only respiratory sign noted during all observations. Some sheep had oronasal depigmented areas, suggestive of healed contagious ecthyma lesions. Body condition scores in collected sheep averaged 86 of a possible 100.

Wigwam

This herd was wary and was scattered as pairs or small groups over the range. Approach was possible by vehicle but sheep dispersed rapidly with disturbance. Field inspection revealed mostly adults of moderate to good body condition. Some groups were uniformly thin. Sheep selected had long pale haircoats and were thinner than average. The two lambs collected (WW1, 3) were very small, thin and lethargic. Both had nasal discharges and obvious oral contagious ecthyma lesions. Oral contagious ecthyma was also severe in WW4, mild in WW5 with residual nasal scars in WW6. Diarrhea with perineal staining was present in WW3 and 5. All but WW5 had Otobius megnini and Dermacentor albipictus ticks in light to heavy numbers. No signs of coughing were observed. Body condition scores averaged 57 out of 100.

Ewin Ridge

Clinical evaluation of these sheep was not possible but the carcasses were examined after collection. The only noticeable abnormality was that the yearling (ER 4) had a pale but otherwise normal haircoat and was of small size. The other sheep were in good body condition with an average body condition score of 81.

2. GROSS NECROPSY

Columbia Lake

Five of the six sheep were classified as having moderate to severe verminous pneumonia. Animal CL 1 was classified with mild lesions. One third to one half of the caudal lung lobes were diffusely swollen and the overlying pleura was pale and thickened. Individual nodules from 0.2 - 2 cm protruded from the lung over the dorsal surface of the diaphragmatic lobe and occasionally other lung lobes. Smaller nodules were more transparent with yellow-grey mottling. On cut section the nodules were firm. Airways were surrounded by prominent white glistening cuffs. The lung changes were consistent with Protostrongylus stilesi infection. P. rushi adults were present in the airways of all six sheep. A small focus in the cranial right lung of CL 6 was atelectatic with multiple tiny white foci. The kidney:adrenal weight ratios ranged from 24.6 to 37.3 with a mean of 30.1 (Table 1).

Wyominia tetoni tapeworms were found in four sheep. Heavy infections were accompanied by bile duct and gall bladder dilation and fibrosis. Cl 4 had two 1-2 cm green lamellated abscesses adjacent to these structures. Multiple 0.2 cm nodules on the abomasal rugae and over cecal and colonic serosae and mucosae were common and were considered to indicate gastrointestinal parasitism due to various Ostertagia and Marshallagia spp..

Wigwam

Mild lesions of verminous pneumonia were present in five sheep with WW5 classified as moderately affected. Opaque white individual nodules rather than diffuse swelling of caudal lobes were more common in these animals. Sheep WW6 was the only animal in which P. rushi adults were identified.

Chronic bronchopneumonia and fibrous pleuritis were noted in four sheep. These ranged from a small area of cranial lobe consolidation in WW5 to bilateral ventral adhesion and focal consolidation in all lobes of WW4. Consolidation was extensive in both lambs with sharp demarcation of affected anteroventral and ventral middle and caudal lobes. The firm, plum-coloured tissue had a cobblestone texture with scattered white foci and a mucoid airway exudate. Extensive fibrous pleuritis and pericarditis was also present in the lambs.

Gastrointestinal parasitism lesions were present in all sheep and were more severe in those with chronic pulmonary lesions. WW4 and 5 had generalized enlargement of lymphoid organs and multifocal pale renal cortical streaking. Contagious ecthyma was very severe throughout the oral cavity and rumen of WW4 and mild in WW5. The lambs had lesions associated with thymic atrophy, serous atrophy of fat, large numbers of gastrointestinal parasites and oral contagious ecthyma. WW 3 was more severely affected with fibrinous peritonitis, serous polyarthritis, decubitus ulcers and contagious ecthyma of the coronet bands. The kidney:adrenal ratio ranged from 9.4 to 29.2, with a mean of 21.8. The lowest ratio, or largest adrenal size was in WW3.

Table 1. Kidney and adrenal gland weight ratios in bighorn sheep collected from the East Kootenays in 1983-84.

Sheep number	Age (Yr)	Sex	Body Weight (Kg)	K:A[a]
CL 1	2.5	M	77.3	29.4
CL 2	0.5	M	40.9	37.3
CL 3	0.5	M	32.7	33.0
CL 4	4.5	F	72.7	24.6
CL 5	1.5	M	64.5	26.5
CL 6	3.5	F	71.4	30.9
			X = 30.1	
WW 1	0.5	M	29.1	23.5
WW 2	3.5	F	71.8	23.8
WW 3	0.5	F	14.5	9.4
WW 4	6.5	F	64.5	29.2
WW 5	3.5	F	65.5	19.3
WW 6	1.5	M	53.2	25.5
			X = 21.8	
ER 1	0.5	F	23.6	34.2
ER 2	4.5	F	67.3	26.3
ER 3	3.5	F	68.2	26.1
ER 4	1.5	M	41.8	27.8
ER 5	7.5	F	81.8	26.7
ER 6	9.5	F	72.7	26.7
			X = 28.0	

[a]K:A = kidney (g):adrenal (g)

Ewin Ridge

Three sheep were classified to have mild verminous pneumonia and the remainder had mild-moderate or moderate lesions. Nodules were mostly small and transparent. The most caudal area of the diaphragmatic lobes was frequently contracted with pleural fibosis. Two ewes (ER 5,6) had small contracted areas of middle lobes with occasional fibrous pleural adhesions. P. rushi adults were present in ER 2 and 3.

The lamb (ER 1) lacked the right ovary with partial absence of the right oviduct. No depigmented areas or active contagious ecthyma lesions were present. Gastrointestinal parasitism lesions were restricted to the abomasum in ER 1,2 and 4 and were moderate in number and severity. Kidney:adrenal ratios varied from 26.1 to 34.2 with a mean of 28.0.

3. HISTOPATHOLOGY

The most consistent findings in all sheep were lesions due to liver and gastrointestinal tapeworm and nematode parasitism. The major liver changes were fibrosis, mononuclear cell infiltration and hyperplasia of bile ducts in portal regions, as well as small, cellular foci scattered throughout liver lobules. These foci were often associated with portal areas and were primarily mononuclear cells with occasional eosinophils and individual degenerative hepatocytes.

Abomasal inflammation consisted of nodular and diffuse mononuclear cell infiltrates. This lesion was less common in CL sheep. The small intestinal changes were diffuse mononuclear and eosinophilic infiltrations of the lamina propria. The more severely affected sections also demonstrated mucosal hyperplasia. Occasional areas of superficial necrosis were associated with intracellular stages of Eimeria spp.. Large intestinal lesions were less severe with less hyperplasia. Eosinophilic granulomas and focal chronic inflammation, suggestive of parasite migration, were present in the intestines, liver, lymph nodes and abomasum in sheep from all herds. All cardiac and skeletal muscles contained cysts of Sarcocystis spp., except in CL sheep.

Kidney changes primarily involved glomeruli or were interstitial with secondary glomerular and tubular effects. Glomerular basement membranes were irregularly thickened and the mesangium was hypercellular. Severely affected glomeruli had adhesions and were shrunken. None of these lesions were considered to be extensive or significant enough to cause clinical signs. The most severe kidney lesions were in WW sheep and were associated with primary diseases in other organs.

Lymphoid tissue was generally hyperplastic in most animals. Systemic illness was accompanied by lymphoid atrophy in WW3. The epithelium overlying the pharyngeal lymphoid tissue in most sheep was altered. Changes ranged from hyperplasia to necrosis. Invasive protozoa were found in the pharynx submucosa or retropharyngeal lymph nodes of ER 4, 5 and 6. There did not appear to be any relationship of the nasopharynx changes to other respiratory pathology. Trachea mucosal pathology was mostly mild with hyperplasia, mononuclear cells and/or necrosis. This was predominantly seen in WW sheep. The generalized lymphadenopathies of WW4 and 5 were the result of a multisystemic lymphoid tumor (lymphosarcoma) and a multiorgan infection of an intracellular parasite, likely Encephalitozoon, respectively.

Pulmonary changes were similar in all sheep, differing primarily in the amount of lung affected by lungworm activity, types of tissue response to inflammation and degree of bacterial bronchopneumonia involvement. The predominant changes involved airways, vessels, interstitial tissue, alveolar spaces and locally diffuse inflammatory reactions to lungworm reproduction. In summary, CL and ER lung histopathology was similar. WW sheep had markedly fewer lungworm stages and accompanying inflammation, as well as less chronic changes associated with the parasite (i.e. fibromuscular hyperplasia). A mild focal bronchopneumonia was present in CL 6, resolving bronchopneumonias were present in ER 5 and 6 and mild to severe chronic bronchopneumonias were present in WW 1,3,4 and 5.

4. LABORATORY ANALYSES

Microbiology

No respiratory pathogens were cultured from CL sheep. E. coli was found in the liver abscess from CL 4.

Pasteurella haemolytica biotype T was present in the bronchial swabs and right cranial lung of WW 1 and the retropharyngeal lymph node of WW 4. A non T biotype of P. haemolytica was cultured from the bronchial swabs, mediastinal lymph node and left lung of WW 4. Staphylococcus aureus was present in joint swabs from WW 3 and the retropharyngeal lymph nodes of WW 3 and WW 5. All other lung cultures from WW sheep were negative or produced insignificant contaminants.

P. haemolytica biotype T was present in the lungs and retropharyngeal lymph node of ER 5. No further significant pathogens were recovered from ER sheep.

No viruses were cultured from any sheep tissues. ER 2,5,6 and WW 2 and 6 had titres to PI3 virus. ER 6 also had a positive titre to RSV virus. All sera were negative to Johne's disease, maedi/visna, EHD and BT virus. A titre to bovine lymphosarcoma virus was not present in WW4.

Parasitology

Fecal flotations indicated mild to moderate levels of usually mixed intestinal parasitism in all sheep. Ova were recovered in larger numbers from lambs, particularly those with systemic illness (WW1 and 3).

Protostrongylus spp. lungworm larvae levels were higher in feces from CL sheep than from WW or ER sheep, with average larvae per gram feces of 799 (CL), 162 (WW) and 166 (ER). Lambs and yearling bighorns from CL had the highest larval outputs while the lambs from WW and the lamb and yearling from ER had very low fecal larvae. The WW yearling had moderate numbers of larvae (Table 2).

Trace Minerals

Liver and kidney selenium levels in all CL sheep were consistent with levels considered to be deficient in domestic sheep. Marginal levels were present in three sheep. Tissue copper levels were considered marginal in two CL, three WW and four ER bighorns (Table 2).

Table 2. Fecal larvae output, liver copper and selenium levels in bighorn sheep collected from the East Kootenays in 1983-84.

Sheep	LPG[a]	Liver levels (ppm) Copper	Selenium
CL 1	172	77	0.10
CL 2	665	14	0.10
CL 3	1971	67	0.06
CL 4	543	43	0.07
CL 5	959	20	0.11
CL 6	484	73	0.06
WW 1	9	91	0.16
WW 2	58	16	0.32
WW 3	3.5	17	0.29
WW 4	167	6.6	0.25
WW 5	321	37	0.19
WW 6	414	63	0.61
ER 1	13	6.5	0.30
ER 2	347	8.3	0.27
ER 3	142	32	0.32
ER 4	51	24	0.30
ER 5	109	8.5	0.29
ER 6	336	5.7	0.29
Normals[b]	deficient	0.5 - 4.0	0.005 - 0.1
	marginal	5.0 - 20	0.15 - 0.25

[a] LPG - larvae per gram feces
[b] liver levels of domestic sheep (R. Puls 1981)

Chemistry

Blood urea was within normal domestic sheep levels in two CL and two ER animals. Levels were less than normal in all other sheep except for increased levels in WW 1, 3 and 4. Serum glucose values were mildly to moderately increased in five CL, four WW and four ER sheep. Two ER sheep had extremely high glucose levels. Total serum protein levels were reduced in four CL, four WW and two ER sheep. Average values were the highest in ER animals and lowest in CL sheep. Average fecal nitrogen levels were similar in CL and WW sheep and considerably higher in ER sheep (Table 3).

Serum and urine cortisol values varied greatly within herds without a consistent pattern. Kidney:adrenal ratios were similar in CL and ER bighorns but lower on average in WW sheep indicating larger adrenal glands in the WW sheep (Table 1).

DISCUSSION

The CL herd appeared to be in good health on the basis of field observation. Animals were calm and in large groups. Clinical signs were restricted to slight variations in the degree of body muscling, fat deposits and coat colour, and a single mildly coughing ewe. Body condition scores were high. In spite of declining lamb ratios and heavy lungworm infections, individual lambs were large and showed no evidence of secondary bacterial bronchopneumonia at 5-6 months.

The WW sheep were wary and were found scattered over the range in small groups. Observers have found that these sheep grazed in large groups, such as seen on the CL range, when at higher population density prior to the 1981-82 dieoff (Davidson pers. commun.). A larger proportion of WW sheep were in obvious poor health. Clinical signs included pale coats, tick infestations, lower body condition scores and active contagious ecthyma in all ages. Chronic respiratory disease was still present in both lambs and adults two years after the acute dieoff. Lamb mortality was very significant by 6 months of age.

The ER bighorns primarily utilize winter ranges where dispersal is limited by the surrounding snow pack (Schuerholz 1984). Animals are therefore generally grouped on snow free slopes. The use of a helicopter prevented visualization of groupings and clinical signs at the time of collection. Body condition scores of the ER herd were high. The lamb and yearling examined were small but in good condition. Mild chronic respiratory disease in adult ewes appeared well localized without debilitating systemic effects. The lesions associated with P. stilesi infections were extensive but contained and were surrounded by increased amounts of fibrous tissue indicating old, healing lung damage.

Gross pathological findings indicated the most severe lungworm infections occurred in CL sheep, followed by ER and WW. Microscopic pulmonary changes and fecal larvae numbers supported the gross estimations of lungworm pneumonia severity and chronicity. Microscopic hepatic and intestinal parasitic lesions were present to similar degrees in all sheep. Gross and fecal examination frequently missed lesions and parasite species and showed little correlation with severity of histologic lesions.

Tissue changes with bacterial pneumonias were the most severe and extensive in WW lambs. The chronic pneumonias of adult sheep on all three ranges varied in extent. There was localization to single lobes in CL and

Table 3. Serum, fecal and urine chemistry values in bighorn sheep collected from the East Kootenays in 1983-84.

Sheep number	BUN (mg/dl)	TP (g/L)	FN (%)	Glucose (mg/dl)	Cortisol (ng/ml) serum	Cortisol (ng/ml) urine
CL 1	2.8	50	0.9	77.4	3.6	18.2
CL 2	10.9	57	1.0	77.4	7.2	63.5
CL 3	11.5	46	1.0	59.4	< 1	66.5
CL 4	3.9	61	1.0	70.2	< 1	NE
CL 5	2.8	42	1.1	64.8	9.5	60.3
CL 6	1.1	64	1.1	52.2	12.8	12.8
X	(5.5)	(53.3)	(1.0)	(66.9)		
WW 1	24.9	57	1.8	55.8	15.6	77.5
WW 2	7.6	60	0.8	72	3.1	NE
WW 3	19.3	61	0.5	52.2	23.8	178.8
WW 4	28.6	46	1.4	81	0.3	39.9
WW 5	3.4	58	1.1	59.4	1.0	NE
WW 6	3.4	58	0.9	108	1.2	41.1
X	(14.5)	(56.7)	(1.1)	(71.4)		
ER 1	9.8	78	2.0	59.4	5.9	NE
ER 2	3.6	66	1.8	108	22.4	NE
ER 3	2.0	63	1.7	626	2.6	NE
ER 4	3.1	61	1.4	93.6	27.7	31.2
ER 5	5.6	56	1.8	46.8	16.9	NE
ER 6	10.6	57	1.8	327	32.1	NE
X	(5.8)	(63.5)	(1.8)	(210)		
Normals[a]	8 - 20	60 - 79	----	34 - 56		

NE - not examined
[a] domestic sheep values

ER ewes. These local reactions suggest an association with focal injury and inflammation as would result from aspiration of Protostrongylus larvae.

Fragments of larvae surrounded by focal granulomas are occasionally present, usually in anterior lobes, in many sheep (Spraker 1979). This was seen in this study, however, the foci were usually without changes related to secondary bacterial infection. The focal bacterial pneumonia in CL 6 did contain larval remnants.

In contrast, chronic pneumonia in WW sheep, when present, affected more than one lobe, extended into the pleural cavity and appeared older. Microscopic changes in chronic pneumonias were similar in all herds and only varied with the age of the lesion.

P. haemolytica type T, a bacterium strongly associated with the recent B.C. and Alberta dieoffs (Onderka and Wishart 1984) was present in a WW lamb with active pneumonia and was cultured from lymphoid and lung tissues of WW4 and ER5, ewes with chronic pneumonias. The presence of the organism in association with other pathogenic opportunistic bacteria in WW 4 may be incidental as her immune system was undoubtedly compromised by the lymphoid tumor. The presence in the focal, mild, resolving lesion in an otherwise healthy ER ewe supports the hypothesis that P. haemolytica type T is an opportunistic pathogen (Onderka and Wishart 1984), and that pneumonias can occur and resolve in individual bighorn sheep without disease epidemics.

The high incidence of chronic diseases, secondary infections and continued presence of lesions from pathogenic pulmonary bacteria in adult and juvenile WW sheep in 1983, strongly suggests residual effects of stressors associated with the acute dieoff in 1982. Spraker et al. (1984) described the mortality of bighorn lambs in captive and free-ranging herds during years following all-age dieoffs. Lambs less than 6 months of age died with bronchopneumonia caused by opportunistic bacteria and showed marked atrophy of the thymus gland. The authors suggested that stressors similar to those which precipitated the all-age dieoff may continue to affect pregnant ewes. Continued high levels of glucocorticoids secreted by the highly stimulated adrenal gland can inhibit the development of the thymus and immune system of the fetus. In addition, the steroids may restrict the production of colostral antibodies. Without a fully functional immune system and the passive immunity provided by the colostrum, the neonatal lamb would be extremely vulnerable to normal microflora. Adult sheep harbouring chronic respiratory infections could easily transmit large doses of pathogens to the susceptible lambs. The pattern of lamb disease and mortality in the WW herd appears to fit this pathogenesis.

Titres to the respiratory viruses PI3, IBR, RSV and other systemic disease viruses which may cause respiratory or debilitating disease, such as BT, EHD and BVD, have been present in all North American wild sheep species examined (Howe et al. 1966, Parks and England 1974, Zarnke 1983, Clark et al. 1985, Dunbar et al. 1985). Isolations of PI3 (Parks et al. 1972, Jessup 1985), RSV (Spraker et al. 1986) and BT (Robinson et al. 1967, Kistner et al. 1975) have been made from bighorns with clinical disease. Maedi/visna is a viral disease of domestic sheep which causes a slowly progressive interstitial pneumonia and has not yet been identified in bighorn sheep. Serological results in this study suggested little exposure of the E.K. bighorns to these viruses or to Johne's disease.

Marginal copper levels were present in all three herds, but not in all samples. Marginal selenium levels in some WW sheep and levels consistent with deficiency in all CL sheep suggest the presence of deficiency related disorders in these two herds. Similar levels of copper and selenium were present in tissues from some WW bighorns which died in the E.K. dieoff in 1981 (Davidson 1982). Since that time WW mineral licks have been supplemented with a livestock trace mineral mix. It is possible that those sheep collected from the WW range had artificially high trace mineral levels and that deficiencies may have played a more important role in the herd prior to supplementation.

It is recognized that the soils of the E.K. area are generally deficient in selenium and that domestic animal syndromes are diagnosed in animals grazing on pasture in this area (Puls per. commun.). Hebert and Cowan (1971) examined mountain goats, forages and mineral licks from the E.K. area and suggested that myodystrophies seen in that species were predisposed by selenium deficiency. Eastman et al. (1971) determined that copper levels in forage plants common on low elevation winter ranges in the E.K. were especially low.

The consistently higher levels of selenium present in ER bighorns supports the findings of Hebert (1973) that alpine forages contain higher levels of trace minerals and suggests that these sheep do not suffer from selenium deficiency.

Serum chemistry profiles for healthy captive and wild bighorn sheep (Davies 1976, Franzmann 1971a, Franzmann and Thorne 1970, Woolf and Kradel 1970), stone sheep (Franzmann 1971b), Dall sheep (Foreyt et al. 1983) and Nelson desert sheep (McDonald et al. 1981), as well as for sick captive and wild bighorn sheep (Woolf and Kradel 1973, Spraker et al. 1984) have been examined. In this study healthy and sick sheep were shot, usually without prior disturbance. Samples were expected to reflect actual physiologic values in CL and WW sheep, while the use of a helicopter was expected to increase parameters affected by acute stress, such as cortisol and glucose (Franzmann and Thorne 1970), but not total serum proteins and blood urea nitrogen. The study chemistry values were compared to the above reported levels for wild sheep species as well as those for domestic sheep.

East Kootenay bighorn glucose values were similar to literature reports as well as to domestic sheep levels. Mild to extreme increases were present with excitement, the highest in helicopter herded ER sheep. Glucose levels vary with excitement and habitat, however, without further forage evaluation no habitat quality assumptions may be made from this data (Franzmann 1972). Blood and urine cortisol values varied too greatly for accurate interpretation. In general, disturbed, clinically ill and chased sheep serum cortisols were high, although these findings were not consistent and there was no relationship with the size of individual adrenal glands. Urine cortisol levels should not have been affected by acute stresses, however, they were not corrected for urine concentration when analyzed. There was then a trend towards higher cortisol values in the order WW > CL > ER, however, the diagnosis of stress levels by this method requires more rigorous sampling technique and further research before proper assessments can be made.

The TP of the study animals was within normal domestic and bighorn sheep limits in ER sheep, decreased in CL juveniles and low normal in CL adults. The sick WW lambs also had normal TP in spite of their poor body condition. TP in these animals may have been artificially elevated due to dehydration and/or high circulating immunoglobulin levels in response to systemic infections. Other WW sheep had low normal TP except for low levels in the ewe with lymphosarcoma.

The levels of BUN were low in the majority of the study sheep. Mild increases were present in sick WW sheep, likely due to body protein catabolism. Levels similar to moderately low CL, WW and ER values were reported in healthy and sick bighorns (Franzmann and Thorne 1970, Spraker et al. 1984) and were suggested to reflect the low protein content of forages. Many of the apparently healthy sheep in good condition from CL and ER ranges had BUN values far below those reported.

The project bighorn FN values were comparable to Hebert et al. (1984) values for sheep from October to December. The average ER values were highest and corresponded with levels in migratory sheep seen in that study. WW and CL values were equal and matched the lowest levels that were found during winter months in Hebert et al. (1984) evaluations. Variations in FN of sick WW animals were likely due to nitrogen losses from systemic illness.

The low TP, BUN and FN values of CL sheep suggest very inadequate winter range protein content. This substantiates estimate of poor quality winter range quality for this herd. Similar findings in w sheep should be further investigated due to the variations seen in chronically ill animals. In contrast, low BUN values of ER sheep were present with normal TP and higher FN content than either of the other herds. Hebert (1972) compared high and low altitude forages in the E.K. and found those from high altitude pastures to be of higher nutrient quality. Stelfox (1976) and Schuerholz (1983) assessed the mountain grasslands of national park and E.K. bighorn habitats and found them to be of high productivity. They were also easily available due to the preference of sheep for south facing, snow free slopes. Schuerholz (1983) also noted a lack of interspecific competition for forage at this altitude. The low BUN values and marginal tissue copper levels do not completely support the prsence of higher quality of feed on the ER winter range, howver, sample numbers were low without actual feed analysis of these animals. Larger numbers of coordinated samples of forages, soils and animals over time would be required to fully understand these results.

Columbia Lake Treatment

The B.C. Wildlife Branch was advised to attempt treatment of CL sheep for the high levels of lungworm infection and mineral deficiencies. A reduction of animal density was considered to be a necessary part of this remedial action.

Sheep on Columbia Lake winter range were conditioned to eat fermented apple mash during the spring of 1984. Fenbendazole anthelmintic was added to treat each sheep three times at weekly intervals. Mineral licks had been supplemented with livestock trace mineral mix since the fall collection. A group of 25 sheep of mixed ages and sexes were live captured after treatment and moved to a suitable unoccupied winter range at some distance from CL.

An additional three CL sheep were collected and a poached animal examined in the fall of 1984. Similar procedures were performed as described for project sheep. Fecal samples were taken from transplanted sheep and the CL range for lungworm analysis.

Three of the sheep collected in 1984 had deficient and one had marginal selenium levels. One of the four had marginal copper values. Lungworm larvae were very low in an adult ewe and a yearling, moderate in one lamb and high in a second (Figure 2). Fecal larvae levels in range collected or trapped sheep were zero following spring anthelmintic treatment but returned to near previous levels in some animals by the fall.

It is believed that the committment to intensive management of this herd has allowed a reduction in parasite load of CL bighorns. Therapy and research must continue, however, in the face of constant reinfection from the range and lack of significant changes in selenium and copper levels. Range improvement and reduction of sheep numbers through transplantation must be considered extremely important and integral remedial elements for the successful treatment of this herd.

CONCLUSION

The low sample size of this study prevents any conclusive statements, however, the results do suggest that there are differences between the low and high elevation wintering bighorn herds of the East Kootenay region of British Columbia. The differences were primarily related to the factors which were suggested to predispose E.K. bighorns to an all-age dieoff in 1981, high animal density, poor nutrition, parasitism and trace mineral deficiencies. High lungworm levels, reduced nutritional indices and lower selenium levels occurred in the CL herd at high animal density. Sheep wintering at high elevation on the ER range, at lower density, appeared to have access to better quality nutrition and maintained lower levels of lungworm infection. The effects of a previous pneumonia outbreak appeared to have a longterm influence on the WW herd and resulted in residual chronic disease in adult bighorns and a marked reduction in the viability of young lambs for at least 3 years post-dieoff, in spite of lower levels of lungworm infection and reduced animal density on winter range.

Although there may be a background level of some or many of the previously discussed factors in all sheep herds, at a certain population density, additional or increased levels of preexisting stressors appear to overwhelm the functional immune system and precipitate the occurrence of epidemic disease. Bighorn sheep management and research must continue to emphasize the identification of density and stressor levels where outbreaks occur. The status of a population appears to be best determined by the use of a group of indices. Hanks (1981) advises the characterization of population condition by the assessment of physiological parameters together with reproductive capacity, habitat condition and trend. Comparison of population nutritional condition and parasite levels between herds over time may then indicate and predict when stress conditions and sheep density move into the critical range before dieoffs occur and allow remedial actions to maintain and increase wild sheep populations.

RECOMMENDATIONS

The method of sampling used in this study may not be practical or indicated for many management or monitoring schemes. The results, however, underline the importance of invasive and noninvasive monitoring techniques. Of these, we believe the collection of fecal samples from individual sheep over successive seasons and years remains the method of choice, economically and practically. Feces may be examined for lungworm larvae per gram, (Uhazy et al. 1973) to determine parameters such as mean LPG, LPG annual trends and the proportion of heavily infected (> 1400) sheep per herd (Holmes and Samuel 1974). Fecal nitrogen levels have proved useful but require further studies in field situations, again, over time. Although blood and urine cortisol levels were not useful in this study, further studies with these and a potential method for fecal cortisol metabolites (Spraker pers commun.) may allow the determination of sheep baseline cortisol secretion and allow the evaluation of levels indicative of overall herd stress. The submission of freshly dead animals or hunter kills for necropsy and liver tissue for trace mineral analysis is also advised whenever possible.

These sampling procedures must be considered only as corollaries to the observation and study of stable and fluctuating sheep herds, their dynamics and range conditions for trends over time.

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Questions

Jim Bailey, Colorado -- You said your blood and urine cortisol levels were highly variable.

Schwantje -- Yes, they were generally high in animals that I could predict would be high, like those hazed by helicopter. Some of the levels from those sheep were low. In the other herds other animals I expected to be high were not.

Bailey -- I guess that answers my question. I was going to ask you if you attempted to correlate cortisol levels with any other factors, in particular, the thymus and adrenal glands.

Schwantje -- The blood and urine cortisol levels for those animals with small thymuses and large adrenals were higher than other sheep in the same herd but were similar to sheep with normally sized glands in other herds.

Development Impacts

Proc. Fifth Bienn. Symp. North.
Wild Sheep and Goat Council 1986

MOUNTAIN GOAT POPULATION CHANGES IN RELATION TO ENERGY EXPLORATION ALONG MONTANA'S ROCKY MOUNTAIN FRONT

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Abstract: A mountain goat (Oreamnos americanus) study was initiated in 1981 along the east slope of Montana's Rocky Mountains (823 km^2) to quantify population parameters and monitor energy exploration activity. Twenty-four radio-marked goats provided seasonal home range information. Observations of the radio-marked and 8 neckbanded goats provided reproductive histories for adult females, and annual survey efficiency. The adult female population trend was stable in the Birch-Badger segment but declined significantly in the Teton-Dupuyer segment. Kid:adult female (K:ADF) ratios in the Birch-Badger segment dropped 81% from 1983 to 1984, and 62% in the Teton-Dupuyer segment from 1982 to 1983. Beginning in 1981, energy exploration dramatically increased. From 1981 to 1985, about 579 km of seismic lines were shot within mountain goat habitat. This activity peaked during 1983 and 1984. Radio-telemetry information did not indicate abandonment of home range, however the peak in seismic activity did coincide with declining adult female numbers, kid numbers, and productivity in the Teton-Dupuyer segment. Differences in population characteristics in the Birch-Badger and Teton-Dupuyer segment appear to be attributable to differences in levels of human disturbance within each area. Other factors were addressed which may have influenced mountain goat population characteristics, including weather, hunter harvest, livestock grazing, timber harvest, and disease. The added impact of seismic activity, over and above other human activities in the Teton-Dupuyer segment, appeared to be the primary cause of changing population characteristics.

Native mountain goats of Montana's Rocky Mountain Front (RMF) occur along the theoretically petroleum-rich Overthrust Belt. Industrial and recreational projects have been implicated in declines of native mountain goat populations throughout North America (Chadwick 1973, Hebert and Turnbull 1977, Kuck 1977, Pendergast and Bindernagle 1977, Foster and Rahs 1983, Rice and Benzon 1985). Therefore, concern about human impacts from energy exploration has focused upon mountain goats along the RMF as the pace of exploration accelerates and gas/oil field development begins. Research on mountain goats from 1981 through 1986 was conducted to describe the mountain goat population along the RMF, document changes in population parameters, and describe the upsurge of human activity within the area and the possible consequences of human-induced stress upon the population.

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STUDY AREA

The RMF study area (Fig. 1) occured in the Sawtooth Mountains of northcentral Montana. Lying along the east slope of the Continental Divide, the study area extended some 82 km south of Glacier National Park to the main Sun River and was bordered on the east by the prairie. The study area was divided into 3 segments (Fig. 1) based on relatively autonomous mountain goat population segments. The Deep-Sun segment is not considered in this analysis because it was not intensively surveyed and was therefore not comparable.

Geological forces shaped the magnificent reefs of the RMF. The awesome cliffs and ridges of the RMF are composed primarily of Madison limestone from the Cambrian era, although the bulwark of the mountains is Precambrian sedimentary rocks (Alt 1985).

Gale-force chinook winds, often blowing over 100 km per hour, melts and blows away snow on the eastern slopes and exposes forage. The coldest average winter temperatures (January) range from -8.9°C at East Glacier to -6.0°C at the Sun River's Gibson Dam. The warmest average summer temperatures (August) range from 15.9°C to 16.7°C, respectively. Yearly precipitation averages 59.7 cm at East Glacier and 47.0 cm at Gibson Dam (Nat. Oceanic and Atmos. Admin. 1980-1985). Maximum snow pack occurs in April with depths (from north to south) averaging 252.5 cm at Badger Pass (2103 m), 168.1 cm at Mount Lockhart (1951 m), and 148.3 cm at Wrong Ridge (2073 m) (U.S.D.A. SCS 1922-1985) (Fig. 1). Meteorological data indicate a subtle gradient toward warm and dry, moving from north to south along the RMF. Detailed descriptions of vegetation, habitat types and landtypes are described in Harvey (1980), Thompson (1980), Holdorf et al. (1980) and Holdorf (1981).

METHODS

Repeated, systematic helicopter surveys were conducted on that portion of the population north of the Middle Fork Teton River (823 km², Fig. 1). Surveys were flown during July, from 1981 through 1986, during morning and evening hours, by the author in a G3 47 Bell helicopter. Subsequent to each helicopter survey, a radio-relocation flight was made to determine the presence or

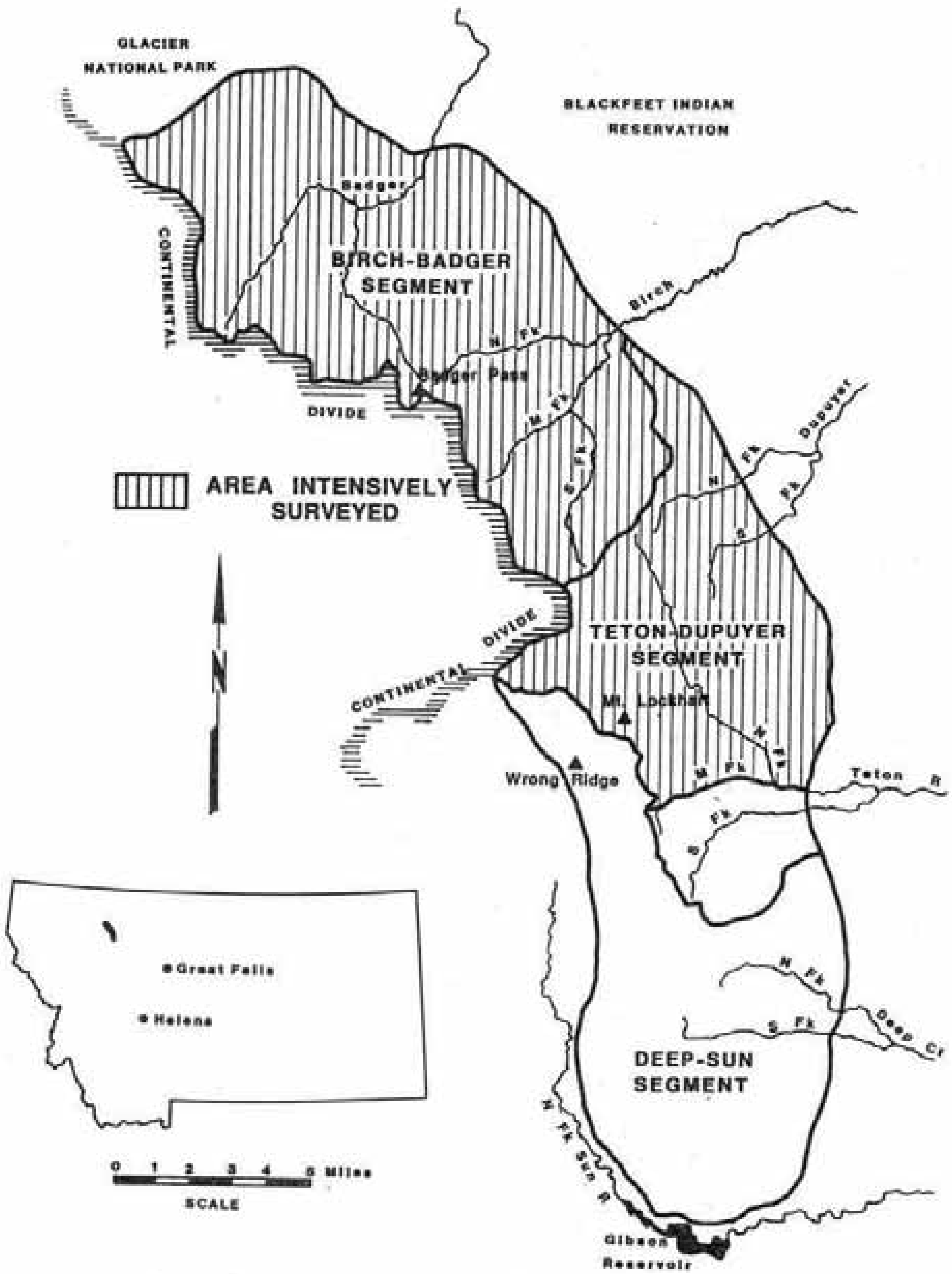

Figure 1. Rocky Mountain Front Study Area.

absence of radio-marked goats within the Teton-Dupuyer area. The percentage of radio-marked and neckbanded animals observed during annual surveys provided the basis for establishing survey efficiency.

Thirty-five mountain goats in the Teton-Dupuyer segment were fitted with radio collars (23), neckbands (8), and eartags (4), from 1979 through 1982 (Joslin 1986). Nine and 6 adult males, 8 and 2 adult females, and 6 (4 females and 2 males) and 0 subadults were marked with radio-collars and neckbands, respectively. Four male kids were eartagged. All radio-collars placed on subadults were expandable elastic collars which were not observable from the air. During aerial telemetry, observations of radio-marked animals were obtained when possible. Both air and ground observations provided data on the reproductive histories of 11 radio-marked and 2 neckbanded females. Mountain goats were classified as adults (male or female), 2-year-olds, yearlings, and kids based on morphological features, molting patterns, and group association.

Seasonal home range sizes (convex polygons) of 24 radio-marked mountain goats were calculated based on bi-monthly radio-relocation flights. Average number of fixes used in calculating home ranges for adult animals was 56 (range 25-120).

Snow depth information was collected from 3 snow survey sites which occur in the Birch-Badger, Teton-Dupuyer, and Deep-Sun segments of the study area, respectively (Fig. 1). These sites occur either within mountain goat winter range, or in the case of Badger Pass, which is at the edge of the study area, at an elevation which coincides with mountain goat winter range.

Information concerning energy exploration activities was provided by the Rocky Mountain Ranger District, Lewis and Clark National Forest. The term seismic activity, as used here, includes all ground and air activity associated with seismic line set up, shooting, and clean up.

RESULTS

Population Characteristics

Home range information was collected for 9 adult females, 9 adult males, and 6 subadults in the Teton-Dupuyer segment (Joslin 1986). Comparing adults for which at least 2 years of information was available, the largest yearlong home range was 181.5 km^2 for a male while the smallest was 16.0 km^2 for a female. Only 1 male had a yearlong home range (22.9 km^2) smaller than the average for females (34.9 km^2), while all female ranges were smaller than the average for males (89.4 km^2). The average female summer range (19.2 km^2) was slightly smaller than the average winter range (22.2 km^2), but the reverse was true for males (48.5 and 46.4 km^2). Although goats tended to adjust their movements over the course of the study, none were known to abandon their established home range.

All marked goats generally confined themselves to the Teton-Dupuyer segment. Over the course of the study, observability of marked adult females was higher (80%, SD=13) than marked adult males (30%, SD=18) (Table 1). Because observability of adult females was consistently high, population trends were based on actual number of females and kids observed in both the Teton-Dupuyer and Birch-Badger population segments.

Table 1. Observability of marked adult mountain goats, July 1981 - 1986.

YEAR	MARKED FEMALES	NO. OBSERVED	% OBSERVED	MARKED MALES	NO. OBSERVED	% OBSERVED
1981	3	2	67	3	0	0
1982	7	6	86	11	4	36
1983	7	5	71	8	1	12
1984	7	7	100	10	5	50
1985	4	3	75	8	4	50
Total	28	23	399	40	14	148
Average			79.8			29.6

Population trend of female goats in the Teton-Dupuyer segment from 1981 through 1986 is presented in Table 2. The decline in adult females in this segment (Fig. 2) was significant ($R=-0.851$, $p < .05$). The trend in the Birch-Badger segment on the other hand was not significant ($R=-0.833$, $p > .1$) (Table 3 and Fig. 3). At the beginning of the study, numbers of adult females in both population segments were similar, but by 1986, adult females in the Teton-Dupuyer segment had dropped about 50%.

Table 2. Summer helicopter surveys of mountain goats in the Teton-Dupuyer segment, 1981-1986.

YEAR	TOTAL	ADM	ADF	SA	KID	K:100ADF
1981	75	13	33	17	12	36.3
1982	60	16	25	10	9	36.0
1983	43	13	22	5	3	13.6
1984	58	15	28	9	6	21.4
1985	37	12	18	3	4	22.0
1986	32	9	15	6	2	13.3

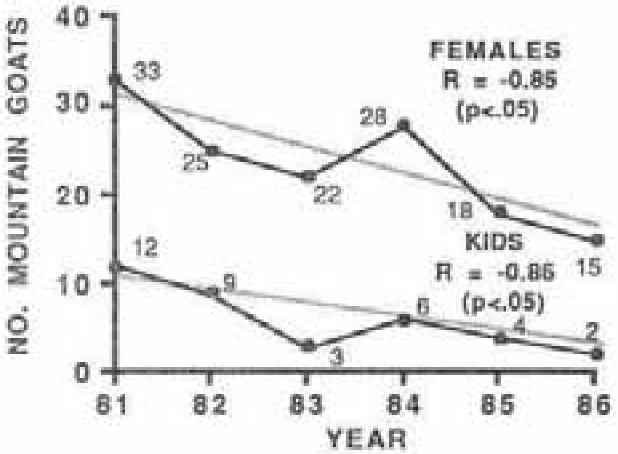

Figure 2. Adult female and kid mountain goats observed during annual surveys of the Teton-Dupuyer segment.

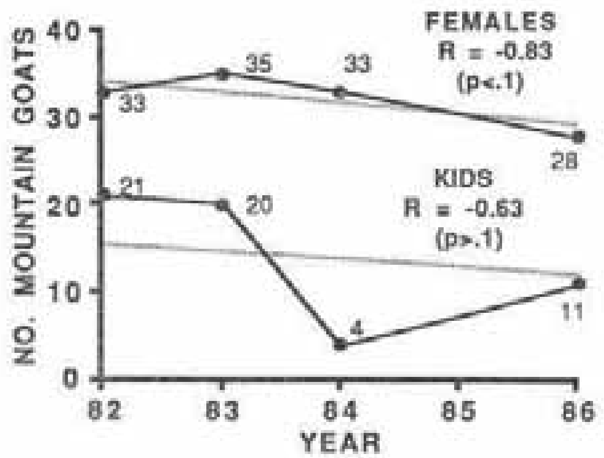

Figure 3. Adult female and kid mountain goats observed during annual surveys of the Birch-Badger segment.

Table 3. Summer helicopter surveys of mountain goats in the Birch-Badger segment, 1982-1986.

YEAR	TOTAL	ADM	ADF	SA	KID	K:100ADF
1982	77	15	33	8	21	63.6
1983	80	9	35	16	20	57.1
1984	56	10	33	9	4	12.1
1986	72	21	28	12	11	39.3

Even though population levels were similar at the onset of this study, kid production levels were not. In the Teton-Dupuyer segment, kid:adult female (K:ADF) ratios in 1982 were over 40% lower than in the Birch-Badger segment. By 1983 and 1984, kid production dropped 62% and 81% in the Teton-Dupuyer and Birch-Badger segments, respectively. By 1986, kid production in the Birch-Badger segment appeared to be recovering and had more than tripled from a low of 12 K:100ADF (Fig. 3). But kid production in the Teton-Dupuyer segment improved only slightly in 1984 and 1985, then dropped back to the low of 13K:100ADF in 1986 (Fig. 2).

Reproductive histories of 11 marked adult female goats indicates the possible cause of decline in both females and kids in the Teton-Dupuyer segment. From 1 to 6 years of reproduction information was documented for each marked adult female (Table 4). Potentially 42 young could have been born to these females over the course of the study, assuming 1 kid born per female per year. Six of 18 kids that were born died, while the fates of 4 others were undetermined. No twins were produced. Sixty percent of the kids that died did so between July and September. Production ranged from a maximum of 100% (N=3) in 1979 to 0 (N=5) in 1984. Recruitment was highest prior to initiation of this study (Thompson 1980), then it dropped to 0 (1984-86). Apparently, the consistently low kid production and poor recruitment resulted in a lack of reproductive females being recruited into the population, and therefore, the population continued to decline.

Table 4. Reproductive history of 11 marked female mountain goats.

Radio #	Age Marked (Yrs.)	1979	1980	1981	1982	1983	1984	1985	1986
1172	4	K →	Y K →	Y K-died	K-died	0	0	Trans[a]	
1082	4	K →	Y ?	?	?	0 Trans			
1052	3	K-died	K →	Y K-died	K Trans				
1222	3		K →	Y K →	Y K →	Y Trans			
1290	AD				K-died	K	Dead[b]		
1230	AD				K →	Y 0	0	0	0
42[c]	5				0	0	0	0	0
32[c]	AD				0	0	0	K	0
1240	2				---	0	0	0	0
1814	4				K-died	K/Dead[b]			
492	3					0			

[a] = transmitter failed
[b] = adult goat died
[c] = neckband

Energy Exploration

Seismic exploration activity along the RMF has increased 37 fold from the 1960-1980 period when an average of 9.5 km of line was shot per year, to 1981-1984 when an average of 351.0 km of line was shot per year (Fig. 4). Wildcat drilling in the 59 years between 1921 and 1980 amounted to an average of 1 well drilled every 2.7 years. From 1981-1984 an average of 1 well per year was drilled. Although only a portion of this seismic and drilling activity occurred within the study area, the trend is clear. Nearly all of the 579 km of seismic lines which were shot in the mountain goat study area since 1981 were helicopter supported. An estimated 21.7 man days and 6 to 8 helicopter km are associated with each km of helicopter based seismic line shot

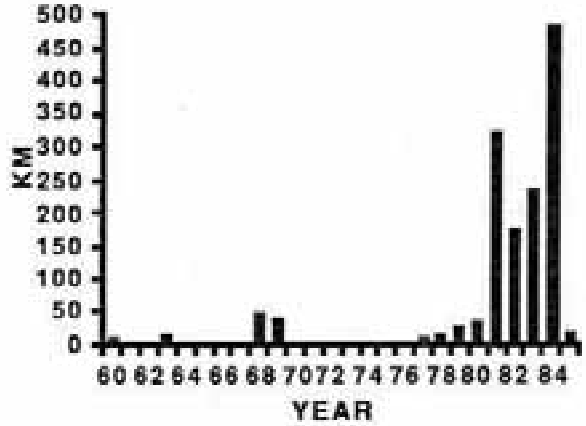

Figure 4. Rocky Mountain Front seismic exploration.

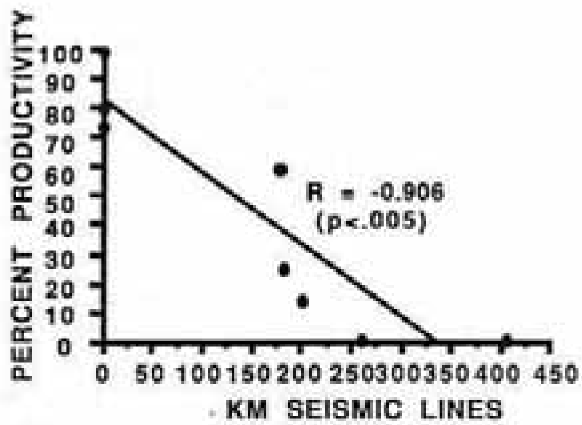

Figure 5. Productivity of radio-marked adult females in relation to cumulative seismic activity (2 previous years).

within mountainous terrain along the RMF. This equates with 12,564 man days and about 4,053 km of helicopter activity within the study area since 1981.

Declines in adult females, kids, and productivity of marked adult females in the Teton-Dupuyer segment were negatively correlated with the amount of seismic activity occurring in mountain goat habitat within the study area from 1979 to 1986. A regression of the amount of seismic activity occurring 1 year prior to the July annual population survey, and the number of females observed during that survey, accounted for 71% (R^2) of the variability in adult females ($R=-0.846$, $p < .05$) over the course of the study. The number of kids present in the population segment was inversely correlated ($R=-0.875$, $p < .05$) with the sum of seismic activity occurring 2 years previous to the year in which the population was surveyed, i.e. km of seismic line in 1979 plus 1980 were compared to the number of kids present in 1981. As might be expected, number of kids in the segment was positively correlated with number of females in the population segment ($R=0.874$, $p < .05$). As the number of adult females declined so did numbers of kids, indicating that compensatory reproduction was not occurring. This was also illustrated by reproductive information from marked adult females. Although the correlation between productivity and seismic activity that year, or the previous year was weak, the correlation of productivity and seismic activity for two years prior to the birth year was highly significant ($R=-0.906, p < .001$) (Fig. 5). Thus, the amount of seismic activity during 2 years explained 82% (R^2) of the variation in productivity during the birth year.

DISCUSSION

The objective of this study was to evaluate changes in the RMF mountain goat population in relation to energy exploration. At the beginning of this study, kid production was higher in the Birch-Badger segment than the Teton-Dupuyer segment. Reasons for this difference are not fully understood, although it may be related to the degree of human activity historically occurring in these areas. The Birch-Badger segment is relatively inaccessible, and has not been greatly influenced by human activities. In contrast, the Teton-Dupuyer segment has had a much higher level of human activity, including a seasonal ranger station, timber harvest, and developed recreation involving a downhill ski resort, a guest ranch, groomed snowmobile trails, developed campgrounds, and major trail head parking facilities. This has resulted in traditionally more motorized access and use.

Prior to the increase in helicopter based seismic activity along the RMF in 1981, it appeared that the Birch-Badger segment contained an undisturbed mountain goat population that had good reproductive performance, while the Teton-Dupuyer segment was comparatively more heavily utilized by people and contained a mountain goat population that had relatively low reproductive performance. The number of adult females in the Birch-Badger segment remained relatively stable from 1981 to 1986, but declined in the Teton-Dupuyer segment. During this period, the total number of kids in the Teton-Dupuyer segment declined, while the number of kids in the Birch-Badger segment showed a sharp decline in 1984, and then some increase in 1986 (although still substantially below 1982-1983 levels). The reproductive decline appeared coincident with the peak in seismic activity along the RMF from 1981 through 1984. The recovery of kids in 1986 in the Birch-Badger segment also appears coincident with the cessation of seismic activity in 1985. However, kid production, number of kids, and number of adult females in the Teton-Dupuyer segment continued to decline through 1986. The Teton-Dupuyer population did not respond as the Birch-Badger population had, once seismic activity ceased, possibly due to the long-term additive effects of several stressors upon the Teton-Dupuyer segment.

Other factors which may have influenced mountain goat population characteristics include weather, hunter harvest, livestock grazing, timber harvest, and disease. Several authors have documented an inverse correlation between winter snow depths and kid survival (Chadwick 1973, Rideout 1974, Smith 1976, Bailey and Johnson 1977, Thompson 1980, Johnson 1983, Swenson 1985). The average of March, April and May snow depths from 3 snow survey sites in or near mountain goat winter range along the RMF from 1980 through 1985 indicated that winter snow pack has been at or below normal during 5 of 6 years. A regression of Teton-Dupuyer kid:non-kid ratios upon snow depth showed little correlation ($r=0.5$, $df=5$, $p > 0.1$). The relatively low snow depths apparently did not have an influence on kid survival.

Cool wet summers are also known to affect survival of newborn young (Brandborg 1955, Johnson 1983). Temperature and precipitation data during June, July and August from 1980 to 1985 indicated that summers have generally been slightly warmer and dryer than average. The month of June in particular, is critical, but 1981 was the only year slightly cooler than normal (-0.4 C below average), and 1983 and 1984 were the only years slightly wetter than normal (1.0 cm and 0.1 cm above the average, respectively). A combination of abnormally cold and wet conditions did not occur during the course of the study.

Numbers of hunting permits issued for the 2 districts along the RMF have varied from 15 to 8 between 1978 and 1985, and currently stand at 8. An average of 4 to 5 mountain goats have been harvested per year. Since the beginning of this study in 1981, when population levels were first estimated (Joslin 1986), mountain goat harvest has not exceeded 4% of the population, and has averaged 3%. Females have composed 46% of the harvest, or between 2 and 3 per year. Analysis of harvest indicated that adult females in the Birch-Badger segment were neither negatively nor positively influenced by existing harvest levels ($R=0.321$, $p < .5$). A positive correlation between number of females harvested and number of females in the Teton-Dupuyer segment indicated that females were harvested in proportion to their abundance ($R=0.876$, $p < .05$). Hunting, therefore, does not appear to be responsible for the observed kid decline, although it is possibly a contributing stressor to the Teton-Dupuyer population segment.

Livestock grazing peaked along the RMF in the early 1900's. Changes in allotment size, duration of use, species use, and management systems have helped reduce livestock competition with wildlife. Generally, livestock use is now at its lowest level in 50 to 80 years, and the current level of use has been maintained since the most sweeping changes were instituted in allotment use 10 to 20 years ago. Although livestock grazing continues to be a significant land-use activity along the RMF, the extent and degree of use has not appreciably changed in the last 2 decades, and would not appear to have created a new or increased stress upon the mountain goat population.

Approximately 7,600 cubic meters (1 million board feet) per year of timber has been removed from the RMF over the past decade (USDA Lewis and Clark National Forest Plan 1986). All of the few logging roads that created access into mountain goat range occurred in the Teton-Dupuyer segment, but timber sales have generally not been located in critical mountain goat range. The decline in kid production in the Birch-Badger segment was not related to timber harvest since none occurred in this area. However, limited harvest in the Teton-Dupuyer segment may have indirectly affected that area's population.

The drop in mountain goat kid production in 1983 and 1984 tends to parallel the pattern of bighorn sheep decline due to a pneumonia die-off along the RMF in 1983 and 1984 (Hook 1986).

Onderka and Wishart (1984) indicate that in bighorns, some adults initially succumb of respiratory disease complex, while others may survive to become carriers and thus bare a poor lamb crop.

Mountain goat deaths as a result of respiratory disease complex were not documented, although 2 possible cases were discovered. In 1983, 2 mountain goats were found dead along the RMF, one along the South Fork Teton River in Green Gulch (T. Bivins 1983, pers. commun.) and the other near Many Glacier in Glacier National Park (K. Keating 1985, pers. commun.). The Teton goat, a 5-6 year old male, was diagnosed as having fibrinopurulent bronchopneumonia (Corynebacterium sp.) (J. Rhyan, DVM, Lab Rpt. No. 8-470 Veterinary Lab, Bozeman, MT). The Glacier goat also suffered from severe suppurative pneumonia (M. Harries DVM, Path. No. L83-3228-H Alberta Animal Health Division, via Glacier National Park, MT). Harries noted that the pathological changes in the Glacier goat were essentially similar to those of the bighorn sheep which had been suffering from a Pasteurella hemolytica biotype T pneumonia in areas of Alberta, British Columbia, and the RMF of Montana. Although significant bacteria could not be isolated, similar organisms to those of the sheep had very likely been present (op. cit.).

Limited evidence indicates that broncho-pneumonia might have been a contributing factor in the observed mountain goat population changes. Respiratory disease complex is often stress-induced (Onderka and Wishart 1984). If this stress-related pneumonia was latent in mountain goats along the RMF, it is possible that this disease, and the stress-inducing effects of seismic disturbance could have acted in concert to cause the observed decline in females and kid production.

The correlation between mountain goat productivity and seismic activity in previous years, suggest that the stress induced by this seismic activity is cumulative over the years. The 4 year period of very intensive activity probably created more stress than it would have, had the individual years of activity not been consecutive. Stemp (1983) indicated that pre-natal stress is of particular concern because the extreme sensitivity of the young is related to their rapid development, and the most rapid development of a mammal takes place as a fetus. Particular organs and behaviours are especially susceptible during the critical periods in which they are maturing most rapidly (Scott 1962). Changes in development can be so pronounced that the individual's emotionality and behavior, phenotype, and even viability can be profoundly and permanently altered (Stemp 1983).

A number of researchers have reported upon behavioral and physiological response of wildlife to helicopter harassment. Helicopters, sonic booms, gunshots, people on foot, stopped occupied vehicles, and domestic dogs elicit strong behavioral and/or heart rate responses from a variety of wildlife (Horejsi 1976, Ward and Cupal 1979, Gunn et al. 1983, Stemp 1983, Irwin and Gillin 1985). MacArthur et al. (1982), Stemp (1983), Ward and Cupal (1979) and others have indicated that behavioral response does not necessarily reflect physiological response to harassment. Despite the animals outward behavior, Stemp (1983) reported that heart rate of bighorn sheep was significantly elevated and remained elevated as long as helicopter activity occurred in their vicinity. Up to 45 minutes was required after the disturbance was gone for heart rate to return to normal. He indicated that "behavioral response can be extremely misleading: helicopters can sensitize bighorns and can produce marked and prolonged physiological responses in the absence of pronounced--or even any--behavioral reaction".

To avoid stress-inducing disturbance, an animal may withdraw, but withdrawal is also costly because exertion demands increased energy expenditure. Also, injury is a risk during escape attempts, and the opportunity to feed at that location is removed. If animals withdraw from key habitat areas, carrying capacity can be reduced (Geist 1975). During this study, mountain goats generally moved away from human activity, and used topographic relief to screen themselves from line-of-sight disturbance. Although they did redistribute themselves within their home ranges to avoid disturbance, fidelity to familiar terrain was strong and none abandoned their traditional home ranges.

Abundant literature exists detailing the maladaptations that may result from repeated or prolonged stress stimulation, including decreased resistance to infection and disease (Hudson 1973, Stein et al. 1976), and impaired or complete failure of reproductive function (Geber 1962, 1970; Petropoulos et al. 1972, Sontag 1970 - in Stemp 1983). Stemp (1983) indicated that "any stressor sensitizes the individual to other stressors. Moreover, a prolonged stress response decreases an individuals ability to cope psychologically (Shanan et al. 1976) which is likely to make them more susceptible to subsequent stressors". This is particularly evident in the Teton-Dupuyer segment where seismic activity appeared to be additive to other long-term, human-induced stressors. A constant level of stress may explain why kid production in this area did not improve, even though seismic activity ceased in 1985. Although the Birch-Badger segment was relatively immune from long-term stressors, it appeared that seismic activity did cause a decline in kid production in 1984. Once seismic work ended, productivity improved. In comparison, mountain goat populations in adjacent Glacier National Park (where no seismic activity occurred) appeared to be stable (K. Keating 1985, pers. commun.)

This study indicates that efforts should be made to reduce human activities in the Teton-Dupuyer segment in order to allow mountain goat population recovery. If the Birch-Badger segment remains inaccessible and relatively free of human activity, it appears that it might be able to recover from temporary, short-term disturbance. Monitoring will be necessary to determine whether mountain goat production returns to pre-1981 levels along the RMF.

Detailed multi-agency guidelines were developed to ameliorate the effects of energy exploration activities upon wildlife along the RMF (Interagency Rocky Mountain Front Wildlife Guidelines 1984). One objective of the guidelines was "to avoid or minimize human related activities which may adversely impact selected species of wildlife". The mountain goat population declines suggest that the guidelines were insufficient to maintain pre-development kid production and female population levels in the face of intense human activity. Application of the guidelines was particularly deficient in controlling distribution of seismic activity. If the mountain goat population is to increase and be maintained at or above the 1980 level, managing the timing and intensity of human activity within mountain goat habitat will be critical.

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QUESTIONS AND ANSWERS

Bruce Smith, Wyoming: Gayle, I was interested in your juvenile mortality rates and wonder if you could tell us how you determine those for kids and yearlings. Yours were fairly high.

Gayle Joslin: They were fairly high. They were determined from five consecutive years of actual survey information.

Smith: So it was actual counts of kids during consecutive years and comparing them from year to year?

Joslin: yes and over the course of the year by watching kids of radio-marked adult females from week to week.

Smith: Were you surveying during the winter?

Joslin: No, I surveyed in July.

Smith: You had an inverse correlation between productivity of the goats and the seismic activity, is that right?

Joslin: Right

Smith: Was there any correlation between the mortality rates of kids and yearlings and the activity in the areas you looked at. For example, before the seismic activity increased, did you have lower mortality of kids and yearlings than you did after you had higher levels of activity in the area.

Joslin: Yes. Using both yearly survey data and monthly observation data from marked females which had kids at side, I could see that as consecutive years of seismic activity elapsed, either productivity or survival or both decreased.

Smith: So then there was a correlation?

Joslin: Yes.

Nicki Goodson, Colorado: Do you have any information on distribution activity, or movement patterns of goats relative to disturbance?

Joslin: Regarding distribution, radio-marked goats did not leave established home ranges when disturbance occurred, but they would use topography to screen themselves from human activity by moving out of a drainage where the activity was occurring. I observed four marked goats do this. When disturbed, goats would often watch the activity for quite some time. They would be alert, not feed, and they seemed to chew their cud less, but this was not a behavior study per se, so I don't have quantitative ethological data. Doug Chadwick's thesis gives excellent descriptions of mountain goat response to disturbance. I did not observe anything during this work which was counter to what Chadwick reported.

Jim Bailey, Colorado: How far did they move?

Joslin: They always stayed within their home range, but males would move the greatest distances. It was common for three radio-marked males to travel about nine air miles over the Continental Divide into the Flathead drainage to summer, but that was more of a seasonal movement. Males had the opportunity to avoid the activity more because their home ranges included more wilderness area and were, therefore, more isolated.

Bailey: You said that was a seasonal thing. I was asking in addition to Nicki's question, how far do these animals move in response to seismic.

Joslin: Let me explain a complicating aspect of this work. Several of us who were collecting data along the Rocky Mountain Front at that time will attest that we often did not know where or when a seismic line would be shot. Communication from the Rocky Mountain Ranger District to field biologists regarding seismic activity was limited. So, we were often not aware that a particular line had been shot until it was too late to monitor an animal's response. Relative to those goats which I did observe subsequent to disturbance when I had the opportunity, they would often move no more than a half mile. They would go over a ridge to get away from direct line-of-sight disturbance. It is this kind of limited reaction by goats which elicits a judgment that goats are not affected by disturbance. However, in the case of mountain goats at least, I believe the population data is more revealing than behavioral reaction.

Wayne Heimer, Alaska: Is this exploration over at this point or ongoing?

Joslin: Good question, we would like to know, too. When the price of oil goes back up, I suppose we'll see more exploration. They do have three exploratory wells that are pending right now.

Heimer: The other question is, presuming with the price of oil being low like it is, there won't be anything going on right away, are you going to continue watching to see if the stress goes away if things get better?

Joslin: There's no more funding. No.

Heimer: There ought to be.

Peter Davidson, BC: There was obviously a lot of activity by helicopters in that area. I assume that most of this is done from helicopters judging by the terrain. You mentioned Raymond Stemp's work, University of Calgary, was there any attempt to collect that type of information from these goats?

Joslin: No heart rate response or fecal cortisol information was gathered so there was no direct measure of stress effects.

Davidson: I'm suggesting that the helicopters might have had as much effect as the blast itself or more.

Joslin: I think it had more. That's my personal opinion, but I think it had more. There was a great deal of helicopter activity.

Kirby Smith, Alberta: You said you lost 60% of your kids by September, did I miss the explanation or do you have any explanation? Were you watching kids on cliffs during helicopter passes or anything like that? Do you think it was because of falls or what?

Joslin: I don't know what the exact mechanism of the kid decline was. Of the kids born to marked female goats, six were known to have died. Four of these six disappeared between July and October.

Ted Benzon, South Dakota: After the seismic activity was gone, how long did it take before the goats went back into that area?

Joslin: Some times by evening they would come back. Especially when they were on salt licks. Goats will take big risks when their drive for salt is high. They almost seem suicidal.

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POPULATION CHARACTERISTICS AND HABITAT USE BY MOUNTAIN SHEEP PRIOR TO A PNEUMONIA DIEOFF

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Abstract: A study of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) ecology along the east slope of the Rocky Mountains in north central Montana was conducted during 1982-83. Objectives were to provide baseline information on seasonal distribution, habitat use, population status, and responses to oil and gas exploration in an area that supported a transplanted population and a population formed through colonization. Three population units and their seasonally important ranges were delineated based on the distribution and movements of 9 radio-collared and 9 neckbanded sheep. Population estimates based on the Chapman index for the entire study area were 253 in winter 1982-83 and 258 in summer 1982. The January 1983 lamb:ewe ratio was 45:100 and the ram:ewe ratio was 48:100. Our data indicated the sheep herds in the study area were expanding in range and numbers during 1982-83. Availability and distribution of habitat components utilized by sheep seemed adequate to support greater sheep numbers than we observed. Species composition of the diet appeared consistent with a healthy, expanding herd. Ground approaches by humans led to local displacements initially but sheep quickly habituated. Helicopter surveys resulted in a mean flushing distance of 364 m. Seismic activities in seasonal ranges occupied by radio-collared sheep were limited to 3 weeks during summer 1982. Sheep were displaced from a lambing area during one seismic operation but were only locally displaced during another operation. In autumn 1983, a pneumonia outbreak was noted north of the Teton River. By March, dead sheep had been found in all herds along the east slope from Birch Creek to areas south of the Sun River. Mortality in herds in the Sun River area was estimated at 22%. The herds in our study area suffered comparable or greater mortality.

The east slope of the Rocky Mountains in northcentral Montana (Fig. 1) supports one of the largest herds of Rocky Mountain bighorn sheep in the United States (Couey and Schallenberger 1971). Winter ranges along the Sun River have been

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continuously occupied since European settlers entered the area. Sheep occupying most, if not all, winter ranges north of the Sun River were eliminated prior to the 1930's. Within the last 25 years, 3 winter ranges have been reestablished (G. Olson 1982, pers. commun.)

The first record of resident wintering sheep on the Ear Mountain winter range (Fig. 1) occurred in 1960-61 when 30 sheep were counted. Counts by Montana Department of Fish, Wildlife, and Parks (MDFWP) personnel prior to this study fluctuated from a low of eight in 1965-66 to a high of 74 in 1972-73 (MDFWP 1961-81, unpubl. P-R Reps., Helena). This winter range was presumably colonized by animals from established winter ranges in the Sun River area.

The Walling Reef winter range was established with animals transplanted by MDFWP from the Sun River area in March 1976. The single transplant consisted of 37 sheep (23 adult females, 7 adult males, and 7 lambs). Although sporodic sightings of sheep had been reported in the area prior to the transplant, no resident wintering animals had occupied Walling Reef since a herd was eliminated in the early 1920's. The Choteau Mountain herd evidently was established around 1978 by sheep moving north from Ear Mountain or Deep Creek (a winter range in the Sun River complex) and was supplemented by sheep moving south from the Walling Reef transplant site.

This study was initiated in 1982 to determine population status, movements, and habitat use patterns of mountain sheep in the recently established herds north of the Sun River. The information we collected allowed us to contrast population character in a transplanted herd (Walling Reef) and a herd formed via colonization (Ear Mountain) with that of the herd from which both originated (Sun River). An outbreak of bacteria (*Pasteurella hemolytica*) - lungworm (*Protostrongylus* spp.) associated pneumonia in 1983-84 allowed us to retrospectively assess population vulnerability in the three situations.

This project was funded by the U.S.D.A. Forest Service through a contract with the Montana Department of Fish, Wildlife, and Parks. The supplemental data, field assistance, and advice provided by MDFWP biologists J. McCarthy and G. Olson were essential to the success of this study. Fecal analysis was completed by W. Kasworm. Assistance provided by R. Evans, D. Getz, D. Hook, G. Joslin, R. Kinyon, G. Sherman, and L. Young was greatly appreciated.

STUDY AREA

The study area, a 780 km^2 portion of the Sawtooth Range, extended from the Continental Divide to the foothill/prairie

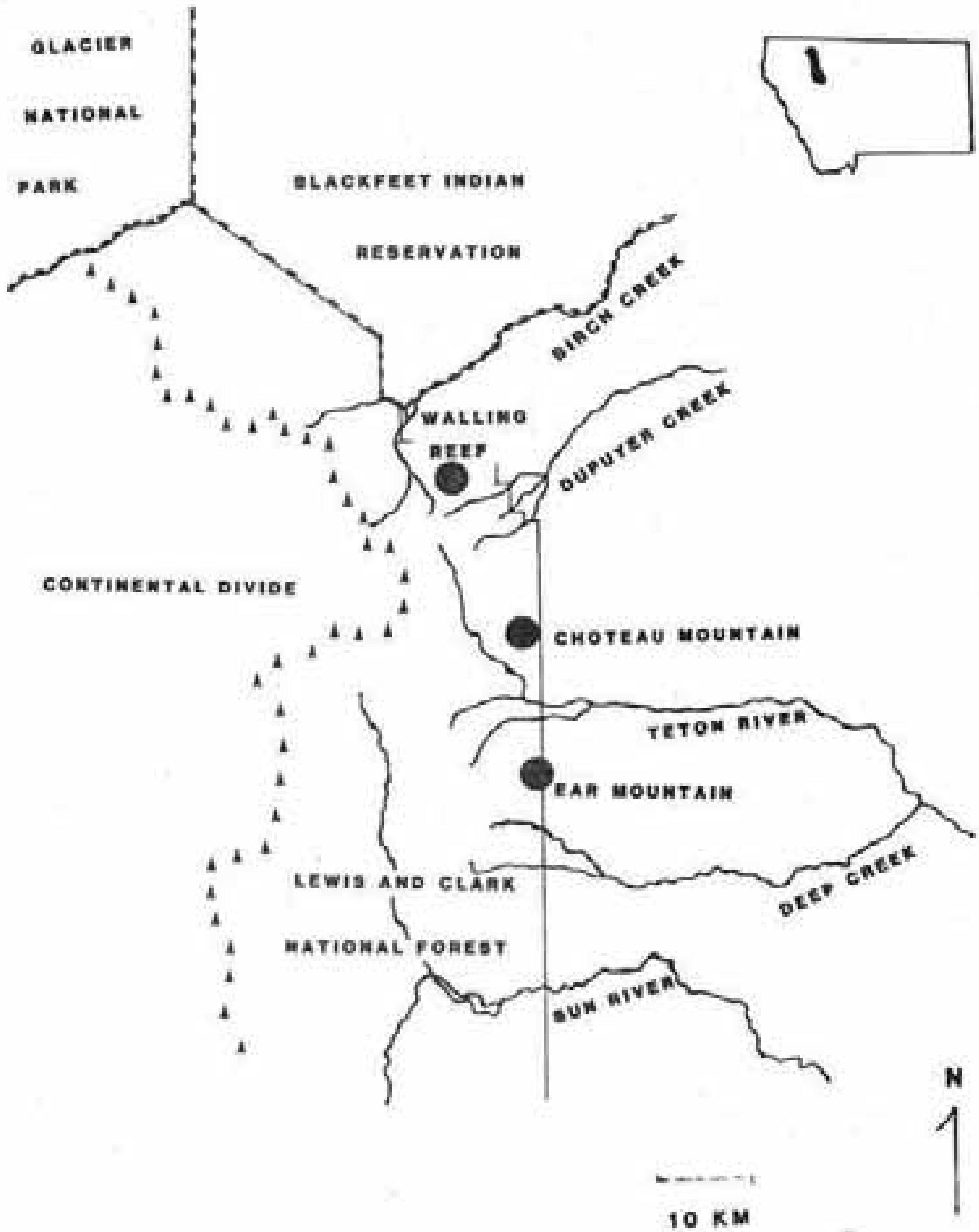

Figure 1. Map of the study area with names of major features.

ecotone of the mountain front (Fig. 1). This area is located in the Lewis Overthrust Belt and is characterized by a series of parallel north-south ridges separated by narrow stream courses. Dominant habitat types included the subalpine fir (Abies lasiocarpa), Douglas-fir (Pseudostuga menziesii), limber pine (Pinus flexilis), rough fescue (Festuca scabrella), bluebunch wheatgrass (Agropyron spicatum), alpine grassland, and rockland habitat series (Pfister et al. 1977, Mueggler and Stewart 1980, Kasworm 1981). Extensive areas of subclimax/disclimax grassland and shrubland existed in the study area as a result of burns and past livestock use.

The average annual temperature along the mountain front is approximately 5 C. Annual precipitation averages 38 cm on the prairie/foothill ecotone and over 200 cm in the alpine zone. Although 60-80% of the precipitation falls as snow, southwesterly chinook winds periodically reduce snow cover on the mountain front during winter. Conditions during winter 1981-82 were approximately average. Conditions during winter 1982-83 were much milder than average. In 1983-84, early winter weather was more severe and late winter weather milder than average (U.S. Dep. Comm. 1981-84).

METHODS

SEASONAL DISTRIBUTION AND POPULATION DYNAMICS

Distribution and movements of 9 radio-collared animals were determined from 20 relocation flights made from April 1982 - April 1983 using a Piper Supercub (Andryk 1983). Flights were made twice a month during April - August 1982 and January - March 1983 and approximately once a month during September - December 1982. Additional movement and distribution data were obtained from sightings of 9 neck-banded sheep. Distribution of sheep within the study area during 1976-81 was obtained from MDFWP surveys and incidental sightings recorded in MDFWP files (MDFWP 1976-81, unpubl. P-R Reps., Helena).

Seasonal distribution and sex/age ratios were determined from helicopter (Bell 47B-2) surveys in August 1982 and January 1983 and from ground surveys during April 1982 - April 1983. Counts from helicopter surveys were considered minimum population estimates. Chapman indices (Chapman 1951), derived from observations of marked and unmarked animals in the entire study area and apportioned between population units, were utilized as an alternate means of estimating numbers.

HABITAT CHARACTERISTICS AND USE

Vegetation measurements were made during July and August 1982 on Walling Reef and Ear Mountain summer and winter concentration areas. Sample plots were placed randomly within mountain sheep concentration areas at a density of 20 per 2.59 km^2 and at all radio and neckband relocations recorded during March - August 1982. At each site, three 0.1 m^2 plots were used to estimate canopy coverage (Daubenmier 1959) in the ground stratum (grasses, forbs, and shrubs <30 cm in height). Canopy coverages of plants in the mid (woody plants 30-180 cm) and upper (woody plants >180 centimeters) strata were estimated in a 375 m^2 plot at each site (Pfister et al. 1977). No plots were established on Choteau Mountain because of the limited number of relocations of marked sheep.

Spearman's rank correlations (Snedecor and Cochran 1980) were employed to test differences in canopy coverage between random and relocation plots. Student's t-tests were used to test differences in canopy coverage between random plots in Walling Reef and Ear Mountain concentration areas. Significance levels were designated as $p<0.05$ unless otherwise noted.

Habitat use patterns were described based on information collected from all sheep observations (radio relocations, aerial observations, and ground sightings). Habitat components recorded were: terrain type, cover type, elevation, aspect, slope, and distances to timber and escape cover. Slope was obtained using a USGS slope grid and 1:24,000 topographic maps. Escape cover was defined as cliffs or broken rock areas that provided security from predators.

DISTURBANCE

Human activity in seasonal ranges occupied by sheep was noted whenever observed. Reactions of sheep to ground approaches by researchers were quantitatively assessed in April - May 1982. Flushing distance (diagonal measurement calculated from the helicopter altitude as determined from the altimeter and the map-measured distance between the helicopter location and the locations of sheep groups at the time they flushed) was noted for all sheep observed during helicopter surveys in August 1982 and January 1983.

Three seismic exploration lines (surface charge) were run in the study area during summer 1982. Radio relocations were obtained prior to and after two lines were completed on Walling Reef. A ground survey of sheep distribution was conducted three days after completion of the lines. Behavioral responses of sheep were observed during one of the eight days on which seismograph teams worked in the Ear Mountain area.

DOCUMENTATION OF THE DIEOFF

Reports by hunters, local landowners, and MDFWP personnel were used to chart the appearance of sick or dead animals in individual population units. Ground and aerial surveys conducted by MDFWP personnel during winter 1983-84 and summer 1984 provided the bases for assessing the relative severity of the outbreak.

RESULTS

DISTRIBUTION

Helicopter surveys, relocations of marked animals, and ground observations during 1976-83 allowed us to delineate three winter ranges in the study area (Fig. 2). The presence of 3 marked animals from the Walling Reef transplant on the Choteau Mountain winter range and the movement of a male lamb marked on Ear Mountain to winter range on Choteau Mountain as a yearling indicated that linkages existed between the ranges.

Sheep were widely dispersed and range overlap occurred between population units during summer and autumn. Distribution of sightings during the 1976-83 period (Fig. 2) indicated that the Walling Reef unit was expanding to the north, south, and west and the Ear Mountain unit to the north and west.

POPULATION DYNAMICS

Counts of sheep in individual nonoverlapping counting areas indicated minimum population levels of 172 in summer 1982 and 149 in winter 1982-83. Population estimates for the entire study area (Table 1) based on Chapman indices were 253 during August 1982 and 245 during January 1983. Thirty-five, 17, and 48% were associated with the Walling Reef, Choteau Mountain, and Ear Mountain units, respectively. Minimum densities on winter range were: Walling Reef = 1.4 (54/39 km^2); Choteau Mountain = 1.4 (18/13 km^2); and Ear Mountain = 2.8 (77/28 km^2).

Lamb:ewe (all females greater than 1 yr) ratios of 50:100 in June 1982, 49:100 in August 1982, and 45:100 in January 1983 indicated light summer - autumn lamb mortality. Lamb mortality through March 1983 was negligible. If yearling males sighted in the January 1983 helicopter survey were representative of yearling survival for both sexes, the yearling to adult ewe ratio in January 1983 was 41:100. Known adult mortality in the study area during spring 1982 through spring 1983 was 24, 1 coyote kill and 23 hunting kills.

HABITAT CHARACTERISTICS AND USE

Seasonal Habitat Use by All Observed Sheep

Approximately 70% of sheep observations were within 91 m and

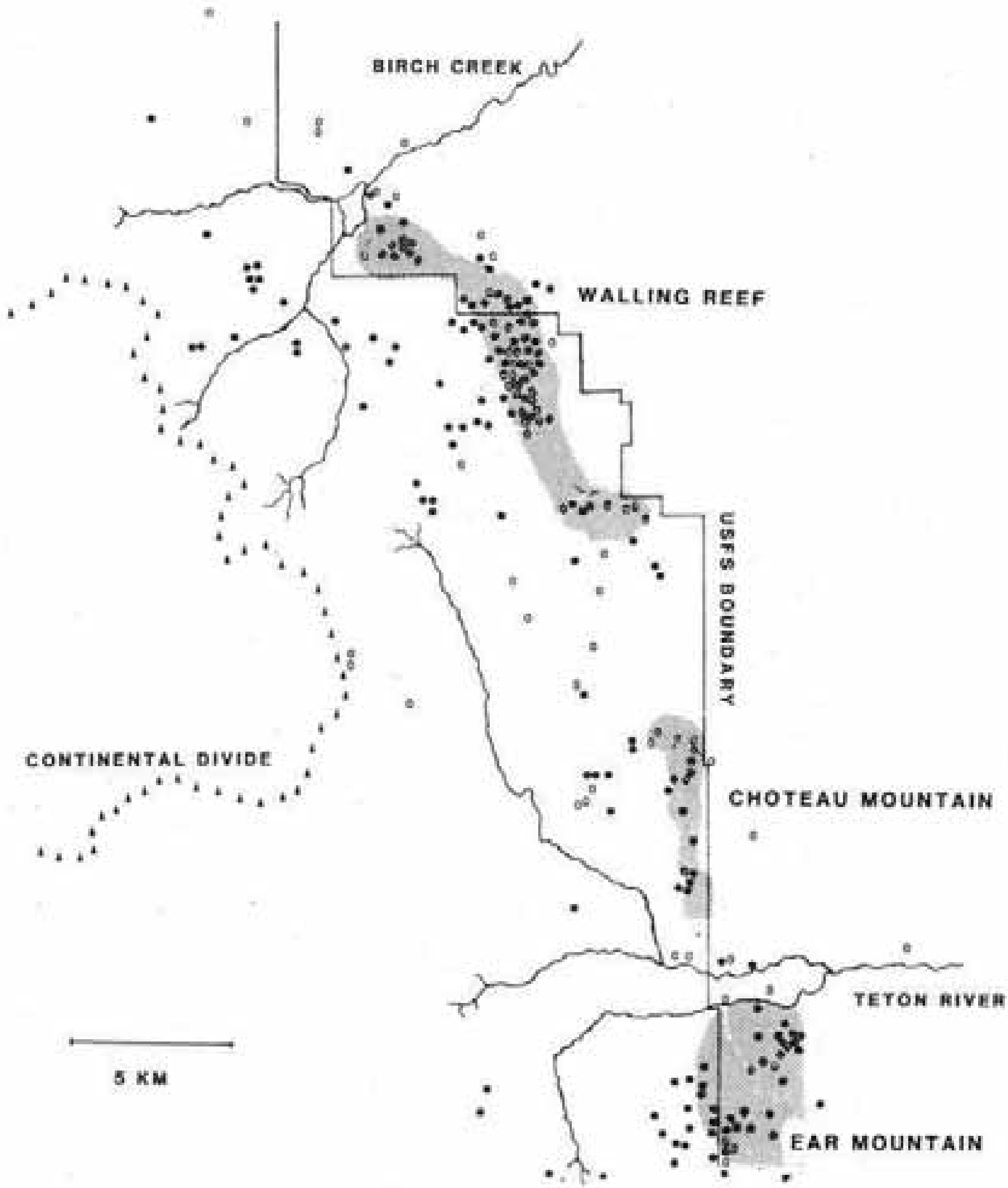

Figure 2. Mountain sheep distribution within the study area, 1976-83 (1976-81 sightings = o ; 1982-83 sightings = ●).

Table 1. Total numbers observed and Chapman index based population estimates for mountain sheep populations in the study area obtained during helicopter surveys in 1982-83.

Unit	Count	Estimate
August 1982		
Walling Reef	56	82
Choteau Mountain	37	55
Ear Mountain	79	116
Total	172	253[a]
January 1983		
Walling Reef	54	89
Choteau Mountain	18	30
Ear Mountain	77	126
Total	149	246[b]

[a] Based on sightings of 12 of 18 marked animals.

[b] Based on sightings of 10 ot 17 marked animals.

93% were within 230 m of escape cover. Bighorns in all populations within the study area used grass-forb cover types, slopes with southern exposures, and low relief terrain more on winter-spring than on summer-fall ranges (Table 2). Bighorns on summer-fall ranges used higher elevations, steeper and more rugged terrain (bluffs, cliffs, cirques, and talus), slopes with east exposures, and sites closer to escape cover more than did animals observed in winter-spring.

Differences in observed use between winter ranges were related to land form and vegetation availability. Sheep on the Walling Reef winter range made heavy use of windswept north-facing slopes that supported open grassland on old burns. Sheep on the Ear Mountain winter range evidently preferred dry south-facing foothill slopes. Both situations provided the least snow cover and access to the greatest areas of herbaceous vegetation available on the respective winter ranges.

Table 2. Habitat use (percentage of total groups observed) by mountain sheep in the study area during April 1982 - April 1983. Total numbers of groups observed were 186 in winter - spring (December - June) and 81 in summer - fall (July - November).

Habitat division	Dec-Jun	Jul-Nov	Habitat division	Dec-Jun	Jul-Nov
Terrain type			Aspect		
Bluff	10	17	N	6	5
Cliff	13	10	NE	9	4
Cirque basin	2	10	E	12	37
Talus slope	1	14	SE	8	2
Broken slopes	5	9	S	41	22
Ridge	15	15	SW	10	6
Park	4	1	W	8	21
Riparian	4	2	NW	5	2
Sidehill	46	22			
Cover type*			Slope		
Timber	5	16	0-20%	5	5
Shrub	6	8	20-39%	40	11
Grass-forb	60	39	40-59%	25	26
Rock-bare ground	22	28	60-79%	12	42
Old burn	8	8	>79%	18	16
Elevation (m)			Distance to escape cover (m)		
1402-1525	3	1	In or <9	25	19
1526-1678	24		9-91	55	54
1679-1830	30	1	92-230	17	21
1831-1983	13	16	231-400	6	5
1984-2135	17	22	>400	2	1
2136-2288	8	28			
2289-2440	4	27	Distance to timber (m)		
2441-2593	1	4	In or <9	15	19
			9-91	56	37
			92-230	17	21
			231-400	8	23
			>400	4	

* Total observations were 261 and 135 in Dec - Jun and Jul - Nov, respectively because a single group sometimes occupied more than 1 cover type.

Winter Range Vegetation and Ungulate Use

The Walling Reef winter range was located on a subalpine plateau at 1,647 - 2,196 m a.s.l. The Ear Mountain winter range was located in a foothill area at 1,586 - 1,830 m a.s.l. Randomly located plots indicated canopy coverages of grasses, forbs, and herbaceous litter were lower and shrubs and rock were higher on the the Walling Reef winter range than on the Ear Mountain winter range (Andryk 1983).

Seventy-five of the 130 species identified in plots on Walling Reef and the 107 species in Ear Mountain plots (Andryk 1983) were found on both winter ranges. Dominant grasses on Ear Mountain were rough fescue and Idaho fescue (F. idahoensis). Dominant graminoids on the Walling Reef winter range were Idaho fescue and sedges (Cyperus spp.). Top ranking forbs/half shrubs on Ear Mountain were balsamroot (Balsamorhiza sagittata) and fringed sagewort (Artemisia frigida). Dominant forbs on Walling Reef were bedstraw (Galium boreale) and false vetch (Hedysarum sp.). Dominant woody plants in plots were shrubby cinquefoil (Potentilla fruticosa) and rose (Rosa spp.) on Ear Mountain and kinnikinick (Arctostaphylos uva-ursi) and shrubby cinquefoil on Walling Reef.

The Walling Reef winter range encompassed approximately 39 km^2 and the Ear Mountain winter range approximately 28 km^2 at the time of the study. At least 80% of both areas had been protected from livestock grazing for 10 or more years, Walling Reef by precipitous cliffs and Ear Mountain by fences. The proportion of the winter range grazed by cattle was higher on Ear Mountain (~20% grazed) than on Walling Reef(~10% grazed) at the time of the study. Walling Reef had higher elk (Cervus elaphus) and mountain goat (Oreamnos americanus) use than Ear Mountain. Ear Mountain supported more mule deer (Odocoileus hemionus) and bighorn sheep use than Walling Reef.

There was a significant positive rank correlation (r_s = 0.85-0.89) between ground coverage characteristics in random plots and plots at relocations of marked sheep on both the Ear Mountain and Walling Reef winter ranges (Andryk 1983). The close association between availability and use suggests that sheep were distributed randomly relative to ground coverage categories within both winter ranges.

Sixty-four percent of plant taxa identified on Walling Reef and 57% on Ear Mountain were found in both random and sheep relocation plots. Seven and 6 of the 10 highest ranking plant species by canopy coverage in random plots on the Walling Reef and Ear Mountain winter ranges, respectively, were also ranked in the 10 highest in plots at sheep relocations (Andryk 1983). Although this indicated that sheep were distributed somewhat in proportion to plant availability within winter ranges, sample sizes were too small for rigorous evaluation.

Summer Range Vegetation and Bighorn Use

Both Walling Reef and Ear Mountain sheep summered in alpine ridge and peak areas at elevations of 2,013 - 2,440 m. Tests of ground coverage in randomly distributed plots within both summer ranges (Andryk 1983) indicated that forb and shrub coverages were higher and rock coverage was lower in the Walling Reef unit.

Of the 92 plants identified in random plots on Walling Reef summer range and the 88 on Ear Mountain summer range, 60 were found in both areas (Andryk 1983). The two highest ranking grasses, Idaho fescue and rough fescue, and forbs, false vetch and goldenrod (*Solidago* spp.), were similar in both summer ranges. The dominant shrubs were shrubby cinquefoil in the Walling Reef area and kinnikinick in the Ear Mountain area.

There was a significant positive rank correlation (r_s = 0.81-0.82) between ground coverage characteristics in random plots and plots measured at sheep relocations on both summer ranges (Andryk 1983). Forty-five percent and 42% (including 4 of the 10 highest ranking plant taxa by canopy coverage in each case) of plants found on Walling Reef and Ear Mountain summer ranges, respectively, were identified in both random and relocation plots. These data suggested a lower positive association between availability and use than was observed on winter ranges.

FOOD HABITS

Grasses were the dominant forage items in fecal samples from the Walling Reef and Ear Mountain units during fall, winter, and spring (Andryk 1983). Forbs were the most heavily used items in summer.

Fescues were the most common plant genus in fecal samples during all seasons in both units. *Astragalus* spp. ranked second in Walling Reef and Ear Mountain summer samples. Wheatgrasses were the second most common item in Walling Reef winter samples. Big sagebrush (*Artemisia tridentata*) was the second most common item in Ear Mountain winter samples.

HUMAN DISTURBANCE

Although we observed few incidences of human presence on any seasonal ranges and no incidents in which sheep were displaced by recreationists, the study area was utilized by horse and backpackers in summer and hunters in autumn. A portion of the Ear Mountain winter range overlooked a county road, but sheep were apparently habituated to the light vehicle traffic on it in winter and even used cliffs less than 100 m above the road as lambing sites in early summer.

Our ground observations led to local displacement, but this decreased with frequency of observation. During April and May 1982, sheep on the Ear Mountain winter range were approached 57 times. Flushing distance decreased from >200 m in early April to <100 m in mid May. Sheep on the Walling Reef winter range were approached less frequently. They maintained a flushing distance >200 meters throughout the study but did not leave regularly used portions of their seasonal ranges due to our presence.

Helicopter surveys produced more pronounced displacement. During the August 1982 and January 1983 surveys, flushing distances were determined for 21 sheep groups. Mean flushing distance was 364 m (S.D. = 232 m). In most incidents, all sheep in a group ran as the helicopter approached and continued running until the helicopter left.

During 16-24 June 1982, 2 seismic exploration lines were run on Walling Reef when sheep were lambing there. The 4 radio-collared sheep (3 ewes and a 2-yr-old ram) present in early June moved 4-6 km to an adjacent drainage by 17 June. Intensive ground surveys were conducted on Walling Reef on 20-22 June, and no sheep were observed. This was the only time during the entire study when no sheep were seen in this area during ground surveys. Ewe groups returned by 10 July and were regularly observed on Walling Reef for the remainder of the summer.

The seismic exploration line on Ear Mountain was completed during 17-25 June 1982, a period when most lambs on Ear Mountain lambing ranges were a week or more old. Sheep in this area did not leave during or after seismic operations although lambing sites were within 2.5 km of the seismic line.

One group of ewes and lambs (34 animals) was observed on a salt lick 1.6 km north of the line on 24 June. The lick was in the flight corridor used by the crew to move men and materials to the line. Andryk observed 14 helicopter passes directly over the sheep at ~5-min intervals and heights of 300 - 400 m. No behavioral response was noted in response to the sound of the helicopters, but on seeing the machine, the sheep bunched and ran. On 11 of the passes, flight distances were <50 m. However, on 3 of the last 5 passes, they ran to escape cover (90-200 m). Total behavioral reaction time (time from initial response to resumption of foraging) was 3-5 minutes per pass.

DESCRIPTION OF DIEOFF

On 1 December 1983, a fixed-wing aerial survey of Walling

Reef indicated no lambs were present with observed ewes. Sick rams and ram carcasses were first reported to MDFWP near the Teton River on 30 December 1983. On 22 January 1984, sick animals were first noted on Castle Reef in the Sun River area. By February, deaths were reported on interior winter ranges along the Sun River. By mid March, dead animals had been located on the southermost winter ranges in the Sun River complex (J. McCarthy and G. Olson 1984, pers. commun.).

All population units in the study area and in the Sun River complex experienced mortality. Four of 8 sheep with functioning radios in our study area died between November 1983 and February 1984. Spring 1984 and winter 1985 population surveys indicated mortality of approximately 22% in the Sun River area with deaths concentrated in young and old age classes (J. McCarthy 1985, pers. commun.). Counts on winter ranges in our study area were 40-50% lower than those obtained in helicopter surveys in 1982 and 1983, but weather conditions during the surveys were poor and may have led to incomplete counts (G. Olson, J. McCarthy, and G. Joslin 1985, pers commun.).

Mortality was evidently due to bacteria - lungworm associated pneumonia. Observations by biologists, hunters, and local residents suggested that the outbreaks moved sequentially from north to south.

DISCUSSION

The 1976 transplant on Walling Reef was one of the most successful single introduction transplants in Montana. Based on expansion patterns believed to have occurred in Sun River herds, the Walling Reef introduction accelerated establishment of bighorns in the Birch Creek drainage by at least 40 years (Andryk 1983). The success of this transplant may be attributed to any or all of 4 factors: 1) reintroducing bighorns into habitat that historically supported viable populations, 2) transplanting in a period in which 4 of the first 7 winters following the transplant were milder than average, 3) closure of Walling Reef to livestock in 1972, 4 years prior to the transplant, and 4) reintroducing bighorns into an area in which dispersing bighorns were already present (Geist 1971:111).

Habitat use and food habits of bighorns in the Ear Mountain and Walling Reef herds were similar to those observed in the Sun River area (Schallenberger 1965, Erickson 1972, Frisina 1974, Kasworm et al. 1984). Horn growth in harvested rams from the study area was similar to horn growth in the Sun River area (Andryk 1983). Productivity in 1982-83 in our study area was comparable to that in the Sun River (48 lambs:100 ewes in December 1982; MDFWP, unpubl. P-R Rep., Helena) and indicative of ratios found in healthy expanding herds (Woodgerd 1964, Shackleton 1973).

Based on information available through winter 1982-83, management strategies employed at Walling Reef, Ear Mountain, and Sun River appeared to be an unqualified success. The 1983-84 dieoff raised serious questions about these strategies. Five factors (or combinations thereof) are commonly suggested as triggers for pneumonia dieoffs in mountain sheep: 1) over-used range, 2) weather (cold winters that stress sheep or wet springs that favor lungworm production), 3) excessively dense or sendentary wintering populations of mountain sheep, 4) direct or indirect competition with other ungulates, especially domestic sheep, and 5) stress resulting from disturbance (Buechner 1960, Forrester 1971, Stelfox 1971, Uhazy et al. 1973, Foreyt and Jessup 1982, Goodson 1983, Lawson and Johnson 1983). None of these factors was consistently implicated in the East Front dieoff.

Range on portions of the Sun River area and in our study area showed indications of overuse and carried scars from past livestock grazing, but the overall condition for all winter ranges was fair to good (Kasworm et al. 1984, G. Olson 1986, pers. commun.). Distribution patterns in summer and winter indicated that sheep in the Walling Reef and Ear Mountain units did not limit their activities to rare landforms or habitat types that could have been locally overgrazed. Major items in sheep diets were plants that sheep along the East Front would be expected to utilize under favorable grazing conditions.

Population characteristics in our study area in 1982-83 were indicative of healthy expanding herds. We found no evidence of poor yearling survival or noticeably poor ram horn growth in the 1981-82 or 1982-83 winters.

Spring weather in 1983 was ~23% drier than the mean and was unlikely to have been abnormally favorable to lungworm larvae on the ground or to their snail hosts. Winter weather in December 1983 and January 1984 was severe (U.S. Dep. Comm. 1983-84), but late winter and spring were much milder than average. Bighorn populations in other areas of the state experienced similar weather patterns without pneumonia outbreaks (L. Irby and S. Stewart, unpubl. data).

The buildup of lungworm larvae on winter range due to continual occupation of a winter range over long periods of time might have been a cause of the outbreak in the Sun River complex, but Walling Reef, occupied less than 10 years and with 1/5 the sheep density (based on 1983 counts of 827 sheep on 130 km^2 of winter range in the Sun River complex; MDFWP, unpubl. P-R Reps., Helena), experienced as much or more mortality than herds in the Sun River. Counts of larval lungworm from sheep fecal samples were relatively high during 1983-84 in the Sun River area but were several times lower than counts from the Cinnabar Mountain herd on the northern border of Yellowstone National Park (D. Worley, unpubl. data). No deaths of adults were noted in the Cinnabar herd (L. Irby, unpubl. data).

Competition with elk had been cited as a possible cause of earlier sheep dieoffs in the Sun River area (Picton and Picton 1975). During 1983-84, elk numbers were below those associated with earlier dieoffs, and few elk used the Ear Mountain and Walling Reef winter ranges. The only other numerous indigenous ungulate, mule deer, had low levels of dietary overlap (Kasworm et al. 1984) with sheep. No positive association between density of deer and extent of mortality in sheep was apparent.

Livestock use of mountain sheep range was limited to cattle and horses, and <25% of the Ear Mountain and Walling Reef winter ranges were grazed. Stocking rates for livestock either remained approximately the same or were lower in 1983-84 than in 1981-83. The closest domestic sheep allotment was >15 km from occupied wild sheep range.

Although cumulative stress from several years of seismic operations could have triggered a population decline (Hook 1986, Joslin 1986), levels of gas and oil exploration during our study were low. Sheep responded to the activities, but adherence to mitigation guidelines (Andryk 1983, Hook 1986) accepted by the U.S. Forest Service and the Bureau of Land Management should have reduced disturbance to sheep after our study was completed. Other human activities in the study area, predominantly light to moderate hunter and hiker traffic, were similar to those that had occurred while sheep populations were rapidly expanding.

If, as the pattern of pneumonia outbreaks suggested, deaths were the result of the continued southward movement of a pathogen that caused widespread bighorn deaths in British Columbia and Alberta in 1981-83, Glacier National Park in 1982-83, and central Montana and central Idaho in autumn 1984, the mode of spread across gaps in mountain sheep distribution has not been ascertained (J. McCarthy, pers. commun.). We identified what appeared to be a 30-40 km gap between summer distributions of animals from the Walling Reef unit and animals from sheep populations in Glacier National Park. Dispersing sheep could have carried a pathogen across the remote mountainous terrain associated with this break in distribution, but the probability of a vertebrate vector carrying a pathogen across gaps of 100 km or more of human occupied lands to spread pneumonia into central Montana and central Idaho would seem almost nil. Despite the absence of a logical vector, the sequential spread of a virulent pathogen seems a better explanation than a chance sequence of independent dieoffs.

Whatever the ultimate cause, the most disturbing aspect of this outbreak was its unexpected appearance. Although we were involved in a much more intensive monitoring program than most state and federal agencies would be able to support on a longterm basis, we were unprepared for a major dieoff. None of the data we collected had any predictive value. Transplanted, colonizing, and resident sheep were equally vulnerable to the dieoff and gave equally few clues of its impending approach. If the Walling Reef transplant served as a conduit for invading pathogens, arguements could be put forth for isolating major mountain sheep herds by creating buffer zones through hunting or maintaining existing buffers by foregoing transplants. The failure of what we thought was an adequate buffer zone and the great distances between the 1983 outbreaks and those reported in autumn 1984 suggest this approach is futile. Until more is learned of the dynamics and control of the pneumonia cycle, managers should concentrate on increasing the overall area of suitable habitat occupied by mountain sheep herds, controlling human activities on critical seasonal sheep range, and educating the public to recognize dieoffs as natural occurrences from which sheep populations usually recover.

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QUESTIONS AND ANSWERS

Bill Shuster, Colorado: You mentioned fescues were important in winter, fall and spring range. Somewhere you said forbs. Can you give us a hint on what kind of forbs you're talking about?

Tim Andryk: Yes, Astragalus spp. was the most common forb in the diet during the summer. Graminoids were the most dominant part of the diet during three seasons of the year, while forbs were the most common item in the diet in the summer. In the summer, sheep utilize high latitude areas. They migrate back into the interior away from the Front winter sites and they will associate more with rocky terrain and rocky cliff areas that produce more forbs than grasses.

Bill Samuel, Alberta: I think the emphasis on lungworm is the wrong way to talk about it, and I think Dr. Onderka presented the best way to consider parasites in the die-off scenario. This is just one man's opinion, and I haven't thought about it any more or less than you have, but the way this die-off went in time and space suggests to me an infectious agent. I don't know about the gaps, but that just points to me how complex this whole bloody situation is and how little we know. But that scenario makes more sense to me than anything else in spite of the gaps in space. Tim Andryk, I agree with you completely.

Peter Davidson, British Columbia: I'm the guy that started this disease. I just wanted to point out the gaps that Bill was talking about. We had sheep that were perfectly healthy a stone's throw across Elk River Canyon, from the dying Wigwam sheep, and they did not die as long as they didn't come across onto the flats. We've got sheep north of the Kootenai River that didn't die and we know that there's contact in both of these areas with ewe and ram bands between the herds. There's some real anomalies that we haven't fully explained.

Andryk: One thing that we have been discussing is that sheep that have experienced these die-offs before are maybe more immune or less susceptible to die-offs in the future. Like along the Front. At the Sun River they had a 22% mortality. Roughly that. We feel mortality was probably greater, much greater, in the newly established herds north of the Sun River.

Allan Dale, Colorado: Do you have any information on what the lamb survival has been following this die-offs the last couple of years?

Andryk: Yes, we had a couple of years of very poor lamb survival. Down on the Sun River, John McCarthy was talking around 10 percent and since then the populations have come back and lamb/ewe ratios are getting back to normal at around 50-60.

Dale: So that's what, three years after the die-off.

Andryk: Yes.

Gayle Joslin, Montana: Tim, do you think that perhaps goats are filling the gaps between sheep populations? Goats and sheep overlap at hundreds of salt licks, and licks constitute likely places where sheep might be picking this disease up.

Andryk: We considered that possibility and passed it around for awhile. There probably is something to that, but the problem is it is not consistent with what happened when the die-off spread to central Montana and central Idaho. When it spread across large regions of human occupied agricultural lands, towns and villages and stuff.

Joslin: Are you talking about the Beartooth Game Range when you refer to giant geographic leaps?

Andryk: Yes, starting with the Beartooth Game Range and the outbreak at the Snake River in Idaho.

Joslin: I don't know about the Snake River, but we do have straggling goats coming back and forth across the Missouri River between the Beartooth Game Range and the Front.

Andryk: I'd appreciate some comments from the lungworm specialists that are in this room. I heard five different talks on lungworm today.

Bill Samuel, Alberta: What do you want me to say? Sheep have them, they all have them. We don't know beans about lungworm. I think we know less than you know about the ecology.

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IMPACTS OF SEISMIC ACTIVITY ON BIGHORN MOVEMENTS AND HABITAT USE

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Abstract: In April 1982, eight bighorn sheep were radio-collared on the Ford Creek winter range. This range is utilized by the southern segment of the Sun River population. As part of a continuing effort to evaluate effects of gas and oil development on big game populations along the Rocky Mountain Front, the yearround movements of these sheep were monitored for four years. In the fall of 1983, three seismic lines (helicopter porta-drills) were run concurrently across the Ford-Fairview Plateaus which represents the major portion of this herd's fall - winter range. In September-October 1982, prior to disturbance, 71% (10 of 14) of the radio relocations occurred on the Ford-Fairview Plateaus. During the September-October 1983 seismic activity, no relocations occurred on the plateaus. Instead, 100% (17) of the sheep relocations were to the south along the Crown Mountain-Wood Lake Hogback, which is part of their summer range. In September-October 1984, post disturbance, 45% (5 of 11) of the relocations were again on the Ford-Fairview Plateaus. In 1983, average annual home range size declined 28% from 25.9 square miles in 1982 to 18.6 square miles. Following disturbance in 1984, it increased to 29.7 square miles. Data on habitat use for three years is presented.

In October, 1980 a study was initiated along the Rocky Mountain Front in Montana to evaluate impacts of gas and oil activity on bighorn sheep, elk and mule deer populations. As part of this effort, eight bighorn sheep were captured on the Ford Creek winter range and radio-collared. The movements of these animals have been monitored. In the fall of 1983, seismic activity occurred on the Ford-Fairview Plateaus which makes up the major portion of the Ford Creek winter range for bighorn sheep. This paper presents the movements and habitat use of these marked animals, during years previous to, concurrent with, and after the disturbance.

METHODS

Bighorn sheep were captured in April 1982 on the Ford Creek winter range with a net gun fired from a helicopter. Seven adults ewes and one lamb ram were captured and fitted with PVC pipe collars containing radio transmitters. Relocations were obtained primarily from fixed-winged aircraft. Due to the terrain, ground tracking was limited. Aerial tracking was conducted yearround. From the time of capture in April 1982 through August 1982, 60 relocations on eight bighorn sheep were obtained during eight flights. From August 1982 through June 1983, 91 relocations were made on seven bighorn sheep during 15 flights. From July 1983 through June 1984, 56 relocations were made on six bighorn sheep during ten flights. Relocations were plotted on USGS topographic maps. When visual sights were not obtained, locations were plotted to nearest one half mile. Data on percent slope and elevation were recorded from the maps. For each relocation data on topography, cover, and habitat components were recorded according to preselected types (Table 1.). Data on seismic activity were obtained from the Lewis and Clark National Forest seismic activity summary for the Rocky Mountain Ranger District.

RESULTS AND DISCUSSION

Movements:

In 1982, the summer range of this herd was more extensive than previously recorded by Erickson (1972) and Frisina (1974). The sheep made extensive use of the Crown Mountain - Wood Lake Hogback divide during late spring, summer and early fall (Hook, 1985). Individuals made extensive movements throughout this period frequently crossing the Benchmark road from the Ford Creek area to the Crown Mountain divide and back again often within a one to two week period. By mid-September most of the sheep had returned to the Ford-Fairview Plateaus and remained there for the winter. During the fall of 1983, three seismic lines were run across the Ford-Fairview Plateaus (Figure 1.). These lines were run by Frontier Exploration under AMOCO Oils permit. Lines 1-3 were helicopter supported porta-drilling operations. A fourth line was a conventional truck-mounted drilling operation that followed an existing road adjacent to the Plateaus. The porta-drill operation was requested by the United States Forest Service with AMOCO's compliance to reduce the disturbance associated with surface-charge surveys. Weather and equipment problems resulted in a request from the seismic operator to bring in a second crew. The District Ranger approved this request based on his authority under permit clause number 46 which allows concurrent activities closer than the recommended nine mile spacing and the Lewis and Clark Programatic Environmental Assessment for seismic activity which allows "for concurrent activities, if they are close together, because one area is essentially affected and the period of time the company will be working is reduced". The result was at least two seismic lines being run concurrently often within 1-3 miles of each other over approximately a 45 square mile area for a minimum of four weeks (September 9 to October 18).

Figure 2 presents the fall radio relocations for 1982, 1983, and 1984 shown in relation to the 1983 seismic lines. During two flights in September and October, 1982, ten of 14 (71%) relocations were on the Ford-Fairview Plateaus. Only four relocations (29%), representing four individuals, were on the Crown Mountain-Wood Lake Hogback Divide. All seven individuals were located at least once on the plateaus during the fall of 1982.

During September and October 1983, 17 relocations of six sheep were made during three flights (Figure 2.). All the relocations in 1983 were along the Crown Mountain-Wood Lake Hogback Divide. In the year following the seismic activity, 5 of 11 (45%) relocations were again on the Ford-Fairview Plateaus during the September to November 8, 1984, time period.

Due to the small numbers of seasonal relocations it was impossible to calculate fall home ranges for individual sheep. However, the effect of the seismic activity can be seen in that the average annual home range size significantly ($p \leq .05$, F test) declined (28%) from an average of 25.9 square miles in 1982 to 18.6 square miles in 1983. Following the disturbance, average home range size significantly increased ($p \leq .05$, F test) to 29.7 square miles in 1984 (60%) versus 1983 figures. The effect of the seismic activity is further illustrated by the annual home range of adult ewe number 3204 (Figure 3.). The home range for this individual measured 24.3 square miles, 18.3 square miles, and 21.6 square miles in 1982, 1983, and 1984 respectively. The lack of use of the Ford-Fairview Plateaus accounted for the reduced home range size in 1983.

HABITAT USE

Data on habitat use from September-October relocations are presented in Table 1. Elevations and slopes on which sheep were located did not differ significantly among years. Cover type use shows a shift from the open timber type to the rock/bare ground type from 1982 - 1983. This if further increased in 1984. Habitat use in 1984 was considered to be strongly influenced by the severe fall weather conditions encountered. Low temperatures and heavy snowfall affected habitat use with the sheep making extensive use of ridges. Habitat components show 1982 fall use of ridges, talus slopes, and cliffs accounting for 60% of the observations. Mountain grass lands and sidehill parks represented 40% of the sheep observations. In 1983, 94% of the observations were in the rock type components. 1984 data also show predominate use (91%) of these types.

Frisina (1974) found 64% of his fall observations in his Rocky reef habitat type and 34% in his Bunchgrass type. These data would compare closely to the 1982 data from this study.

The Ford-Fairview Plateaus are significantly different land types compared to the Crown Mountain-Wood Lake Hogback Divide. According to United States Forest Service land typing, the Ford-fairview Plateaus are predominantly fescue grasslands (75%) and mixed limber pine and Douglas fir forest on gently sloping to moderately steep mountain foothills. The major land type along the Crown Mountain-Wood Lake Hogback Divide is very steep limestone rockland and scree supporting open growing stands of Douglas fir, alpine fir, spruce, and white bark pine on forested scree.

CONCLUSIONS

The impact of the 1983 seismic activity can be evaluated in terms of the direct response of the sheep to the disturbance, and in terms of the potential consequences of that response. The decision to allow a second crew and to amend the guidelines to allow lines to be run concurrently (as opposed to the nine mile spacing requirement) resulted in the exclusion of bighorns from a major portion of their traditional fall range. Porta-drill operations have been considered less disturbing than surface charge operations. However, the result of simultaneously operating two crews on three lines over open mountain plateaus dramatically increased helicopter activity. It is this intense helicopter activity that is apparently responsible for the dislocation of bighorns from the plateaus in 1983. Erickson (1972) and Frisina 1974) found the Ford-Fairview Plateaus to be a major component of this herds fall range. 1982 and 1984 data from this study would support those findings. The 1983 data would indicate that the direct response of bighorns to the seismic activity was abandonment of a major portion of their fall range.

The consequences of this change in range use can be seen in the differences between habitats of Crown Mountain-Wood Lake Hogback and Ford-Fairview Plateaus and the potential effects on the population. The Ford-Fairview Plateaus are gently sloping grasslands as compared to the very steep rockland and scree of the Crown Mountain-Wood Lake Hogback Divide. The increased energy costs associated with disturbance, and in negotiation more rugged terrain, may be met with increased forage intake. However, if forage availability is reduced, the increase in energy expenditure results in deteriorating animal condition due to the necessity to draw on body reserves. Forage availability is much higher on the plateaus than the divide. Individual habitat use data shows a shift in cover type and habitat component use from the open grassland types in 1982 to steeper rocky terrain in 1983. During the period of severe climatic conditions in 1984, the shift from grassland to rocky terrain was also evident.

During the fall, bighorns should be improving their body condition by increasing forage intake in preparation for the stress of the coming breeding season and winter. Rams face a period of increased stress associated with the rutting season, and ewes are confronted with the biological demands of breeding and carrying a lamb to full term. The impacts of forcing a population from its most productive range, in terms of over winter survival and reproductive success, could be quite severe. Measuring that response can be difficult, especially since this herd and the entire sheep population on the Front experienced a major die-off during the winter following the seismic disturbance due to a pneumonia - Lungworm outbreak.

As a result of these findings a recommendation was made to the interagency committee overseeing gas and oil activities that the date for termination of gas and oil activities on bighorn winter ranges be moved from November 1 to September 15.

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QUESTIONS AND ANSWERS

Wayne Heimer, Alaska: Dan, this isn't so much of a question for you as it is just a comment. I look at the schedule here and see that we may be coming to the end of the helicopter papers. I don't know whether this is fair, but Frank Singer has probably spent more time than any other living man or person inside a helicopter looking out at sheep, and I just wondered if he cared to make a couple of comments about what his impressions are having seen so many Dall sheep from the inside of a helicopter, as opposed from on the ground looking up. I don't know whether that's a fair spot to put you in, Frank, but I know you've got a lot of experience there.

Frank Singer, Wyoming: Well, basically, we did see some big differences between populations. Most of the populations I surveyed were in national parks, a lot of herds weren't hunted or flown over very much, and we got what we thought were acceptable levels of disturbance. We did have a couple of herds, however, one of them was in Noatak National Preserve, and some of those animals did react quite a bit to the helicopter. Did that answer your question, Wayne?

Heimer: I don't know whether it was a question. I just thought it seemed appropriate since you have more experience than anyone else, you might share a few thoughts, if you have an impression, I was just interested in what it was.

Singer: What I guess I'm trying to say is I think the level of hunting on these herds makes a difference, as well as, the types of other disturbance, as to how an individual group is going to react to a helicopter. Back to the mountain goat question - I worked with a herd in the southern tip of Glacier National Park and we did a lot of blasting near those animals, and we did not see much of a reaction. This was along U. S. Highway 2 when it was reconstructed. We concluded at the end of that paper, that based on a review of the literature and some things that Doug Chadwick, for example, observed with a hunted herd that the fact they were unhunted and they weren't harassed much may have them a little amenable to that level of disturbance.

Heimer: Another question I have is do you guys own a U-2 or something to get those beautiful pictures of your study area? How do you guys do that anyway?

Dan Hook: I get mine from John McCarthy - I should give him credit for that.

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PRESCRIBED BURNING AS MITIGATION FOR ENERGY DEVELOPMENT ON BIGHORN SHEEP RANGES IN WYOMING.

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Abstract: Approximately 4000 Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) inhabit the Shoshone National Forest (SNF) of northwestern Wyoming. Analysis indicates high potential for extracting oil and natural gas from bighorn winter ranges on the SNF. Preliminary results are reported from the first year of a 5-year project using prescribed burning to improve bighorn sheep habitat conditions as off-site mitigation for energy development. Bighorn sheep selected ($p < 0.05$) old burn and irrigated meadow vegetation types over sage/grass and sage/grass/juniper types. Of time spent in four vegetative types, sheep foraged significantly ($p < 0.01$) more in the irrigated meadow type. Although not significant, ($p > 0.05$), preliminary data suggest bighorns foraged more efficiently in open habitats with good visibility than in denser-canopy, shrub-dominated communities. Use of prescribed burning as potential mitigation for impacts created by energy development is discussed.

Key words: bighorn sheep, habitat improvement, oil/gas development, seismic exploration, Wyoming.

Public lands in the Overthrust Belt of the northern Rocky Mountains have received considerable attention in the search for new hydrocarbon reserves. The Overthrust Belt underlies a significant portion of the habitat occupied by Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*). Sharp conflicts have arisen over energy development and maintenance of existing mountain sheep populations (Bromley 1985).

Approximately 4000 bighorn sheep are found on the Shoshone National Forest in the Absaroka and Wind River Mountains of northwestern Wyoming. Historical accounts (Honess and Frost 1942, Buechner 1960) and recent reports (Thorne et al. 1979, Hurley 1985) indicate large populations of bighorn sheep persisted in the Absaroka Mountains for the past 200 years. On the SNF, increasing seismic exploration, over 300 existing oil and gas leases, and more than 140 pending lease applications pose new challenges for maintaining these bighorn populations.

These sheep herds may be incapable of withstanding human disturbance and associated stresses from seismic explosions, helicopters, survey crews, heavy equipment, and drilling rigs, for two reasons. First, many portions of the low-elevation winter range provide less-than-optimal forage resources. This is due to advancing forest and shrub succession in the absence of periodic wildfires, and in some cases, because of heavy use by

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domestic livestock. Second, up to 25% of the sheep west of Cody, Wyoming are infected with psoroptic mange or scabies (Hurley 1985), a parasitic disease associated with historical and recent dieoffs of mountain sheep in the western U.S. (Buechner 1960, Lange et al. 1980).

Mountain sheep on a high nutritional plane, dispersed over high quality habitats, are better able to withstand stresses from harsh weather, infectious diseases, recreational harassment, and industrial disturbance (Herman 1969, Lance 1980, Thorne et al. 1979, Welch and Bunch 1983). Therefore, our goal is to improve habitat conditions for wintering bighorn sheep, with the intent of minimizing impacts caused by human harassment and industrial disturbance.

Several alternatives are available to manipulate mountain shrub/grassland winter ranges, including prescribed burning (Hobbs and Spowart 1984), fertilizing (Bayoumi and Smith 1976), herbiciding (Krefting and Hansen 1960), chaining (O'Meara et al. 1981), and grazing management (Holochek et al. 1982). For the Absaroka Mountains study, prescribed burning is the treatment selected.

Major goals of the 5-year (1985-1989) study are to:

1) Enhance bighorn sheep winter range by implementing and monitoring a habitat improvement program, primarily via prescribed burning;

2) Describe responses of bighorn sheep to changes in habitat condition, and monitor behavioral and distributional responses to oil and gas exploration and development; and

3) Evaluate the applicability of wildlife habitat improvement as off-site mitigation for oil and gas development.

The predictions from several hypotheses will be evaluated using changes in foraging rate, forage and diet quality, activity profiles, habitat use, and vegetation composition and production on treated plots. For this paper, three null hypotheses will be addressed:

H1: Vegetation types are used in proportion to occurrence;

H2: Bighorn sheep activity profiles are the same among treated and untreated vegetation types; and

H3: Foraging rate is equal among treated and untreated vegetation types.

In 1985, research included collection of baseline data on foraging behavior and habitat use while planning a series of small prescribed burns along the South Fork of the Shoshone River. Our work is supported by the Wyoming Game and Fish Dep., U.S. For. Serv., Found. for North Am. Wild Sheep (FNAWS), Marathon Oil Co., Amerada Hess Corp., Natl. Rifle Assoc., C. A. Lindbergh Fund, Wisconsin Safari Club Int., FNAWS Chapters in Wyoming and Illinois, Cody Country Outfitters Assoc., Cody Country Sportsmen's Assoc., and the Bur. of Land Manage.

STUDY AREA

Research is being conducted in a southeast-facing valley along the upper South Fork of the Shoshone River, at 1970 m in elevation, approximately 65 km southwest of Cody, Wyoming (Fig. 1). Between 250-300 sheep use a narrow, 3760-ha wintering area located between steeply-dissected mountain slopes and gently-sloping riparian bottomlands. Detailed descriptions of the study area, land status, vegetation, geology, and climate were given by Hurley (1985).

Mountain shrub/grassland communities were dominated by big sagebrush (*Artemisia tridentata*), rabbitbrush (*Chrysothamnus* spp.), Rocky Mountain juniper (*Juniperus scopulorum*), horizontal juniper (*J. horizontalis*), bluebunch wheatgrass (*Agropyron spicatum*), Sandberg's bluegrass (*Poa sandbergii*), and prairie junegrass (*Koeleria cristata*). Stringers of Douglas-fir (*Pseudotsuga menziesii*), limber pine (*Pinus flexilis*), and lodgepole pine (*P. contorta*) were found at middle elevations and on north and east aspects. Charred logs, stumps, and snags indicate a comparatively-abundant coniferous savannah occurred on this low-elevation winter range within the past century. Barring influence by man, fires likely occur every 20-50 years in mountain shrub/grassland communities (Hobbs and Spowart 1984). Five vegetational types were recognized, varying primarily with the amount of tree or shrub components: Sagebrush/wheatgrass, Sagebrush/wheatgrass/juniper, a 10-year-old Burn (prescribed), Upland Conifer, and Irrigated Meadow. The meadow was comprised primarily of smooth brome (*Bromus inermis*).

The Absaroka Range is an erosional remnant of the vast sheet of volcanic strata that formerly extended eastward across the Bighorn Basin (McKenna and Love 1982, *in* Love 1985). The potential appears good for oil and gas reserves in the study area, and several seeps have been identified in the Absaroka region, where oil exudes onto the ground through shallow volcanic strata (USDI-BLM 1984, Love 1985).

METHODS

Ten adult bighorn sheep (8 ewes, 2 rams) were immobilized and radio-collared; more than 12 others could be identified by pelage or horn characteristics. Ground surveys, radio-telemetry, and aerial tracking flights were used to locate marked and unmarked sheep and to determine winter habitat use. Foraging behavior was determined through direct observation of randomly selected sheep. Winter was defined from 1 October to 31 May.

Vegetative communities on the upper South Fork winter range were mapped, and areal extent of the five vegetation types was determined from 212 random points located on winter range maps and color aerial photographs (Marcum and Loftsgaarden 1980). Habitat preferences of sheep were identified by comparing proportions of radiolocations in each vegetation type to percent availability (Neu et al. 1974).

Behavioral activity profiles for adult ewes were developed in 4 vegetation types. Adult ewes were randomly located throughout the day and observed for 10 minutes. Ten instantaneous samples, one minute apart, were

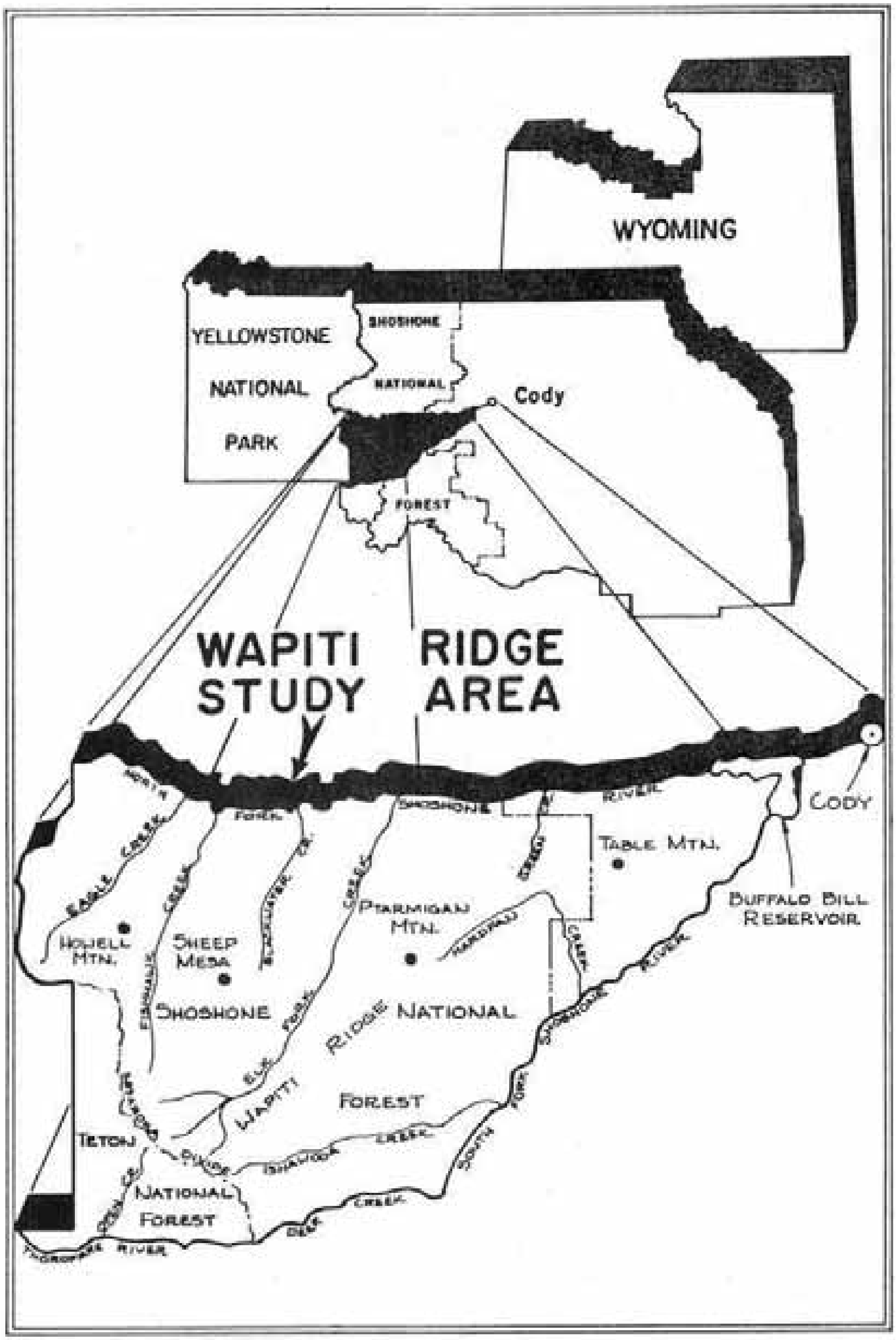

Fig. 1. Location of the Wapiti Ridge study area, South Fork Shoshone River, Wyoming.

collected during each 10-minute bout, and activity was categorized as feeding, bedding, walking, running, standing alert, courting and other. Percentages of time spent in each activity were normalized by arc-sine transformation (Zar 1974); logarithmic variance ratios were calculated and tested for differences in activity profiles among vegetation types (Zar 1974). Student's t-test was used to compare differences in distance traveled/minute of observation. Habitat quality and forage availability in each vegetative type should be reflected in the time spent feeding, bedding, moving, or watching for danger, similar to results reported by Risenhoover and Bailey (1985) for sheep in Colorado.

Foraging behavior of adult ewes in the 4 most important vegetation types was recorded. Grazing time was defined as time spent searching for, ingesting, or chewing forage, and was expressed as the time required for an animal to achieve 100 bites. Number of bites was recorded, stopping the clock when the ewe was obscured from view by topography, vegetation, or another sheep. Activities other than feeding were not included in grazing time calculations. During feeding trials, groups of bighorn sheep were observed from a vehicle, from 5- to 100-m distances, without obvious disturbance.

Forage production was determined within 30-m exclosures, in the Old Burn, sage/grass, and sage/grass/juniper types. In each exclosure, four permanent 25-m line-intercept transects were sampled to determine shrub canopy. Twenty 20- x 50-cm quadrats were located at 5-m intervals on alternating sides of line transects. Within each quadrat, graminoids and forbs were identified, percent canopy cover by species was estimated, and total wet weight of all graminoids and forbs was estimated. At alternating plots, an adjacent plot (off the line) was clipped to ground level. Graminoids and forbs were later separated, weighed, oven dried for 24 h at 60 C, and re-weighed. A regression equation to predict dry weight of all plots was calculated using data from estimated weight and actual weight in clipped plots.

RESULTS

Significant differences occurred between habitat availability and usage ($p < 0.001$, $\chi^2 = 367.4$, d.f. = 4); the null hypothesis was therefore rejected. Sheep used the Sage/grass and Sage/grass/juniper vegetation types in proportion to availability, selecting the Old Burn and Irrigated Meadow types, and avoiding the Upland Conifer community (Table 1). The burn and Irrigated Meadow types provided significantly more forage (i.e., graminoids and forbs) than did less-preferred habitats ($p < 0.05$).

Activity profiles, based on 1182 minutes of observation, showed adult ewes spent proportionately more time foraging in the Irrigated Meadow type than in the Old Burn, Sage/grass, and Sage/grass/juniper types ($p < 0.01$) (Fig. 2). Bighorn ewes traveled significantly faster ($p < 0.025$) per minute of observation while feeding in the Sage/grass and Sage/grass/juniper habitats than in the more open and more productive Irrigated Meadow and Burn types (Table 2). Based on preliminary data, rate of travel/minute of observation appeared inversely related to forage production.

Table 1. Winter habitat selection of bighorn sheep, South Fork Shoshone River, Wyoming.

Habitat Type	Proportion of total acreage	Number of relocations expected	Number of relocations observed	Proportion observed in each area	Confidence interval on proportion of occurrence (90% simultaneous CI)	Selection behavior[a]	Dry Weight[b]
Sage/Grass	0.514	109	93	0.439	$0.351 \leq P \leq 0.526$	NS	171-197
Sage/Grass/Juniper	0.288	61	67	0.316	$0.234 \leq P \leq 0.398$	NS	187-208
Old Burn	0.005	1	17	0.080	$0.032 \leq P \leq 0.128$	+	306
Irrigated Meadow	0.024	5	26	0.123	$0.065 \leq P \leq 0.181$	+	1,740
Upland Conifer	0.169	36	9	0.042	$0.007 \leq P \leq 0.077$	-	c
Total			212				

[a]NS = no significant difference in use vs. availability.
+ = significantly greater use than availability.
- = significantly lower use than availability.

[b]kg/ha.

[c]Not sampled for forage production.

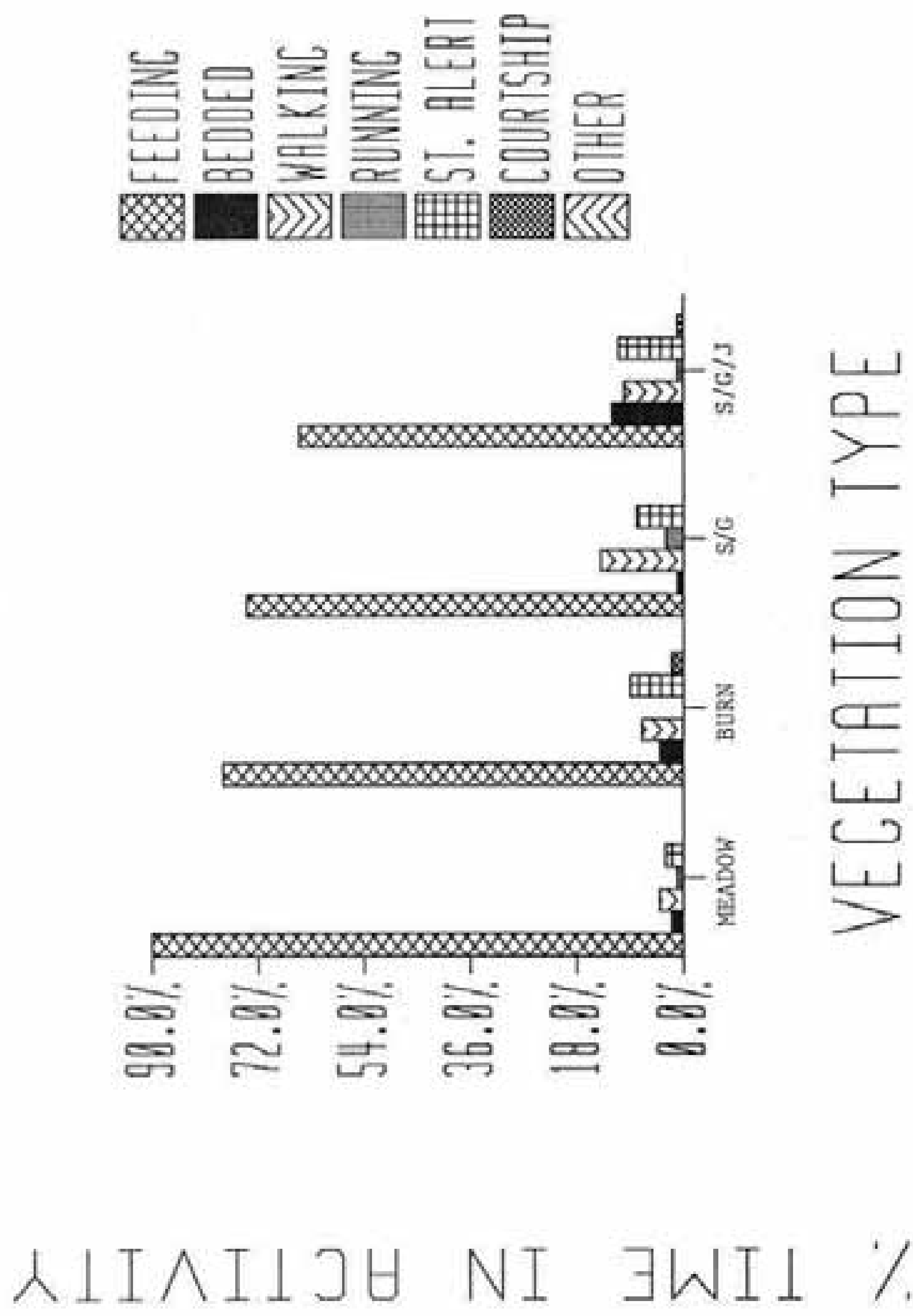

Fig. 2. Bighorn sheep activity profiles, by vegetation type, South Fork Shoshone River, winter 1985-86.

Table 2. Distance traveled (m) per minute of observation of bighorn ewes South Fork Shoshone River, Wyoming, 1985.

Habitat Type	Total Minutes of Observation	Total Distance Traveled (m)	Av. Distance Traveled (m/minute)
Sage/Grass	331.5	1615	4.87
Sage/Grass/Juniper	280.0	740	2.64
Old Burn	180.0	208	1.15
Irrigated Meadow	390.0	332	0.85

Bighorn ewes appeared to forage more efficiently (i.e., less time to achieve 100 bites) in the Old Burn and Irrigated Meadow habitats than in the Sage/grass/juniper and Sage/grass types (Fig. 3), but the only significant difference ($p < 0.05$) in foraging rate was between the Burn and Sage/grass types.

DISCUSSION

Habitat use, rate of travel while feeding, and foraging efficiency may be related to forage production. Further data collection and analysis, including forage quality, will clarify these relationships. Preliminary results indicate that the 10-year-old burn and the Irrigated Meadow were preferred foraging habitats. Significant differences ($p < 0.01$) were found in use versus availability of the burn and meadow types, as sheep selected these communities over adjacent, shrub-dominated vegetation tyeps.

By initiating prescribed burns in the non-preferred types, characterized by relatively lower forage production and reduced visibility, an improvement in foraging efficiency and a change in sheep distribution are anticipated. Based on the findings of Hobbs and Spowart (1983), prescribed burning on the South Fork winter range should increase forage availability and ecological carrying capacity, and positively influence distribution of wintering sheep (Wikeem and Strang 1983).

Although some biologists believe mountain sheep are best adapted to stable, climax bunchgrass communities (Smith 1954, Buechner 1960, Blood 1967, Geist 1971), recent literature indicates extensive bighorn use of seral grasslands created by prescribed burning or wildfires. Peek et al. (1979) noted bighorns made heavy use of prescribed burns in mountain shrub/grassland habitats in Idaho. Riggs and Peek (1980) concluded seral vegetation was at least as palatable to mountain sheep as that occurring in climax bunchgrass communities. Extensive wildfires around the turn of the century contributed to increases in bighorn sheep populations (Stelfox 1976, Peek et al. 1985). Burned areas attract bighorns (Peek et al. 1979, Wikeem and Strang 1983, Risenhoover and Bailey 1985, Spowart and Hobbs 1985), as the sheep respond to increased availability of forage (Elliott 1978, Johnson and Strang 1983) and higher-visibility habitats.

On many bighorn ranges, suppression of periodic wildfires has been indirectly responsible for loss of sheep habitat via shrub and tree encroachment (Stelfox 19/6). These changes in habitat conditions lead to changes in range-use patterns, including loss of traditional migratory patterns (Wakelyn 1984). The most consistent differences between existing vs. historic sheep ranges, and between ranges with large vs. small bighorn populations, are related to the amount of open, high-visibility habitat and escape terrain present (Wakelyn 1984). Bighorn sheep prefer open habitats with low-growing vegetation and avoid habitats with dense, tall vegetation (Smith 1954, Oldemeyer et al. 1970, Constan 1972, Risenhoover and Bailey 1980, Tilton and Willard 1982, Hurley 1983).

In addition to changes in visibility, foraging efficiency, and habitat use, a major benefit of prescribed burning might be that nutritional quality of bighorn sheep winter diets will be increased substantially. The quality of individual forages (i.e., protein content, digestibility) may improve only a few percentage points, but bighorn diets should improve markedly (Hobbs and Spowart 1984). As a result of prescribed fire, bighorn sheep will eat more green grass during winter, because it is much more available after burning (Elliott 1978, Hobbs and Spowart 1984, Seip and Bunnell 1985). Also, earlier spring greenup of grasses following burning (Peek et al. 1979, Seip and Bunnell 1985) provides phenologically younger and thus more nutritious forage for a longer period of time each year. For pregnant ewes, nutrition in spring plays an important role in determining birth weight and subsequent survival of lambs (Geist 1971). In addition, the increased production of palatable forage that is expected following burning in sagebrush communities should provide for a nutritionally superior diet because of greater ability to select the most nutritious plant parts (Jarman 1974, Irwin 1985).

As prescribed burning proceeds in this area, it is planned to gather more data on vegetation response, as well as sheep foraging and habitat use behavior, to fine-tune burning prescriptions. This includes gathering data on fire behavior, weather, and fuel conditions, to achieve maximum forage production. Examination of the relative importance of forage quantity and quality in foraging relationships of bighorn sheep is also planned. Finally, sheep responses to oil and gas-related disturbances will be monitored, to develop recommendations as to the extent of habitat improvement necessary for mitigation.

SYNTHESIS

Positive results from prescribed burning on bighorn winter ranges will be realized only if a proper plan is developed which identifies specific objectives and recognizes factors which limit the population (Peek et al. 1985). Caution must be exercised, as prescribed burning will not always benefit mountain sheep. As with any task, "the right tool for the right job" is an appropriate axiom.

A possible mitigation measure for impacts to bighorn sheep created by oil/gas exploration and development is habitat improvement. To be effective, habitat treatments must be integrated into a scientifically sound program of data collection and population monitoring. Habitat improvement efforts should complement other mitigation strategies, including seasonal operating stipulations on important wildlife ranges, limited human access to critical habitats, grazing management, land acquisition or conservation easements, and environmental awareness education.

Guidelines and operating plans for energy development must focus on maintaining wildlife populations and exploiting management opportunities within wildlife habitats. In this way, exploration and production may proceed, impacts to wildlife and their habitats are reduced, wildlife habitats may be enhanced, and the public will be aware that agencies and industry are cooperatively working to better serve the needs of wildlife.

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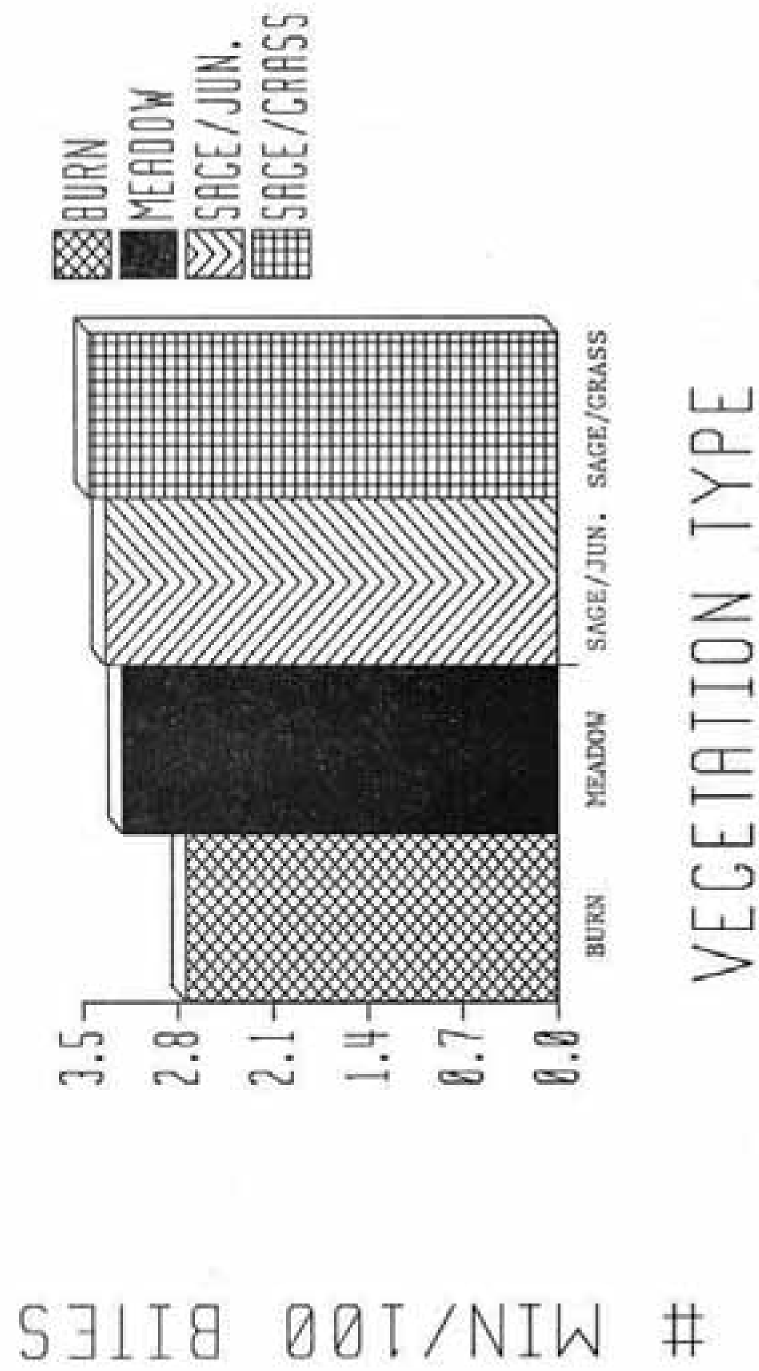

Fig. 3. Forage biting rate of bighorn ewes, by vegetation type, South Fork Shoshone River, winter 1985-86.

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QUESTIONS AND ANSWERS

Bill Shuster, Colorado: You were talking about doing some burns on the winter range. Can you give us an idea of what percentage you're trying to ultimately look at getting burned there, and secondly, do you have much trouble with those areas potentially being completely unavailable in a bad winter? Do you have times where you have enough snow cover where sheep can't get to anything that you burn?

Kevin Hurley: Let me answer the second part of your question first. No, that is mostly a south-facing valley. Snow cover at times would be a foot or more, but it's very temporary. This year was a bad winter, and there were only a few days when there was any persistent snow cover. It's a real favorable snow shadow, based on the topography and the wind patterns in that area, so I don't think we would render any of this unavailable. Elevation is probably 6500 feet where we're working. The first part of your question, about the area we intend to burn or hope to burn; the total of all the areas that we've identified, if we were to burn them all 100% and we know that's not going to happen because of some patchy fuel conditions, we're talking somewhere on the order of 5 - 10% of the winter range, quite a small area in comparison to the size of the winter range and the number of sheep that are in there.

Jon Swenson, Montana: You were talking about how much of that area was wilderness and then you were talking about all the seismic activity and drilling and everything. Is that occurring in wilderness or adjacent to it?

Hurley: Those activities are not occurring in the wilderness, just adjacent to it. The Snyder oil well that I talked about is probably less than 100 yards outside the Wilderness boundary. What happened in October 1984, with the passage of the Wyoming Wilderness Bill, was that the Wilderness line was dropped from ridge line right down to the bottom of the valley. Public pressure tried to get that area totally designated as wilderness, to prevent this very thing, but they were unsuccessful. There was a little sliver of nonwidlerness, and that's right where the oil comparnies want to go. Another possibility being talked about is directional drilling from adjacent private land. The geology of the Absarokas, as you probably well know, is pretty tricky and they're not sure they can directionally drill from any great distance. But, this is another option.

Jim Bailey, Colorado: What is the written legal document that says you can not use habitat management, or prescribed fire in particular, in a wilderness area?

Hurley: Well, the Region 2 Forest Service policy that I'm aware of came out last summer. The way I've read it, and this is their new policy, it says for wildlife habitat improvement purposes, prescribed fire is not a viable option. There are two ways that you can implement fire in the Wilderness, and my understanding is, one, to prevent the great conflagration of every 100 years, and the other one is to maintain certain vegetative communities that may have existed there. So, that's a loophole that possibly could be used to get in and burn.

Shuster: The only other loophole you're talking about is if you can document that man has caused natural succession by stopping fires, something like that. If you can show that somehow, then you can go ahead and burn in wilderness, but that's the only way you can do that.

Ernie Garcia, Washington: I think there are at least two examples of proposals by the Forest Service to get approval to burn in Wilderness, and I think they both involve endangered species. I think they've both been approved. I just read something recently, that indicates there may be some changes in the burning policy real soon.

Hurley: Well, I'll just make one comment. If there is to be a precedent in the Yellowstone area, as far as habitat manipulation within the Wilderness, I think it may possibly occur for the benefit of the Yellowstone grizzly bear, and that may set a precedent which enables some other work to be done for sheep, but that's part of a pending proposal.

Garcia: Right, I think both those examples involved either grizzly bear or red-cockaded woodpecker.

Bailey: Just one final thing now, you're all agreeing that this is a Forest Service policy,. It's not in Congressional legislation?

Hurley: Right

Bailey: It's an edict by the Forest Service?

Hurley: That's my understanding, Jim.

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BIGHORN SHEEP, MOUNT ALLAN, AND THE 1988 WINTER OLYMPICS: POLITICAL AND BIOLOGICAL REALITIES

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Abstract In November 1982, the government of Alberta announced that the alpine skiing events of the recently awarded 1988 Olympic Winter Games would be held on Mount Allan, about 90 road km west of Calgary. Mount Allan is part of a mountain complex that supports a population of about 300 bighorn sheep (*Ovis canadensis*). In proceeding with the development of Mount Allan, former Premier Peter Lougheed and his colleagues contravened provincial, national, and international agreements respecting the wildlife resource. The ecology of the sheep population is not well known. Human activity on sheep range is becoming intensive and will escalate. Provincial policies that reflect a strong anti-wildlife philosophy, and the kinds of developments completed or underway in the Mount Allan area are identified. The sheep population, hitherto problem free, is endangered.

When John A. Allan, pioneer geologist and mountain explorer, strode high above Ribbon Creek on a gently contoured mountain with impressive grass-covered shoulders, he could not possibly have foreseen the controversy that would later involve that mountain. A mountain which later came to bear his name (Fig. 1). During those visits he very likely saw bighorn sheep and probably recognized the area as exceptionally fine sheep range. Today we recognize Mount Allan as part of a mountain complex supporting about 300 bighorns, one of the largest herds under the jurisdiction of the Province of Alberta and a herd which has not, until recently, been associated with any management difficulties.

When the development of Mount Allan became an issue in Alberta, the future of the bighorn sheep population also became an issue. What was known of this sheep population - it's numbers, movement, and ecology? The answer, unfortunately, was not a great deal. More time, money, and effort has since been expended by politicians, committees, and those with vested interests, to assure the public that they have nothing to worry about than has been spent on obtaining basic inventory and ecology data for the Mount Allan sheep population (not to mention the elk, *Cervus elaphus*, mule deer, *Odocoileus hemionus*, and grizzly bear, *Ursus arctos*, populations).

Does there exist a wildlife conservation problem on Mount Allan? Is the concern real? As it turns out, there is more to this issue than just the Olympics. Picture an exceptionally inviting alpine expanse within two km of a paved road and only 90 km from a city of over 600,000 people; with a developed trail, the Centennial trail, leading up the spine of that mountain and through critical sheep winter/spring range, through escape terrain and through a lambing area. Picture a youth hostel at the base of this trail; a major hotel development underway near the hostel; a ski development with lodge and all facilities equally close

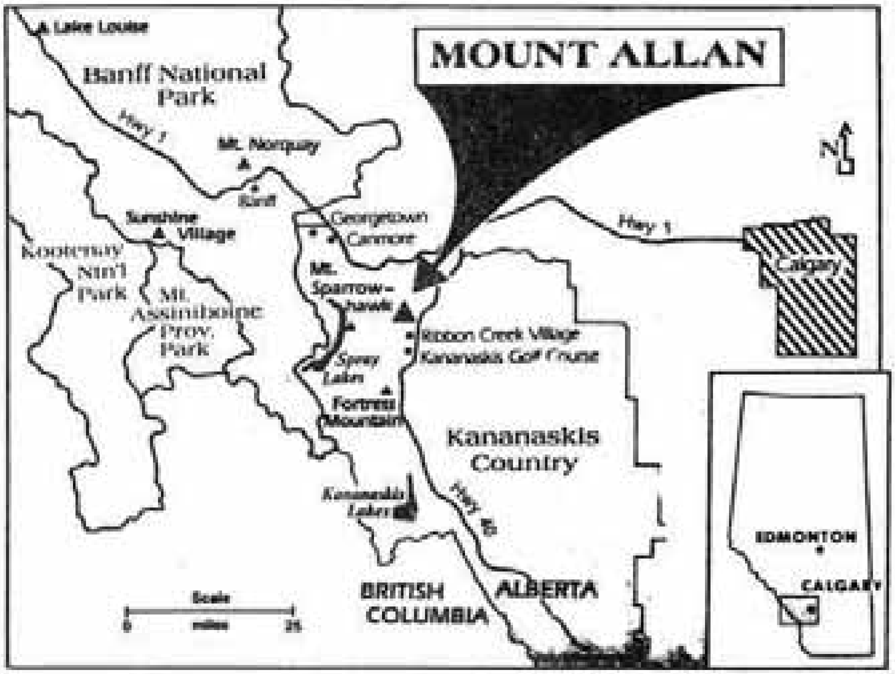

Fig. 1. The location of the Mount Allan study area in southwestern Alberta.

by, and whose upper runs impinge on alpine sheep winter/spring range; a 36 hole golf course and an immense recreational vehicle campground (227 sites spread over 60 ha) as destination points only kilometres away from the mountain; a high level of hunting activity; a relatively great frequency of helicopter overflights; a hiking trail cutting the base of Mount Allan that may have carried up to 45,813 visitors in 1984 (Holden 1985); and, in February of 1988, a period critical to the overwinter struggle every wildlife population faces, a flood of security people (including helicopters and other equipment) that may exclude sheep from the Mount Allan winter range for at least three weeks. And you ask if there's a problem!

METHODS

Field investigations were conducted by Garry E. Hornbeck and the author. We made 30 day-long visits to Mount Allan between 23 May 1984 and 20 June 1985. The objective was to count and classify the sheep using the winter range from the peak of Mount Allan south and east including that part of an adjoining buttress, Mount Collembola, visible from the Olympic ski development. The same route was followed on each visit to the mountain. Sheep were classified according to Geist (1971). The project was funded by the Foundation for North American Wild Sheep.

RESULTS AND DISCUSSION

Considerable numbers of sheep occupy that part of Mount Allan within the immediate sphere of influence of the ski development (Fig. 2).

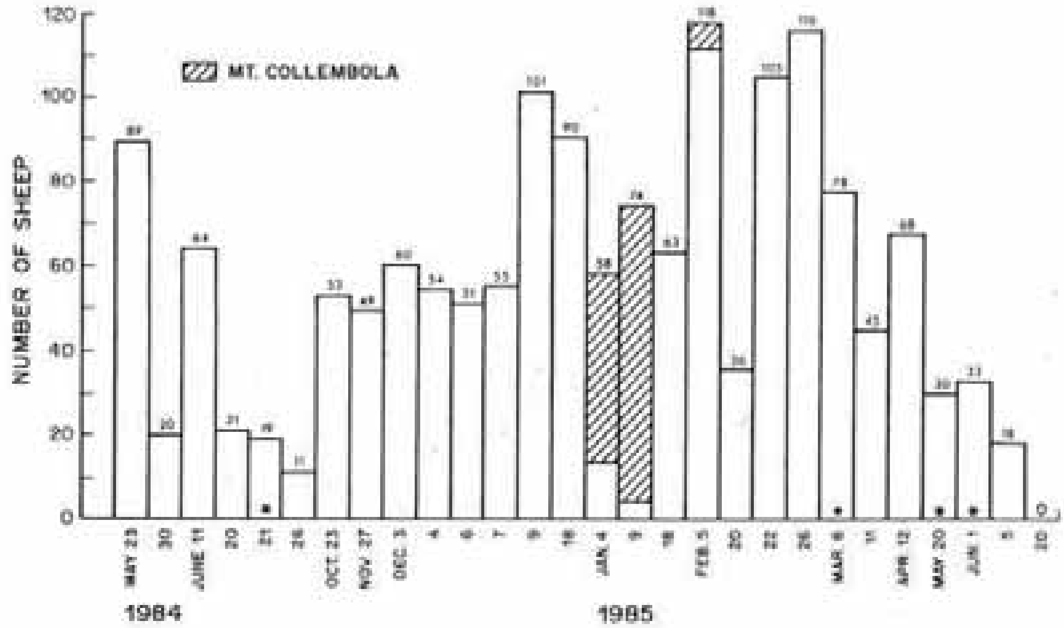

Fig. 2. The total number of sheep observed on Mount Allan during 28 visits between 23 May 1984 and 20 June 1985. Asterisk denotes incomplete count.

Up to 39 females two years of age or greater relied on Mount Allan for winter range (Fig. 3). At least 35 females were observed during the rut and during the mid winter Olympic period. Equally as critical, up to 26 females were found on Mount Allan during the lambing period and, in spring of 1984, we observed 10 newborn lambs in the cliffs on the southeast slopes of the mountain (Fig. 4). Two of these lambs were observed shortly after birth and before they gained full motor abilities. During the winter of 1984/85, at least 22 lambs relied on Mount Allan range for at least part of the winter. Judged on the basis of lamb: female (≥2 years of age) ratios (Fig. 5), those sheep that used the southeastern benches of Mount Allan from fall through spring were relatively successful, with the mean lamb:female ratio, based on 17 days observation, being 55 lambs per 100 females. However, in spring 1985, we were unable to locate any newborn lambs on the southeast slopes of Mount Allan prior to 20 June.

The number of rams (≥Class I♂) observed reached 23 during the rut but peaked at 45 during the Olympic period in February (Fig. 6). Observations during the latter period also yielded the highest male: female ratio (141 ≥I♂:100 females ≥2 years of age).

The important conclusions are that 1) at least 40% of all the sheep in the population depend at least partially on Mount Allan winter range, 2) at least 101 animals were present on the lower slopes of Mount Allan during the rut, and 3) the greatest number of sheep were observed on Mount Allan during February, the month during which the Olympic alpine events will take place.

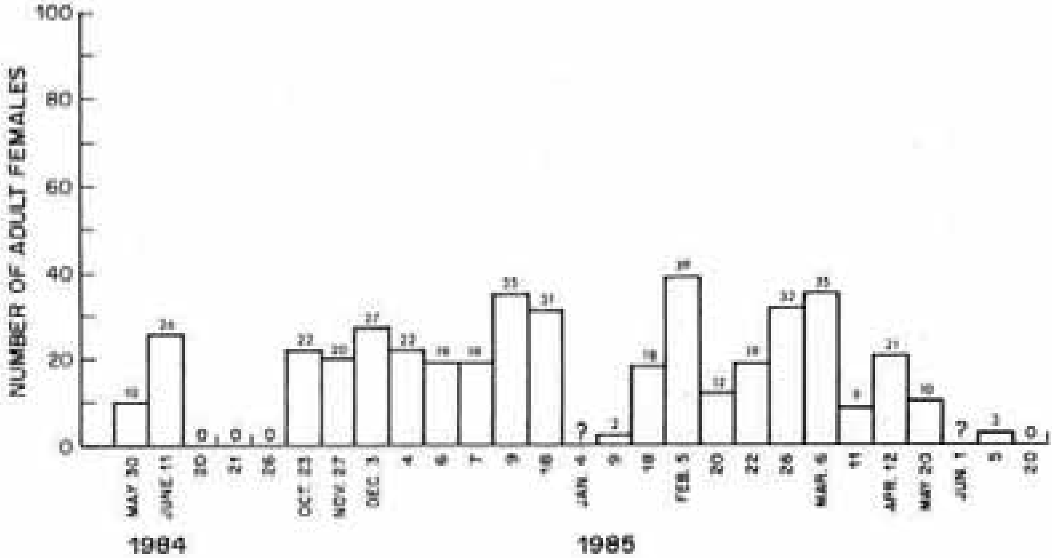

Fig. 3. The number of adult female sheep (≥2 years of age) observed on Mount Allan during 27 visits between 30 May 1984 and 20 June 1985. ? denotes females present but count not obtained.

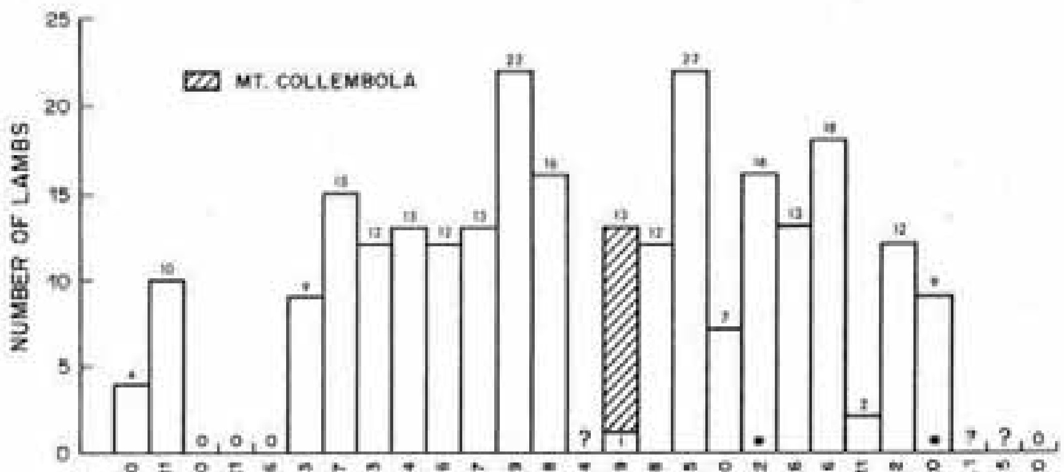

Fig. 4. The number of lambs observed on Mount Allan during 27 visits between 30 May 1984 and 20 June 1985. Asterisk denotes incomplete count. ? indicates lambs present but count not obtained.

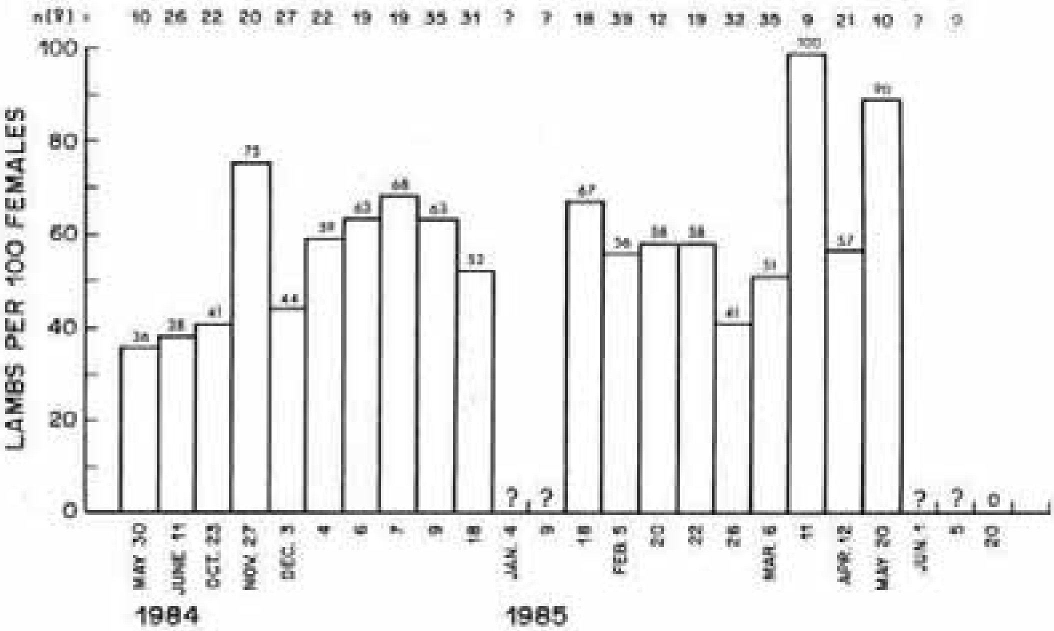

Fig. 5. Ratio of lambs per 100 adult females (≥2 years of age) observed on Mount Allan during 24 visits between 30 May 1984 and 20 June 1985. ? denotes lambs and females present but counts not complete.

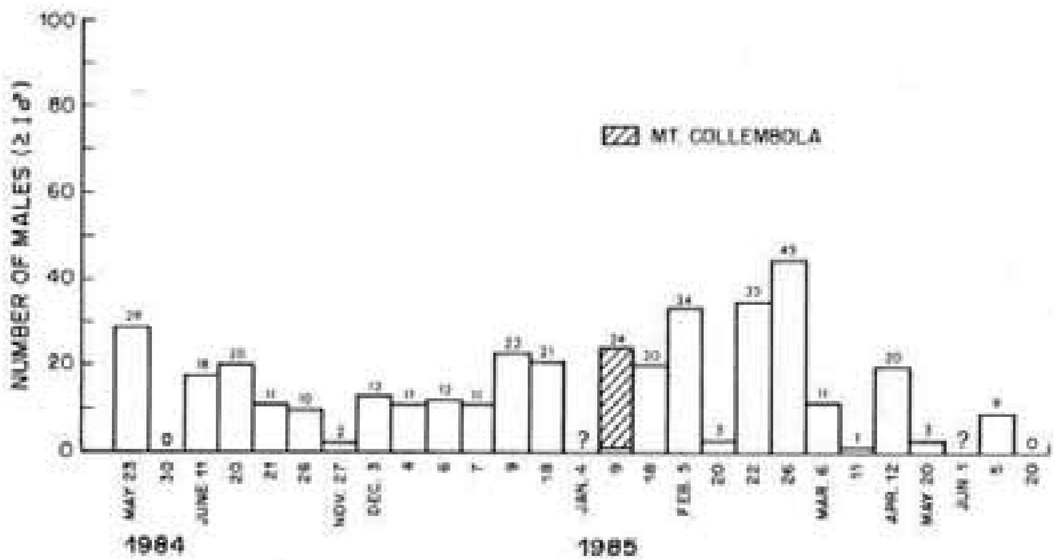

Fig. 6. The number of rams (≥Class I) (after Geist 1971) observed on Mount Allan during 27 visits between 23 May 1984 and 20 June 1985. ? indicates rams present but count incomplete.

The Mount Allan story came to prominence in November 1982 when the government of Alberta officially announced that Mount Allan had been selected as the site for the 1988 Winter Olympic alpine ski events. This story, however, had begun long before that date; possibly as early as the 1960's, with the election of a government led, until 1985, by Premier Peter Lougheed. His government consistently demonstrated an anti-wildlife, anti-public lands, anti-conservation bias, a position that became particularly aggressive and overt in recent years.

On 30 September 1981, the Calgary Olympic Development Association (CODA), with the support of the government of Alberta, was awarded the 1988 Olympic Winter Games on the basis of a presentation focussed on Mount Sparrowhawk, a rugged mountain just a few km southwest of Mount Allan. The Olympic Games Organizing Committee (OCO '88) was formed to manage the games.

The deception and flow of misinformation that has made the 15th Winter Games a political and environmental fiasco began almost immediately. The government of Alberta announced, shortly after the province had been awarded the games, that there would be a site selection process. The games had just been awarded on the basis of a Mount Sparrowhawk development proposal but now there would be a site selection process. The developer whose proposal formed the heart of the Olympic sales pitch later called the decision a "hoax" and an "insult to the country" (Cotton 1982a).

In retrospect, there should not have been a great deal of suprise. Mr. Lougheed had long spoken of his vision of a world class recreation center in the mountains of southwest Alberta, and Mount Sparrowhawk was on the wrong side of the mountains. Mount Allan, on the other hand, was adjacent to an almost completed 36 hole golf course, the prepared site of an alpine village, and the probable site of a hotel. Still, Mount Allan had not officially been made the choice for the olympic development but rather, was listed as one of the possible sites.

Private developers were asked to submit development plans and several did so, including proposals for Mount Allan. Still the government continued to play charades, as though a selection process were actually underway. In reality, the decision had been made, as evidenced by the following. In October 1982, at a public meeting of OCO '88, the following statement was made during a heated discussion between two members "come on Ed, you and I were both there when the Premier told us Allan was the site" (Jeffery and Wilford 1983).

The government was in a difficult position, or so it would seem. In 1978, Mr. Lougheed had proposed a series of alpine residential villages throughout the mountains of western Alberta. In response to this scheme the Alberta Fish & Wildlife Division had cursorily identified the Mount Allan area as extremely valuable wildlife habitat - valuable enough, in fact, to enter into a written agreement with the Department of Tourism that the area would not be developed. The ministers responsible for the Department of Recreation, Parks and Wildlife, Al Adair, and Tourism, Bob Dowling, signed that agreement in late 1979. It now stood in the way of a Mount Allan decision. The solution to this dilemma proved to be simple - ignore the agreement - and so it was that the people of Alberta saw the first in a series of betrayals by elected people entrusted with safeguarding the province's wildlife heritage.

On 9 November 1983 OCO '88 announced what they and the ministers responsible for government departments had known for some time - Mount Allan would be the site for the Olympic alpine events (Cotton 1982b). But they were still trying to ease their flip from Mount Sparrowhawk to Mount Allan by saying they would develop Mount Sparrowhawk as a training facility for Canada's ski team (Cotton 1982b). Some cabinet ministers now tried to isolate OCO '88 as the source of these decisions, recognizing that the public was beginning to view the whole situation with suspicion. In March 1983 Parks Minister Peter Trynchy stated that no one in the government had told OCO '88 to hold the alpine events on Mount Allan (Calgary Herald 1983a). Other members of the legislative assembly misled the public by stating that the International Ski Federation (FIS) had selected Mount Allan as the site for the Alpine events (Embury and Koper 1984). This was interesting in view of the fact that as late as March 1985 the FIS publically stated that Mount Allan's men's downhill run did not meet Olympic standards (Pratt 1985).

On 29 April 1983, two pertinent public announcements were made. Frank King, Chairman of OCO '88, released a letter addressed to the Federal Government asking that Lake Louise, a ski development in Banff National Park, be considered as a site for the Olympic downhill ski competition. That same day, Tourism Minister Al Adair, who had been the Minister of Recreation, Parks, and Wildlife when he signed an agreement in 1979 not to develope Mount Allan, announced that Mount Allan would be developed and financed <u>by the Province</u> not just as an Olympic site, but also as a day-use recreational ski area for Albertans, and as a training facility for competitive skiers. I underscore <u>by the Province</u> because during mid and late 1982 none of the private developers initially lined up to grab a piece of the Olympic gold were prepared to commit themselves once they had taken a serious look at Mount Allan - it readily became apparent to them that it was highly unlikely that this area could be built and operated economically, no matter what scale of development was planned (Cotton 1983). The cost of the provinces new development was estimated at $25 million - I predict final costs will exceed that sum by many millions of dollars. A Calgary member of the legislative assembly sanctimoniously defended the provinces funding as a job creation project (White 1983) - hardly the Olympic ideal. In summary, the provincial cabinet, all self proclaimed advocates of free enterprise, had sanctioned development of a ski hill with taxpayers money, on one of Alberta's finest bighorn sheep ranges, and within 15 km of an existing, privately operated ski hill known as Fortress Mountain.

As this fiasco continued, other issues surfaced. In 1980 Canada had endorsed the World Conservation Strategy (WCS). Alberta was one of the first provinces to support the federal position. Some of the priority issues addressed by the WCS are a narrow sectoral approach to conservation, failure to integrate conservation and development, inadequate environm tal planning, inadequate or unenforced environmental legislation, lack of trained personnel, lack of information, and lack of support for conservation (Inter. Union Conserv. Nat. & Natur. Res. 1980). It's almost as if the strategists behind the WCS had Alberta in mind when they wrote that list, for each and everyone of those concerns applies directly to the province and specifically to the development of Mount Allan. As signatories to the WCS, it is apparent that Alberta, and Canada (hundreds of millions of federal dollars are being poured into the Olympics) have knowingly broken the spirit of that convention. Both levels of government may have broken the letter of that convention as well (Geist 1983a) since one of the agreed upon steps to implementing the WCS is to review developments in relation to each conservation objective. Five years after the initial Olympic decision was made, at a time when development is almost complete, this has not yet been done.

As though the obvious violation of the World Conservation Strategy were not enough of an embarrassment, the Guidelines for Wildlife Policy in Canada (1983) were also ignored. This policy was developed over a two year period by a federal/provincial committee and approved by all provincial wildlife ministers in September 1982. The document states that "by approving these guidelines, governments have agreed to the goals, principles, and elements" that constitute those guidelines. The first goal of the policy is "To maintain the ecosystems upon which wildlife and people depend" (Dep. of the Envir. 1983). The Mount Allan development demonstrates a clear lack of commitment to wildlife conservation by a select group of Albertans, including Premier Lougheed and the Minister responsible for wildlife, Don Sparrow.

At the time Mr. Adair announced that the government of Alberta was going to develop it's own ski hill, he also announced that a master plan would be prepared. This Master Plan was to address all concerns, including the environmental ones, most of which related to the future of the bighorn sheep population. Mr. Adair had earlier announced there would be no impact assessment done on the Mount Allan development.

Concern for the bighorn sheep population on Mount Allan was expressed the moment Mount Allan was mentioned as a possible development site. The Alberta Wilderness Association was among those who voiced early opposition, not just to the choice of Mount Allan, but to the process by which decisions were being made - completely without public input or review (Alberta Wild. Assoc. 1983). The Wilderness Association and representatives from a number of other interested groups met with OCO '88 in November 1982 and were told that the Olympic Committee was not responsible for environmental matters but that they would try to persuade government to take these matters into consideration. A further meeting was scheduled for January 1983, was then delayed, and never did materialize.

In December 1982 the suggestion was made that OCO '88 add an environmental advisor to it's staff. In February 1983 the chairman of OCO '88, Frank King, indicated publically that OCO '88 had set up an environmental advisory board. The "board" was never formally appointed and has never met. The staff environmental advisor has never been seen nor heard from.

As it became apparent that there would be major impacts on the Mount Allan environment, the initial concerns became a flood of protest (Calgary Herald 1983b; Geist 1983a; Geist 1983b; Geist 1983c; Flattau 1983; Stemp 1983; Western Canada Outdoors 1983; Zeman 1983). Noticeable by their absence were the Alberta Fish and Game Association and the National and Provincial Parks Association of Canada (NPPAC). Both of these groups chose to play ball with the provincial government, the first because it had a vested interest it was trying to protect, the second because of a wavering commitment to a principle. The Fish and Game Association had been negotiating with the province who was promising the Association it's own ranch on which a handful of members would manipulate habitat and wildlife. In its desire to get this private playground, the executive of the Association sacrificed the best interests of it's membership by remaining silent on the Mount Allan development. In so selling their principles, they were choosing to overlook government policies and developments detrimental to public lands and wildlife. The NPPAC was concerned that opposition to the development of Mount Allan would force the federal and provincial governments to hold the ski races at Lake Louise in Banff National Park. They were trying to protect the sanctity of the Park, but seriously bending a principle in doing so. It could well turn out that, by remaining silent, they will have lost both battles. Mount Allan is already developed but the prospects of the Olympic alpine events being held in Lake Louise, because of the inadequacy of Mount Allan, appear as of April 1986, to be stronger than ever. This in spite of a Citizens Advisory Committee recommendation that a "more acceptable men's downhill course" could be found on Mount Allan and that such a course be identified and it's approval by the International Ski Federation be sought (Citizen's Advisory Committee 1983). The committee did, however, leave itself an out with respect to Lake Louise, stating that if a satisfactory men's downhill course was not available on Mount Allan, Lake Louise should be used.

Provincial politicians, as insensitive as they were (and remain) to the real concerns being raised, tried not to solve the problems the public was pointing out but instead, tried to quell the public dissent by announcing the formation of a Special Committee for Review of Wildlife and Environmental Matters. It's mandate was to respond to public concerns and develop mitigating measures. The committee, chaired by Director of Fisheries Tom Mill, proved to be a complete failure. In retrospect, failure was built into the committee; it did not include an individual with bighorn sheep or large mammal expertise, consisted only of government employees and therefore had no independence, had no mandate to implement base line data collection or monitoring programs, had no decision making power, and had no funds to allocate. It quickly began to function as a shield for the Premier and his colleagues, a vacuum that prevented the penetration of public concerns and interests to the elected cabinet.

It soon became evident that public concern for the bighorn sheep on Mount Allan was not going to dissipate. The government then began to point to the Master Plan as being the solution to environmental concerns and, in particular, worries about the welfare of the sheep (Calgary Herald 1984). It was therefore with great anticipation that Albertans received the Master Plan in May of 1984. With all the interest expressed regarding bighorn sheep and with at least 18 months having passed since Mount Allan had been chosen by the Premier as the ski development site, there were expectations that the Master Plan would be one of substance. Instead, it was a disaster. There was bitter disappointment and immediate critical reaction (Geist 1984; Horejsi 1984). Reviewers of the plan were appalled by it's superficial treatment of the environmental assessment process, it's methodology, the sheep population and sheep biology. Equally disturbing, it contained serious errors. For example, the map of sheep habitat in the plan did not agree with that available from the Fish & Wildlife Division. The Division's map, although more accurate than that in the plan, was incomplete, perhaps because administrators felt Mount Allan was protected by the 1979 agreement between the Departments of Wildlife and Tourism! The chairman of the International Union for the Conservation of Nature Commission on Environmental Planning stated that "the Olympic committee (the developers) is clearly disinterested if not actively opposed to dealing with the issue" of bighorn sheep (Jacobs 1984). Outside observers described the plan as woefully inadequate (Hutchins 1985). Even the gentlemanly Canadian Society of Environmental Biologists, consisting mainly of corporate biologists who have to chose their words carefully, requested "clarification" (Kennedy 1984). Coming from them, that was serious language!

The Fish & Wildlife Division was pointedly excluded from the planning process, contrary to claims in the Master Plan. This we can attribute to Don Sparrow, Minister responsible for the Division, who has slowly but methodically emasculated the agency. No individual with wildlife credentials was involved in plan preparation, although the plan deliberately deceived the public by stating "respected professionals with expertise in wildlife habitat and behavior" prepared the plan. The one individual involved was a botanist who spent 120 hours on Mount Allan over a 5 year period. This equates to 24 hours per year. His bighorn sheep observations were a post hoc recall of events and locations. Geist (1984) bluntly condemned the plan; this "simple minded projection of bighorn range from plant communities is wrong and unacceptable".

The wildlife part of the Master Plan cost $14,00 out of a budget of $500,000. Fortunately, the deliberate lack of attention to wildlife concerns is obvious to even the untrained eye: there was no evidence that ecological considerations had been integrated in the development design; scientific evidence regarding the consequences of intensive development on bighorn ranges had been ignored; there was no consideration given to the cumulative effect of all the developments in, and proposed, for the Mount Allan area; use of weather and snow data was extremely selective, suggesting a calculated attempt to manipulate results; and the understanding and presentation of bighorn sheep biology was totally inadequate. On page 140, where the development budget was given, zero dollars were allocated for environmental concerns. The plan has proven to be sham - part of a deliberate attempt to mislead the public about the severity of the environmental impact resulting from the development of the Mount Allan area.

CONCLUSIONS

Observations indicate that a significant number of the sheep that occupy the Mount Allan mountain complex rely on the slopes of Mount Allan for rutting and winter/spring range. If there is any turnover in the winter population, as I expect there is, and assuming there is yearly variation in the number of sheep using Mount Allan/Collembola, than easily half of the animals in that population rely on Mount Allan to sustain themselves over winter.

The threat to these animals is not physical loss of habitat. It follows, therefore, that habitat enhancement is not a solution but is instead a political ploy and a terrible waste of money. The threat is a wave of humans that is beginning to and will increasingly prevent sheep from exercising their behavioral and ecological options. I draw the human analogy of not being able to use one or two or three rooms in your house. The implications are extremely serious. In the case of the bighorn sheep on Mount Allan the result will be a sharp reduction in the fitness of individuals. This has grave consequences for the future of this sheep population. It's status has changed from problem-free to threatened.

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THE INCREASE AND DIEOFF OF WATERTON CANYON BIGHORN SHEEP: BIOLOGY, MANAGEMENT AND DISMANAGEMENT

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Abstract: The Waterton Canyon bighorn sheep (*Ovis canadensis*) herd, near Denver was studied intensively during 1978-1982, coincident with construction of Strontia Springs Dam, and was observed occasionally thereafter. The herd has a restricted range, smaller than that reported during 1950-1970. Range restriction is correlated with gradual encroachment of conifers and shrubs, especially on federal land, and with a limited availability of water during summer in the lower Canyon. During construction, the herd increased from 48 to 78 animals. An all-age dieoff with acute bronchopneumonia occurred in late 1980. Several natural and human-related stressors were identified but not quantified. The most acute stressor was airborne dust. Subsequent lamb crops had poor survival, with pneumonia causing deaths of lambs for 1-3 years after the dieoff. A critical need for habitat management, including vegetation control and water development, was noted as early as 1979 and 1980. The Forest Service has received considerable private, state and urban support for developing a plan to manage sheep habitat in the Canyon. The current plan does not address habitat abandoned by this herd before 1978. Vegetation has been manipulated under the plan, but only in the lower Canyon. Critical migration corridors to the upper Canyon have not been treated. Since 1982, reliable data on herd size and composition have not been obtained. The recent history of Waterton bighorn sheep and their habitat suggests that (1) when projects are constructed on bighorn range, adequate mitigation may require pre-project knowledge of the range, and perhaps pre-project mitigation by habitat improvement; (2) long-term plans for managing bighorn ranges are needed; (3) our ability to manage bighorn ranges will be limited by lack of funding, personnel and dedication, risks associated with vegetation manipulation, and personnel turnover; and (4) there is a need to realistically assess how many bighorn ranges we will be able to manage well, in the long term.

The objective of this paper is to document the ecology and demography of bighorn sheep in Waterton Canyon, Colorado, during 1978-1985. In this period, Strontia Springs Dam was constructed in the Canyon. The bighorn herd suffered an all-age dieoff in 1980-81. This episode has often been referenced as an example of the impacts of construction and development activities upon bighorn sheep, as if construction, stress and a dieoff were a certain and simple relationship. Neither biology nor management will benefit from so simplistic a conclusion. In contrast, a more complete awareness of events in Waterton Canyon could enhance our abilities to manage other herds and their habitats, and to mitigate when habitats and herds are threatened by development activities.

A study of Waterton Canyon bighorn sheep was funded by the city of Denver and its Water Department during 1978-1982. The Colorado Division of Wildlife, particularly its Northeast Regional Office, also funded important aspects of the study. The U.S. Forest Service allowed the study on federal land. The Rocky Mountain Bighorn Society, Martin-Marietta Corporation, and Denver funded habitat manipulation on private land in the Canyon. In 1986, the U.S. Forest Service conducted a prescribed burn, again mostly on land owned by Denver and Martin-Marietta.

The following biologists (and their reports and publications) contributed importantly to the study: K. Risenhoover (1981, Risenhoover and Bailey, 1980, 1985, 1986), B. Simmons (1982), E. Rominger (1983, Rominger and Bailey 1982, 1986, Rominger et al. 1986), A. Dale (1986, Dale and Bailey 1982), G. Schoonveld and R. Schmidt of the Colorado Division of Wildlife, and C. Hibler, T. Spraker and E. Williams of the Colorado State University Department of Pathology (Spraker et al. 1984). For clarity, these publications will not be cited repeatedly in this text.

WATERTON CANYON

Waterton Canyon is about 40 km southwest of Denver, Colorado. It contains 13 km of the South Platte River. Elevations vary between 1707 and 2370 m. The lower canyon is dominated by shrubs, especially true mountainmahogany (Cercocarpus montanus) on south aspects, and Gambel oak (Quercus gambelii) in dense stands on north aspects. Gambel oak occurs on south aspects in mid-canyon, where Douglas-fir (Pseudotsuga menziesii) and ponderosa pine occupy north aspects. The upper canyon is dominated by conifers, especially on north aspects, and some conifer stands have oak understories.

Cliffs and steep slopes, used for escape terrain by bighorns, are abundant, especially near the River. Little is known of the bighorn herd in the Canyon prior to 1950. A historic herd of 200-250 has been reported. During 1955-1975 estimates of herd size were between 18 and 50. Bear and Jones (1973) reported that this herd ranged throughout Waterton Canyon and for 10 km upstream from the Canyon (Fig. 1).

The city of Denver constructed Strontia Springs Dam in the upper Canyon during 1978-1982. In the same period, the Colorado Division of Wildlife and Colorado State University (CSU) were funded to monitor the Canyon's bighorn herd, evaluate impacts on the sheep and on sheep habitat and develop mitigation methods. Construction activities on the Canyon road had begun before the study, however.

BIGHORN RANGE

In January and in December, 1979, bighorn sheep were captured and fitted with collars or ear tags. Seven, 5 ewes and 2 rams, received radio collars. Based on almost daily monitoring of the herd during 1978-1982, the bighorn range was determined to be much smaller than that described by Bear and Jones (1973; Fig. 1). The former, larger range was presumably based on observations in the 1950's and 1960's. In 1978-82, the sheep were restricted to Waterton Canyon. The upper Canyon was used

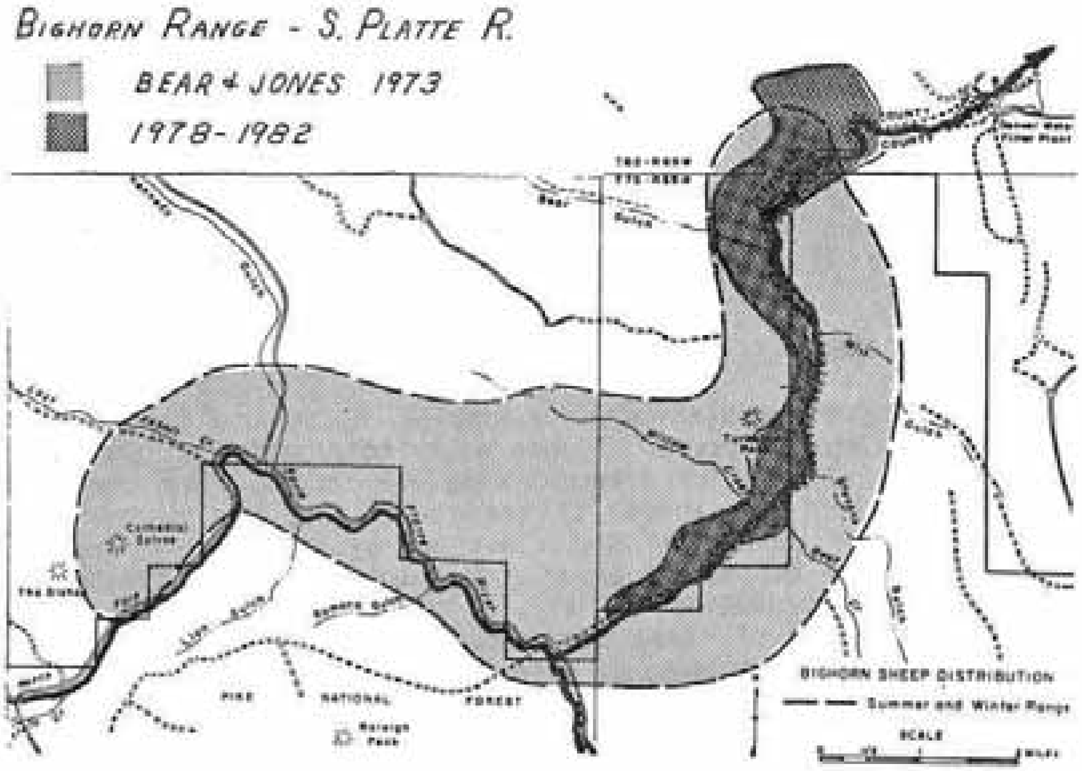

Fig. 1. Historic distribution of bighorn sheep along the South Platte River near Denver. The range reported by Bear and Jones is based on observations from the 1950's and 1960's.

for lambing during April-July, and was summer range for rams and some ewes without lambs. The lower Canyon was used as winter range. In addition, ewes with lambs left the upper Canyon lambing area and moved quickly to the lower Canyon in June or July in 1979 and 1980. Thus, most ewes, including almost all ewes with lambs, used primarily the lower 5 km of the Canyon during summer, fall and winter, or 75% of the year.

The sheep range was also restricted ecologically. The sheep preferred grassy openings, mountain shrub types, and cliffs; they avoided the conifer and oakbrush types, which constituted 78% of the study area. Risenhoover and Simmons documented behavioral adaptations (foraging efficiency, alertness and sociality) of these sheep to habitats that were near escape terrain and afforded good visibility. The sheep were limited mostly to steep, relatively open habitat near the South Platte River and its adjacent road. In late summer, the River afforded the only free water for sheep in the lower Canyon.

Wakelyn (1984) compared habitat conditions between the range of this herd before 1970 vs. the range in 1978-82 (Fig. 1). The recently abandoned portion of the range contained a greater proportion of forest cover and smaller proportions of shrubland, grassland and rocky habitat.

Waterton Canyon has a unique bighorn herd. It is one of only six indigenous low-elevation (below 2440 m) herds left in Colorado. The herd has relatively early and asynchronous breeding and lambing periods. More like desert bighorn sheep, their summer diet consists largely of shrub leaves. Sheep from this and other low-elevation herds in Colorado have exhibited exceptional rates of body and horn growth and have contributed inordinately to the Boone and Crockett and the Pope and Young record books.

POPULATION TRENDS

The bighorn population was estimated, by sex and age classes, each month for almost 4 years. Almost daily observation of the herd on its small range allowed for frequent complete counts. Our conclusion that the entire herd was known, by sex-age class, was supported by the consistency of counts for each class and by frequent samples containing most or all of the marked sheep. Frequent Petersen-estimates indicated that we were accounting for all, or all but one or two, sheep. Each year, the number of lambs born was uncertain, but we began to attain consistent counts of lambs by July.

As the study, and construction for Strontia Springs Dam, began in the fall of 1978, there were 48 sheep in Waterton Canyon (Fig. 2). These included 6 1978 lambs and 6 yearlings. The lamb:yearling:ewe ratio was 25:25:100, indicating low reproductive success and/or recruitment success from the 1977 and 1978 seasons.

As construction activities and the sheep study proceeded, the herd increased through the 1979 and 1980 lambing seasons (Fig. 2). There were 14 lambs in 1979 and 16 in 1980. Survival of lambs (counted in summer) to the yearling class was 100% for the 1978 and 1979 cohorts. Lamb:ewe ratios improved to 52:100 and 55:100 in 1979 and 1980, respectively. By summer, 1980, there were 78 sheep in the herd, a 62% increase during less than 2 years of construction activity in the Canyon (Fig. 2).

The Dieoff

Coughing sheep were first observed on 19 September 1980. By late October most sheep were coughing. The first dead sheep was found in early October and 39 carcasses were found by frequent searches of the Canyon during October-January (Fig. 3). Within age classes, mortality ranged from 69% in ewes and lambs to 88% in rams (Table 1). Spraker et al. (1984) reported necropsies of 18 animals. All had bronchopneumonia which was acute to peracute in the earliest cases, causing death in several days to a week. In later cases the disease was chronic. Early in the dieoff, all sheep had excellent hair coat and body fat (Fig. 4). Of three pathologists conducting necropsies, one consistently noted that the lungs had numerous macrophages containing what appeared to be dust. Lungworm (Protostongylus) burdens were judged low to moderate. The adrenal glands were enlarged and hyperplastic in 9 of the 15 sheep suitable for this examination. In 9 of 14 sheep, the thymus ranged from smaller than normal to completely involuted.

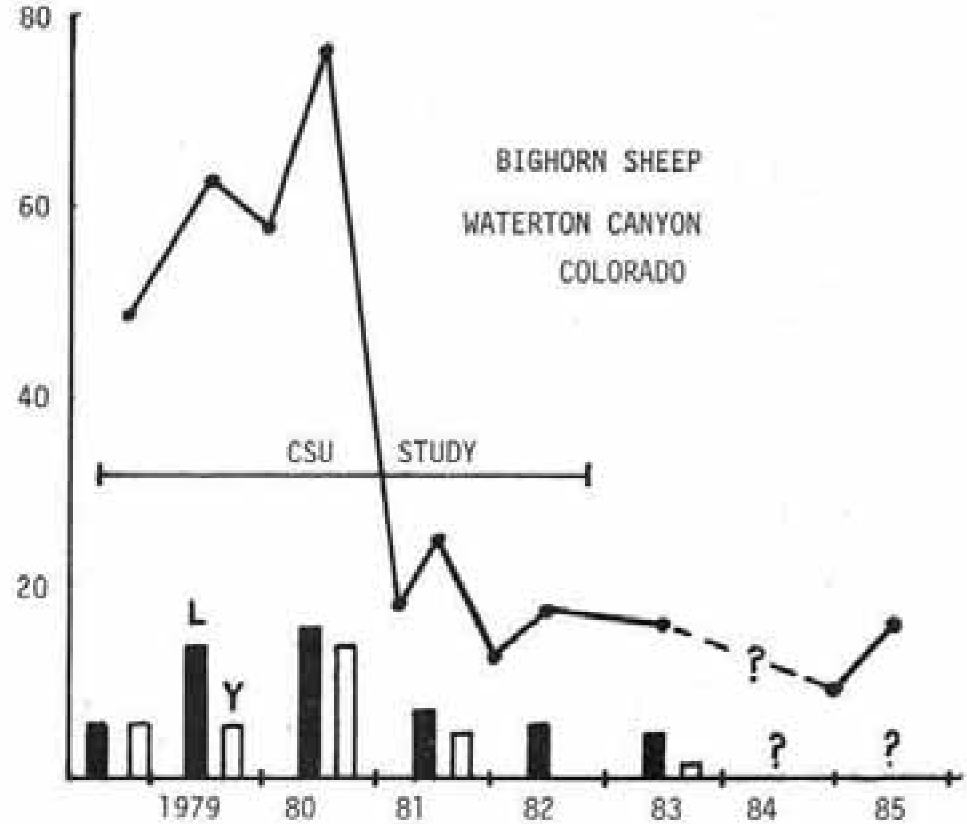

Fig. 2 The bighorn population in Waterton Canyon, Colorado, during and after the Colorado State University study. Shaded and open bars represent numbers of lambs and yearlings, respectively.

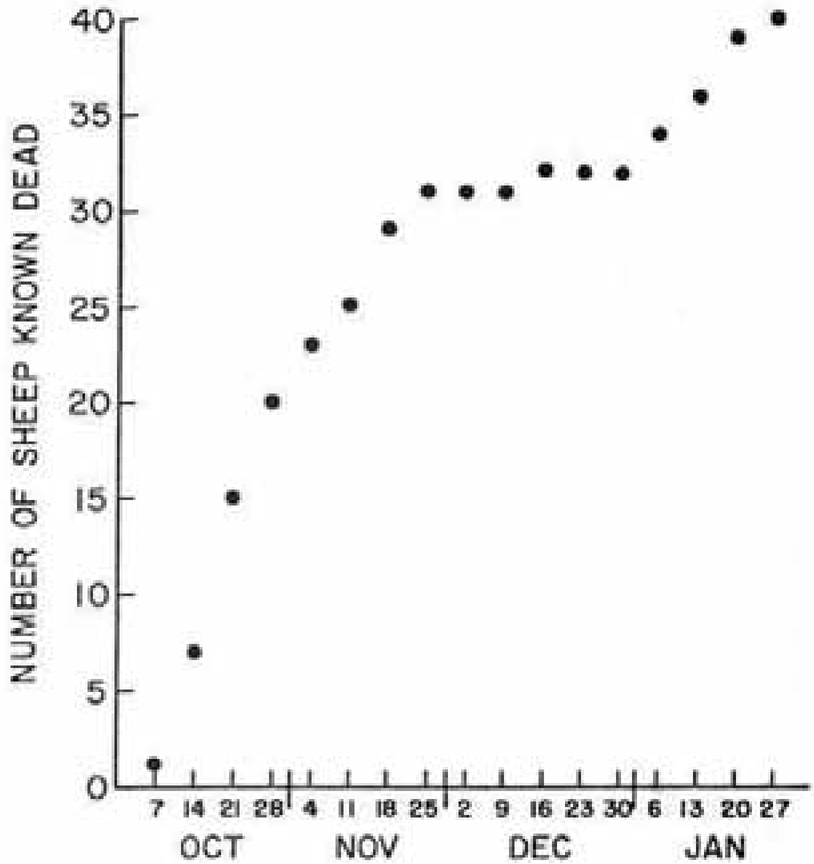

Fig. 3. Cumulative number of bighorn carcasses found during periodic searches of Waterton Canyon, 1980-1981 (from Simmons 1982).

Table 1. Mortality by sex-age class, Waterton Canyon bighorn sheep, October 1980-April 1981 (from Simmons 1982).

Sex-age class	Minimum population Jul 1980	Known alive Apr 1981	Mortality (%)
Ewes	30	9	69[a]
Lambs	16	5	69
Yearlings	(14)	(2)	(86)
Male	8	1	88
Female	6	1	83
Rams	(17)	(2)	(88)
Class I-II	11	--	100
Class III-IV	6	2	67
Total	77	18	77

[a]Excludes ewe poached on 7 Oct. 1980.

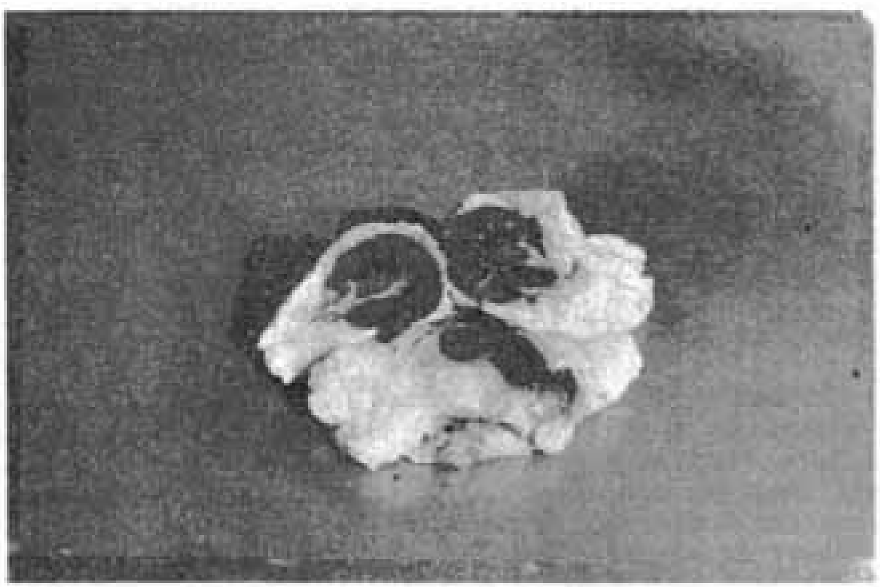

Fig. 4. Kidneys (one sectioned) and associated fat from bighorn dying of bronchopneumonia in Waterton Canyon. Early in the dieoff, the sheep had excellent fat reserves (from Simmons 1982).

Post Dieoff

There were but 18 sheep in Waterton Canyon in April 1981: 11 ewes, 5 yearlings and 2 rams. At least 8 lambs were born (73:100 ewes), mostly in June. This peak of lambing was about a month later than in 1979 and 1980. All 8 lambs were dead by 11 August. They had appeared healthy until 3.5-6 weeks of age, when they coughed and had nasal discharges. Two lambs were necropsied and revealed the familiar pneumonia condition. In contrast to previous years, none of these lambs was moved to the lower Canyon. Their ewes, however, moved down Canyon after the lambs had died.

Five older sheep disappeared during October 1981 - February 1982. Three of the four missing ewes were old and considered chronic pneumonics. The fourth ewe and a yearling had appeared in good condition before their disappearance.

There were but 13 sheep in Waterton Canyon in late winter, 1982: seven ewes, 4 yearlings and two rams. Funding of the intensive study ended with completion of Strontia Springs Dam. Monitoring the herd became the responsibility of the Colorado Division of Wildlife, although Alan Dale of the Denver Water Department observed the herd occasionally.

In summer, 1982, 8 ewes were seen with 6 lambs (75:100). Peak of birth was once again in the first half of May. Two female lambs reached the lower Canyon by 21 July. The other 4 lambs died in the upper Canyon, perhaps from pneumonia. Two 1982 lambs became yearlings in 1983 (Fig. 2).

There were at least 6 lambs again in 1983 (85:100 ewes), with peak lambing in early May. Four lambs reached the lower Canyon, but one with a broken leg was collected and necropsied. It had the same pneumonic conditions as had all previously necropsied sheep.

Lambing success in 1984 and 1985 is unknown. Ten sheep were observed in the Canyon at the end of 1984. The population was presumed to have 16 sheep in summer, 1985 (Fig. 2).

Stress and Stressors

The all-age dieoff was interpreted as stress-related (Spraker et al. 1984). Stress is a well-documented pattern of biochemical, functional and structural responses of higher animals to negative stimuli (Selye 1976), and this pattern inhibits or reduces an animal's immune capacity (Gabrielson and Good 1967, Gisler 1974, Solomon et al. 1974). Attributing the dieoff to stress clarifies the proximate mechanism of mortality, but does little to elucidate the ultimate causes. Without clarification of causes, we have no basis for placing blame, or for avoiding similar debacles in the future. Moreover, if we become satisfied with, or promote, "stress" as an explanation, we may impede development of understanding of the causes of stress in bighorn sheep.

Stress is the cumulative effect of negative stimuli which are termed stressors. For bighorn sheep, the ultimate goal of stress research would be to identify and quantify the various stressors operating on a herd. In Waterton Canyon, several potential stressors were identified (Table 2). While few were quantified in any way, there was evidence for speculation on the relative importances of some of these stressors. Spraker et al. (1984) have considered the roles of lungworms and microparasites in detail.

Table 2. Stress factors that may have predisposed sheep to all-age dieoff, Waterton Canyon, 1980 (from Simmons 1982).

Natural	Man-related
Lungworm	Construction
Microparasites	Traffic
Weather	Dust
Social density	Research
Limited habitat	
Population density	

Summer and fall 1980 were dry along Colorado's Front Range and were among the driest seasons on record for Waterton Canyon. Sheep in the lower Canyon had to cross the Canyon road to drink from the South Platte River. Lack of water away from the River may have abnormally restricted their range to areas near the road.

In 1979 the Canyon road was treated with a dust-reducing substance which deteriorated. The road was subsequently oiled several times but a durable surface was not attained. In the dry summer and fall of 1980 dust was often in the air throughout most of the lower Canyon. While Strontia Springs Dam was being poured, there was a vehicle passage every 5-6 minutes. Occasional watering of the road accomplished little. Airborne dust settled on shrubs and became airborne again as animals walked through the vegetation. Inhaled dust can compromise the immune system of mammals (Rylander 1969, Green 1970, Adney 1981). This dust was the most acute stressor associated with the sheep dieoff (acute in the sense that dust was a potentially serious problem that occurred abundantly and primarily just preceding the dieoff).

Waterton sheep were in excellent physical condition, indicating no shortage of forage. However social density had increased during 1978-80. There were about 31 sheep per square km of used range in the summer of 1980. The level or role of social stress at this density is unknown. If social stress were important in predisposing sheep, subordinate age classes may have suffered inordinately. Yet mortality was high in all sex-age classes.

Since Waterton sheep were restricted primarily to a narrow corridor along the Canyon and its road, they were subjected to abundant traffic and construction noise and activity. Work on the road, including blasting, began in late 1978. Thereafter there was more blasting and abundant, noisy construction equipment almost daily. Our study caused additional stress. Twice in 1979, sheep were trapped and handled. They were observed almost daily, often from within 25 m or less. However, Waterton bighorns were habituated to people and vehicles. They were often on the road and did not always flee when approached. They were observed to walk among parked vehicles, to cross the River on a new one-lane bridge, and to show only modest "head-up responses" to sudden noises such as explosions or the starting of diesel engines. We compared working vs. non-working days for construction crews and found the sheep, on average, slightly farther from the road and slightly nearer to escape terrain on working days in 1980, but not in 1979. With care, biologists could join and remain with a group of foraging sheep to record behavior. The contribution of all this disturbance to stress in these habituated sheep remains unknown. Appearances of sheep may hide physiological changes, including elevated heart rates (MacArthur et al. 1982, Stemp 1982). A key factor in Waterton Canyon was that limited range and lack of free water obligated the sheep to be near the construction activity.

HABITAT MANAGEMENT

A need for improving sheep habitat in Waterton Canyon was recognized early in the CSU study of the herd. Much habitat in the lower Canyon is owned by Denver and by Martin Marietta Corporation. Almost all habitat in the middle and upper Canyon is managed by the United States Forest Service. During 1979-1982, these agencies were frequently alerted to the need for habitat management in several reports. The need for vegetation manipulation was noted in 1979. A water development in the lower Canyon was proposed in 1980. Denver did brush clearing and tree limbing as mitigation for habitat lost due to Strontia Springs Dam in 1979 and 1980. (The Forest Service requested that no large trees be cut in these mitigation clearings.) The sheep used these mitigation clearings, adjacent to existing range, almost immediately. In 1980, the opportunity to improve sheep habitat in the upper Canyon with a fuelwood harvest was noted. This opportunity would be lost when flooding behind the dam would eliminate easy access. In 1981 it was suggested that greatest habitat deterioration due to forest succession had occurred on federal lands in the upper Canyon. Also, the risk of inbreeding in the herd was noted. This risk made habitat improvement more urgent. Two sites for water developments were proposed in 1981. Twelve areas were proposed for vegetation control in 1982. In 1983 Martin-Marietta and Denver bulldozed oakbrush on private lands in the lower Canyon. In addition, local data, results of experimental vegetation manipulation, literature reviews, draft habitat-management plans, funding, volunteer labor, and a public relations program were given or offered to the Forest Service by the CSU study, students from CSU, the Rocky Mountain Bighorn Society, the

Colorado Division of Wildlife and Martin-Marietta Corporation. The Director of the Colorado Division of Wildlife and the Regional Forester both supported, with written correspondence, habitat manipulation in Waterton Canyon. All this support should have hastened development of necessary environmental analyses and a habitat management plan by the Forest Service.

The Forest Service cooperated in a small prescribed burn of oakbrush and mountain shrub habitats on private land in the lower Canyon in 1984. A larger burn, again in the lower Canyon, was conducted in 1986. This burn was funded by the Forest Service, the Colorado Division of Wildlife, the Foundation for North American Wild Sheep, and Martin-Marietta. The Division of Wildlife used the entire habitat-management budget of its Denver Region (one of 5 Regions in the state) for this burn. A wildfire occurred in the middle Canyon in 1986. There has been no development of a water source for sheep in the lower Canyon. In late summer, the only water is in the River alongside the Canyon road where recreationists, on foot or bicycles, are abundant. Other than mitigation clearings established by Denver, there has been no habitat manipulation to maintain a migration corridor between the upper and lower Canyons. Chance observation of young lambs in 1986 has suggested that lambing occurred in the lower Canyon, perhaps an indication that sheep are abandoning the lambing area in the upper Canyon.

Sheep numbers are not being monitored on a regular basis in Waterton Canyon. There were at least 15 sheep in late 1985. The 1986 lamb crop is uncertain. The state Division of Wildlife is considering a transplant to augment the herd, probably with sheep from a high-elevation gene pool. If there are unique genes in low-elevation sheep in Waterton Canyon, the potential for swamping these genes with a transplant is unknown. A conservative approach, using a low-elevation source, or fewer sheep, for augmentation, and monitoring the results, would be more expensive than simply transplanting 10-20 sheep. The Forest Service has a plan for continued habitat management in Waterton Canyon. Funding of activities in this plan is uncertain. The plan does not address habitat, upstream from Waterton Canyon, that sheep abandoned before 1978 (Fig. 1).

During 1978-1986 there was considerable turnover of personnel who dealt with bighorn sheep and their habitat in Waterton Canyon. In the Forest Service there were 4 District Rangers on the South Platte District; there were at least two wildlife biologists in the Forest Supervisor's office; there were three Regional Foresters in the Denver office, two of whom commented in writing on the need for sheep habitat management in the Region. There were two Directors in the Colorado Division of Wildlife. In addition, administration of Waterton Canyon was switched from the Northeast Region of the Division to the new Denver Region. There were at least three state District Wildlife Managers responsible for Waterton Canyon. At least before 1986, there was no trained wildlife biologist on the South Platte District of the Forest Service. The current biologist in the Forest Supervisor's office is responsible for range management, soils, watersheds and mining, as well as for wildlife. Thus lack of adequate personnel and personnel turnover, as well as lack of adequate funding, must have contributed to the slow and uncertain responses of the Forest Service and the Colorado Division of Wildlife to the needs for preserving a unique bighorn herd.

MANAGEMENT IMPLICATIONS

Events during 1978-1986 in Waterton Canyon have important implications for the management of many bighorn herds in the Rocky Mountain Region. It is likely that many bighorn ranges in the region have been degraded by forest and shrub succession (as they have been in Colorado; Wakelyn 1984), and that many are threatened by developments including reservoirs, roads, mines and urban expansion.

Mitigation Opportunities

When bighorn sheep range is threatened by development such as reservoir construction, effective and timely mitigation of impacts will often depend upon having prior knowledge of the seasonal ranges, migration corridors and movement patterns of the sheep herd. Obtaining this knowledge in a project-monitoring study concurrent with construction activities may not be adequate to forestall impacts on the sheep. At Waterton Canyon, the sheep range had been degraded by decades of plant succession before construction of Strontia Springs Dam. The range was already limited to an extent that obligated the sheep to remain near to construction activities. They had no options. Had this been known earlier, habitat manipulation before construction of the Dam, to attract sheep away from the construction activities, may have prevented the dieoff. In the future, pre-project studies of bighorn ranges, and in some situations, pre-project mitigation, will be necessary to avoid impacts on bighorn herds.

Forest fires have been suppressed for up to 65 years in much of the Rocky Mountains. It is therefore likely that very many bighorn ranges have been degraded by forest succession. Consequently, when construction activities and other developments are localized on bighorn ranges, there should be abundant opportunities to mitigate by manipulating vegetation to improve comparable habitat away from the project.

Dust was the most acute stressor preceding the Waterton bighorn dieoff. Yet the importance of dust in this dieoff is unknown. Some herds of northern mountain sheep live in the frequently dusty chinook-zones of recently glaciated mountains, apparently without impacts on their lungs. However, dust-particle sizes may determine these impacts. Until more is known about this threat, it would be prudent to control dust generation when development projects invade bighorn ranges.

At Waterton Canyon, the continuing post-dieoff mortality of subsequent lamb crops emphasizes the need to avoid such a dieoff. Loss of these lambs, due to persisting prevalence of the disease and/or persisting susceptibility of the sheep herd, is delaying any density-dependent response to the current low population size. (The highest lamb:ewe ratios reported here are from the post-dieoff period and perhaps are a response to density.)

Management Planning

I believe that most bighorn herds and ranges are not known well enough for successful management in the long term. We do not adequately monitor populations. More commonly, we do not know the seasonal ranges, migration corridors and movement patterns of herds. In Colorado, the vague herd and range descriptions in Bear and Jones (1973) and the experience of Wakelyn (1984) in questioning field biologists, trying to delineate bighorn ranges, support my position. If we do not know where all of a yearround bighorn range is, we are not managing the range, and we cannot protect it from threats of development. There is a great need for studies, probably with radio telemetry, to determine seasonal ranges and migration corridors of bighorn herds.

Waterton sheep are a mini-example of many bighorn herds in the Rocky Mountains. They have lost range, lost migration traditions, and become more sedentary (Fig. 1). In contrast, most migratory bighorn herds in mountain areas will have a more complex year-round range than one resulting from simple migration within a river corridor (Fig. 5). But

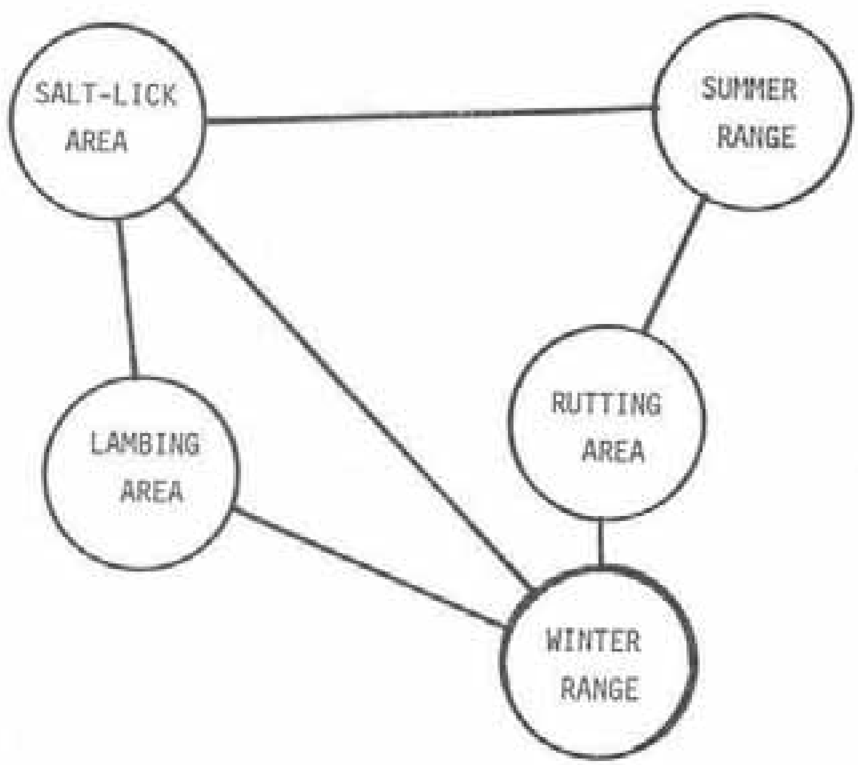

Fig. 5. Hypothetical year-round range of a bighorn herd in a topographically complex mountain area. Several seasonally used ranges are connected by migration corridors. Maintaining a migratory herd will require identification of seasonal ranges and migration corridors and long-term plans for protecting and perhaps managing these range components.

many herds have lost the migratory tradition and are now sedentary on one former seasonal range. They have lost options for responding to variation in weather or to forage conditions, or to threatening human activities. They may be subsisting on poor quantities or qualities of forage, at least in some seasons. The predation and disease implications of their sedentariness are unclear, but could be serious. Thus I believe the goal of most bighorn habitat management plans should be to reestablish or maintain seasonal ranges, migration corridors and migratory sheep. I know of only one such long-range plan. Moreover, most federal land managers are not aware of the value of migration to sheep or of past losses of bighorn ranges and migration corridors on the federal lands they manage.

There is a growing awareness of the impacts of succession on bighorn habitat and a growing interest in habitat improvement, especially on currently used low-elevation winter ranges. However most habitat-improvement projects have a limited, inadequate goal--to improve habitat conditions on one already used seasonal range. Meanwhile, abandoned seasonal ranges and abandoned or still-used migration corridors are ignored. Worse, habitat improvement on the one seasonal range, usually with prescribed fire, is often limited to areas that are safe or convenient to burn, to years with adequate weather for (usually) conservative burning conditions, to years when funds are available, and to times when adequate numbers of interested personnel are present. These limitations are due to serious problems and risks related to funding, to safety, to personnel turnover, and to the career aspirations of individuals. Such problems will always be with us. But a plan with this inadequate goal and these limitations is doomed to a slow failure. The failure occurs so slowly as not to be noticed during the average tenure of a federal biologist on a land unit.

To perpetuate healthy, productive migratory bighorn populations in forested mountains, our land-management agencies must (1) officially recognize establishment or maintenance of migratory herds as a goal; (2) identify existing or needed seasonal ranges and migration corridors that must be protected and managed to achieve this goal; (3) develop long-term plans for manipulating habitat on these ranges and corridors; and (4) realistically evaluate the continuing costs in dollars and personnel that will be necessary to manipulate these habitats.

Currently, such realism is lacking. We are trying to manage bighorn habitat whenever and wherever we find the opportunity. But we have few long-range plans. Realism will force us to ask, "Given the funding, safety, personnel and career problems we will always have, how much bighorn migration and how many bighorn herds can we afford?" For a given bighorn herd, perhaps it will be better to succeed at maintaining a 5-mile migration than to fail at maintaining a 10-mile migration. For a given area, perhaps it will be better to succeed at maintaining 4 healthy, productive bighorn herds than to struggle at maintaining 8 herds that are always unthrifty because of our program limitations. How many herds can we afford to protect and manage well? Which strategy is apt to produce more value from bighorn sheep in the long run?

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LONGEVITY OF AMERICAN MOUNTAIN GOATS

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Abstract: Remains of 12 mountain goats were found in Montana's Bitterroot Mountains from 1973-1975. The mean age (10.8 years) of the 9 remains which could be aged and sexed was significantly ($P<0.001$) greater than the mean age (6.0 years) of 123 harvested goats. Ages of male and female goats were not significantly different in the harvest ($P=0.17$) nor among natural mortalities ($P>0.9$). Age-specific horn breakage, an indication of accidental injury rate, was correlated ($P<0.01$) with age. However, 70% of all horn breakage had occurred by 3.5 years-of-age. Natural longevity of adults is likely dependent upon rate of wear and loss of teeth. Regulations which favor harvest of males and recruitment of juveniles to breeding age could improve management of hunted goat populations.

Longevity, particularly of females, is an important determinant of productivity in species with late sexual maturation, such as the mountain goat. Low fecundity and high juvenile mortality of mountain goats underscore the importance of long life spans of animals reaching adulthood. Some factors affecting productivity, such as birth rates (Brandborg 1955: 101-109, Hall and Bibaud 1978, Taber and Stevens 1980, Youds et al. 1980) and recruitment rates (Rideout 1974, Hebert and Turnbull 1977, Hall and Bibaud 1978, Chadwick 1983:110-114) have been reported. However, longevity of mountain goats is not well documented. This paper provides information on longevity of a hunted mountain goat population native to western Montana.

I thank Dr. B.W. O'Gara and Marco Festa-Bianchet for providing comments on the manuscript. This work was supported by the Montana Cooperative Wildlife Research Unit (U.S. Fish and Wildlife Service, Montana Department of Fish, Wildlife and Parks, Wildlife Management Institute, and the University of Montana cooperating).

METHODS

During an investigation of mountain goat ecology in Montana's Bitterroot Mountains (Smith 1976), ages of mountain goat remains found on winter ranges were recorded. Horn annuli and horn morphology were used respectively to determine age and sex (Brandborg 1955). Age and sex of 123 mountain goats harvested in western Montana from 1973-1978 were likewise determined in the field or at taxidermy shops. Horn breakage observed on the harvested goats was recorded. Broken horns were compared to unbroken horns and when >4 mm were missing, a horn was considered broken.

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RESULTS AND DISCUSSION

Natural Longevity

Remains of 12 goats were found on winter ranges in 1974 and 1975. For 9 of the 12 remains, age and sex were established. This is the largest sample of natural mortalities of adult goats for which age and sex have been reported. Mean age was 10.8 years (SE = 0.87) and ranged from 6.5-15.5 years for 7 males and 8.5-13.5 years for 2 females. The mean age of the males ($\bar{x}$ = 10.79, SE = 1.02) was not significantly different (t = 0.09, P>0.9) than the females ($\bar{x}$ = 11.0, SE = 2.51). Maximum ages reported elsewhere include a 13-year-old male from Idaho (Brandborg 1955), a 10-year-old female from Washington (Johnson 1983:20), 10-year-old males and females from Alaska (Nichols 1980), and 12-year-old female from Olympic National Park (Taber and Stevens 1980). Cowan and McCrory (1970) reported an 18-year-old female and a 14-year-old male from among 165 goat skulls in museum collections. They observed that the average age of the oldest individual from four geographic areas of the species' distribution was 10 years.

Harvested Goats

From 1955-1974, hunters harvested 85 females (N = 335) for every 100 males (N = 396) taken in the Bitterroot Mountains, resulting in a post-season sex ratio of 87 adult males:100 adult females (Smith 1976). Selective harvest of males apparently affected the adult sex ratio of the population.

Females tend to outlive males in most polygamous North American ungulates (Flook 1970, Geist 1971:280, McQuivey 1978, Meagher 1978:125, Gavin et al. 1984) as was reported in an unhunted mountain goat population (Taber and Stevens 1980). Mean age of the 83 males harvested in western Montana ($\bar{x}$ = 5.7 years, SE = 0.34) was less but not significantly so (t = 1.41, df = 121, P = 0.17) than that of the 40 harvested females ($\bar{x}$ = 6.6 years, SE = 0.54). This suggests a similar age structure in the sexes since hunter selection of older animals from one or the other sex is unlikely given similar growth rates of adult male and female horns and the difficulty in distinguishing relative ages of goats observed in the field on the basis of horn size or other physical characteristics once adulthood is reached (Smith 1986).

Hunting apparently removed goats from the populations at an age ($\bar{x}$ = 6.0, SE = 0.29) significantly younger (t = 5.25, df = 130, P<0.001) than did natural causes of mortality ($\bar{x}$ = 10.8, SE = 0.87), but affected the age structure of the sexes similarly.

Remains of only adult mortalities were found in the Bitterroots. The remains of young goats likely disappear faster than the remains of older goats, as is the case with bighorn sheep (Buechner 1960:84, Geist 1971: 293). To avoid this potential bias in examining effects of hunter harvest on longevity, the 11 yearlings (no kids were harvested) were removed from the sample of 123 harvested goats. Then the samples of harvested goats ≥2-years old and natural mortalities were compared. The null hypothesis that mean age of harvested goats ($\bar{x}$ = 6.4, SE = 0.25) is not different than the mean age of natural mortalities ($\bar{x}$ = 10.8, SE = 0.87) was rejected (P<0.001).

Factors Affecting Natural Longevity

Mortality sources among mountain goats have been well documented and most investigators concur that: (1) natural mortality is highest during the first 2 years of life (Brandborg 1955, Rideout 1974, Youds et al. 1980, Hebert and Turnbull 1977, Chadwick 1983:109-114); (2) juvenile mortality is correlated to winter severity (i.e., snowpack) (Cowan 1950, Brandborg 1955, Rideout 1974, Smith 1976, Chadwick 1983:109-114); and (3) avalanches in late winter and early spring and other accidents are responsible for significant numbers of mortalities (Brandborg 1955, Holroyd 1967, Macgregor 1977, Chadwick 1983:109-116).

Among one herd of 30 intensively studied goats in the Bitterroot Mountains, three had broken or deformed horns and several others had one or both horn tips missing. To examine injury rates of goats, due to avalanches, rock slides and climbing accidents, the cumulative, age-specific incidence of broken horns among 123 harvested goats was recorded (Table 1). Thirty percent had 4 mm or more broken off one or both horns. Percent horn breakage was significantly correlated ($r = 0.993$, $N = 4$, $P<0.01$) with age. However, 70% of all horn breakage had occurred by 3.5 years of age (20.9% horn breakage for ages 1.5-3.5 years). Chadwick's (1983:144) observations that juveniles suffer 80% of all climbing accidents precipitated by intraspecific aggression may explain the high incidence of broken horns among goats $\leq$3.5 years of age. Debilitating or potentially fatal accidents may contribute to the high rates of juvenile mortality reported for the Bitterroot Mountains (31% among kids, 23% among yearlings over 2 winters, Smith 1976) and elsewhere.

The higher, although nonsignificant ($X^2 = 0.70$, 2df, $P>0.5$), incidence of broken horns among males versus females (Table 1) may be attributable to male fighting during the rut (Geist 1964), or accidents resulting from rutting behavior and the subdominant status of males in the social hierarchy (Chadwick 1983).

Adult goats experience a far lower annual rate of mortality than juveniles. Life expectancy of adults, as with other ungulates, is largely dependent on the rate of wear of the teeth (Cowan and McCrory 1970). The incisors of most Montana goats over 9 or 10 years of age showed severe wear. An emaciated 12.5-year-old female harvested from the Bitterroots had only 1 incisor remaining, and an old male had none (from hunter questionnaire). Several other old goats were missing one or more incisors and/or had loose teeth. Casebeer et al. (1950) and Brandborg (1955) also reported loss of incisors in Bitterroot goats. Bitterroot goats strip foliose and fruiticose lichens and mosses - high protein food items in winter - from rock surfaces with their incisors. Lost or severely worn incisors would reduce foraging efficiency on those plants and on fibrous herbaceous and woody vegetation as well (Smith 1976: 166).

MANAGEMENT IMPLICATIONS

1) The maximum age of both male and female mountain goats that died or were harvested in western Montana was 15.5 years. This is the oldest male and second oldest female reported in the literature. However, 10-11

years was the average natural longevity of adult goats. Based upon population classifications (Smith 1976) and age distribution of adults (Table 1), <10% of the population exceeded 10.5 years of age. In the absence of population-specific age data, modelers of goat populations might use 10-11 years as the average maximum longevity of mountain goats.

2) The mean age (6.0 years) of harvested goats was significantly less ($P<0.001$) than the mean age (10.8 years) of natural mortalities. Despite the goat's trophy status, hunters harvest animals considerably younger (including subadults) than the mean age of those succumbing to natural causes. The difficulty in distinguishing the age of goats ≥3 years of age (Smith 1986) renders all adults, male and female, of similar trophy value to many hunters. Thus, adult females entering or within their reproductive prime are as likely to be harvested as those that are nearing their natural life expectancy. This has important management implications because of the mountain goat's relatively low fecundity and limited sexual dimorphism upon which to predicate harvest restrictions. Minimum horn length restrictions to protect juveniles and regulations that discourage or prohibit harvest of females (supported by hunter orientation classes and/or literature) could improve management of goat populations.

Table 1. Incidence of broken or deformed horns among 123 mountain goats harvested in western Montana 1973-1978.

Age Group	Number (% of total) in age group		Number (% of age group) with broken horns	
	Male	Female	Male	Female
1.5 - 3.5	31 (37)	12 (30)	7 (23)	2 (17)
4.5 - 6.5	27 (33)	11 (28)	8 (30)	3 (27)
7.5 - 9.5	17 (20)	12 (30)	7 (41)	4 (33)
10.5 - 15.5	8 (10)	5 (13)	5 (63)	1 (20)
Total	83 (100)	40 (101)	27	10
		Average	(33)	(25)

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QUESTIONS AND ANSWERS

Joseph Hamr, Ontario: I was wondering if you considered the possibility that the incidence of broken horns in males was due to fighting with one another? Chamois very often poke one another and I was wondering if the same was true for goats?

Bruce Smith: I did consider that. The difference between chamois and mountain goats is that when mountain goats fight, they fight in an anti-parallel orientation to each other. They're generally hooking one another in the flanks or rumps and its very unusual in watching rutting behavior to see billies strike one another head to head, but they'll use their horns for defense against predators. Although, I couldn't be sure that broken horns were just due to falls and accidents, most of the information available on goats, including how they rut, would make me believe that its probably from some type of fall. We did see quite a few falls with goats.

REPRODUCTIVE SUCCESS OF SHEEP RIVER EWES: A PRELIMINARY REPORT

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Abstract: Information on the reproductive success of 82 individually marked adult bighorn ewes in the Sheep River herd in southwestern Alberta was obtained from April 1981 to February 1986. Location rate increased from 63% among 2-year-olds (N=38) to 100% among ewes of 5 to 9 years of age (N=42 ewes, 127 ewe-years), declining to 90% for older ewes (N=11 ewes, 21 ewe-years). The median lambing date of 2-year-old ewes in 1984 and 1985 (June 5, N = 14) was later than for older ewes (May 25, N=79). Survival to October of lambs born to 2-year-olds was 52% (N=23), compared to 76% (N=123) for lambs born to ewes between 5 and 9 years of age. Two-year-olds and ewes older than 9 appeared to produce an excess of male lambs (male:female ratio = 3.0) compared to other ewes (ratio = 0.88). With the limited sample available, it does not appear that reproduction at age 2 compromises future reproductive performance. However, pregnant 2-year-olds had greater ($P<0.05$) fecal output of lungworm larvae than barren ones, likely because of the energetic cost of gestation. Early reproduction may be an optimal strategy for ewes in good condition, but more data are required before a definite assessment of the advantages and disadvantages of early breeding can be made.

QUESTIONS AND ANSWERS

Wayne Heimer, Alaska: Marco, as I recall, the percent survival of lambs born to two and three year old ewes was about the same. Have you data on whether the lambs that perished, that had mothers three years old, were born to ewes that hd had lambs the year before or not?

Marco Festa-Bianchet: Yes, I do. When looked at by the sample sizes which are very small, I think there were nine of those lambs born to three year olds that were born to ewes that also bred as two year olds. I think four made it and five died. So more died than made it. I only had three lambs born to three year olds that were breeding for the first time. Two of those died and one survived. So you can't really say anything about it. One problem with three year olds is the fact that there was a strong three year old age class last year, and that was the year when a lot of lambs died. That might have had an affect on the overall data. So I looked for that, but I didn't have a large enough sample to really see anything.

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PRELIMINARY OBSERVATIONS ON POPULATION RESPONSES TO AN EXPANDING BIGHORN SHEEP HERD IN ALBERTA.

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Abstract: Population parameters were monitored for 15 years in a Rocky Mountain bighorn sheep (*Ovis canadensis*) population allowed to expand between 1981 and 1985. Prior to 1981, herd numbers were stabilized at approximately 100 by trophy ram hunting and experimental ewe removals. Pre-expansion years were characterized by high survival rates, high productivity, breeding in yearling ewes and rapid initial horn growth. By 1985, indications of decay in population quality were evident. Mean age became older with females comprising 60% of the population. Overwinter lamb survival decreased from an average of 85% between 1975-84 to 72% in 1984-85. Survival of older animals did not change significantly. The incidence of barren ewes increased to 15% in 1985 compared to a 7% average between 1976 and 1981. Although per capita productivity declined in 1985, the number of lambs increased due mostly to an increase in the ewe population. Lamb production from yearling ewes declined in the last 3 years, and annual horn increments of 1- and 2-year-old rams showed a decrease in length.

Characteristics of wildlife populations are commonly used to assess the health status of individual herds. Poor quality Rocky Mountain bighorn sheep (*Ovis canadensis*) are recognized by low lamb survival, low lamb production, small horn size, small body size and longer life expectancy while larger horns, larger body size, high fecundity, rapid growth and short life expectancy characterize expanding or high quality populations (Geist 1971). Changes in these attributes presumably are related to changes in range condition and would be expected to vary as the population reaches carrying capacity.

The nature of the Ram Mountain bighorn herd has afforded the opportunity to collect detailed accounts of its population characteristics and to follow these characteristics through an experimental manipulation of animal numbers. Between 1975 and 1981, population numbers were maintained at a stable level through annual ewe collections (Jorgenson and Wishart 1983). Ewe removals stopped in 1980. Trophy ram hunting continued . The purpose of this paper is to describe the characteristics of this herd during its "stable" years and during its increase. These are preliminary observations and further years of work are required to confirm any trends.

METHODS

A detailed description of the Ram Mountain study area was provided by Johnson (1975). The area is located in west central Alberta (52°25'N, 115°45'W) and forms part of the Brazeau mountain range.

Sheep were trapped during May to September in a corral trap baited with salt (Wishart et al. 1982). Rams ($\geq$1 year) were individually identified with numbered Allflex ear tags while color coded neck collars were placed on ewes (≥1 year old). Colored ear streamers were used to identify individual lambs. Horn measurements (length, base circumference and annual increments) were taken every two weeks if possible for each animal, however, capture frequency was highly variable. Lambs and rams (> 2 years old) were seldom captured more than once each year.

Population size was determined each year from reobservation of marked animals. The only unmarked animals present at the beginning of the summer were lambs but these could readily be counted by pairing with lactating ewes. By September, most lambs were already tagged. Any tagged animal not observed over a field season was assumed to have died the previous winter. The isolated nature of the sheep range reduced emigration and immigration to minimal levels. Animals (N=3) rarely reappeared on the study area after disappearing for a complete field season. Some migration to a small sheep range across the North Saskatchewan River has been documented, however, tagged rams on this area returned to the main study area if they are not harvested by hunters.

RESULTS

Population Size

Between 1975 and 1981, the population averaged 100 animals (range 94-108). With the cessation of ewe removals in 1980, this population had risen to 142 by 1985, an increase of about 31% over pre-expansion years. Density on the summer and winter range combined, had risen from 2.6 in 1975 to 3.6 animals/km² in 1985 (Fig. 1).

Population Structure

Following the last ewe removals in 1980, changes were monitored in the population structure. Comparisons were made in the population structure between years 1975-81 (1981 included, since manipulations made in 1980 influenced 1981's population) and 1982-85. The median age of the population (lambs excluded) in 1981 was 3 years compared with 4 years in 1985. The sex and age structure in 1981 and 1985 are compared in Fig. 2. The greatest age disparity was in the female cohort where the median ages in 1981 and 1985 were 3 and 4 years respectively (Fig. 2). The median age of the male cohort did not change.

Prior to 1982, young females (1-3 years) were the dominant component of the population in most years (Fig. 3). In 1979 they made up about 30% of the total population while older females comprised only 16%. Following the last year of ewe removals, older ewes had been further reduced to only 11% of the population. Four years later this percentage of older females had increased to 25% and they are now the major component. The percentage of younger females in the population has changed very little since 1982.

A considerable decline in the percentage of adult (4+ years) rams has taken place since 1978 (Fig. 3). Between 1975-78, adult rams constituted an annual average of about 24% of the herd, however since 1978 they have been reduced to an annual average of about 15%. The actual number of adult rams present however has not changed.

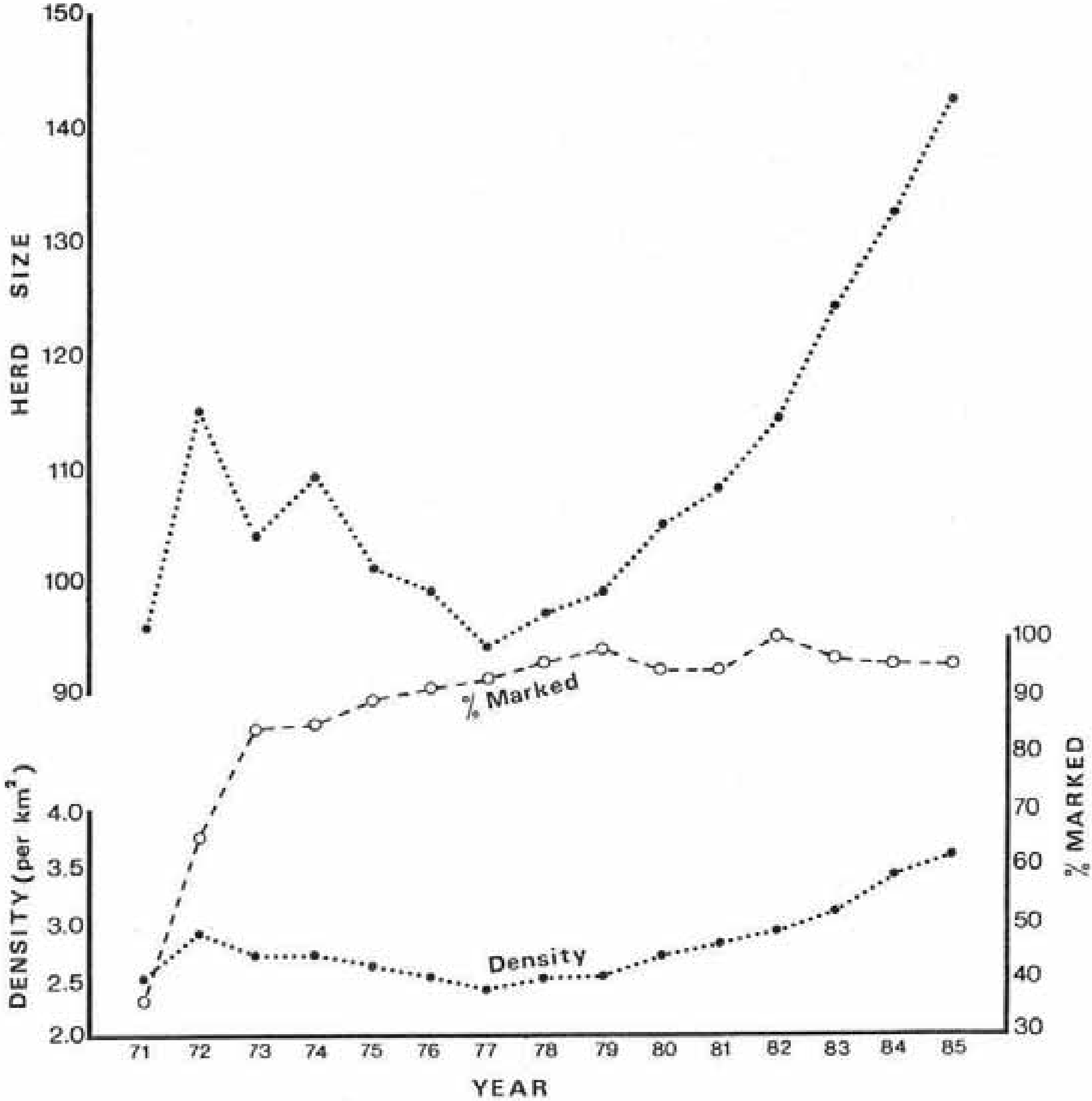

Fig. 1. Population status of the Ram Mountain bighorn herd, 1981-85.

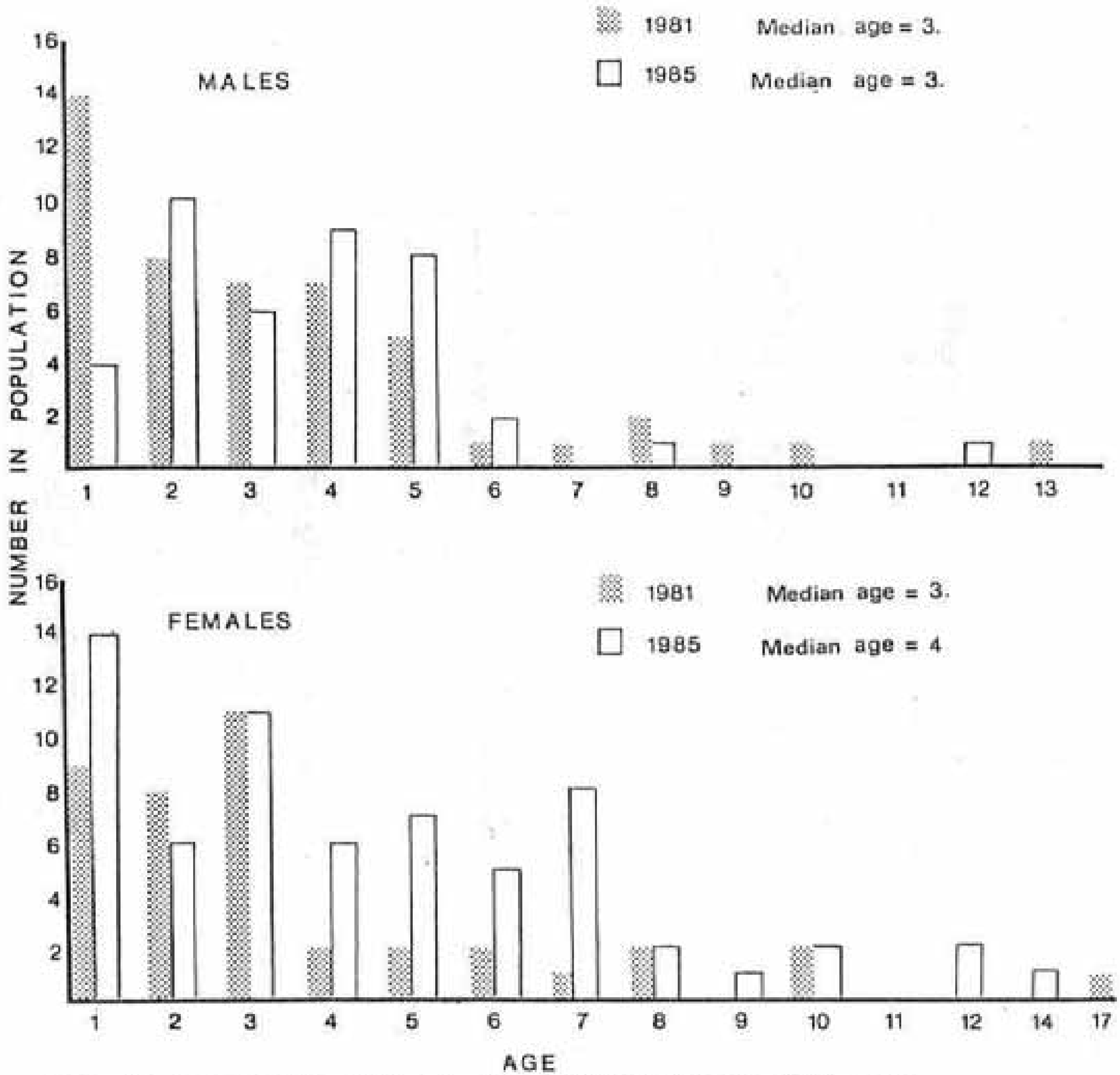

Fig. 2. Age structure of the Ram Mountain bighorn herd in 1981 and 1985.

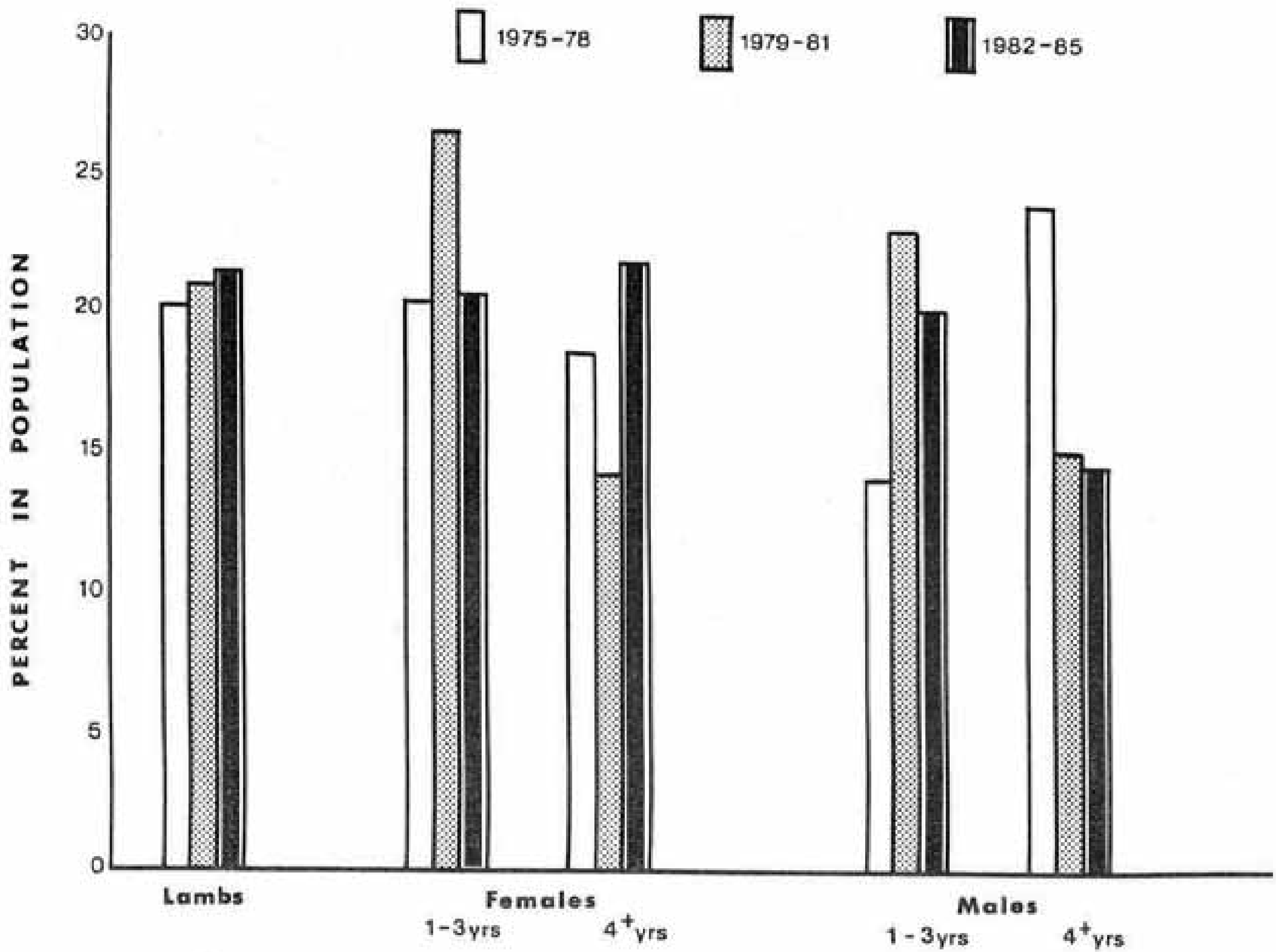

Fig. 3. Age structure of the Ram Mountain sheep population during 3 time periods, 1975-85 (1982-85 is period of population growth).

Survival

Survival rates as discussed here relate to natural mortality only and do not include losses due to hunting, ewe collections and trap-related accidents.

On an annual basis, older rams consistently experienced lower survival rates than young rams or ewes of any age group (except the 1976-77 winter) (Table 1). Although the population expanded from 108 in 1981 to 142 in 1985, combined survival rates for the two periods did not change significantly for any of the three major age groups of either sex (Table 1). Adult ram survival dropped from 83% in pre-expansion years to 68% for the period, 1981-85, however this difference was not statistically different (X^2 = 4.5, $\underline{P}$ > 0.05). Prior to 1984-85, annual overwinter lamb survival averaged 80% while in 1984-85 lamb survival was 72% but this was not a significant difference ($\underline{P}$ > 0.05). Male lamb survival was only 50% (N = 8) over the 1984-85 winter.

Table 1. Annual natural overwinter survival rates of bighorns from Ram Mountain (1975-85).

	Percent Survival				
	Lambs	Ewes		Rams	
Year	(M & F)	1-3 yrs	4+ yrs	1-3 yrs	4+ yrs
1975-76	60(20)[a]	100(15)	100(15)	94(16)	83(24)
1976-77	77(22)	94(18)	87(15)	73(15)	100(20)
1977-78	75(16)	96(23)	92(12)	89(9)	82(23)
1978-79	80(25)	100(23)	100(11)	100(12)	69(16)
1979-80	89(19)	100(22)	92(12)	91(22)	75(12)
1980-81	92(25)	95(22)	100(10)	100(22)	86(14)
Combined 1975-81	79(127)	97(123)	95(75)	92(96)	83(109)
1981-82	89(19)	92(27)	92(12)	72(29)	67(18)
1982-83	81(26)	100(20)	82(22)	96(28)	68(16)
1983-84	81(26)	89(27)	96(24)	80(30)	73(11)
1984-85	72(25)	92(25)	93(30)	89(28)	67(15)
Combined 1981-85	80(96)	93(99)	81(88)	84(115)	68(60)

[a] Sample size.

Lamb Production

Although a record number of lambs were produced in 1985, percent productivity (lambs observed:100 mature ewes) actually declined slightly compared to the 3 previous years (Table 2). During years of population stability, annual productivity fluctuated considerably and has been lower than that observed in 1985, therefore, the drop observed in 1985 may not necessarily indicate a trend toward lower productivity. Productivity reflects viable lambs only and does not consider those that die soon after parturition. Of the 10 adult ewes not producing lambs in 1985, 7 were barren (15.5% of total adult ewes) while the other 3 lost their lambs shortly after birth.

Table 2. Spring productivity of bighorn ewes on Ram Mountain (1971-85).

Year	Number of Lambs	Number of Reproductively mature ewes[a]	Lambs/ 100 ewes	Lambs/ 100 "ewes"[b]
1971	24	33	73	N/A
1972	24	38	63	N/A
1973	25	32	78	N/A
1974	15	36	42	25
1975	20	28(1)[c]	71	45
1976	22	25(1)	88	52
1977	16	27(5)	59	34
1978	25	28(7)	89	55
1979	19	28(0)	68	35
1980	26	31(9)	84	52
1981	20	27(4)	74	37
1982	26	32(3)	81	50
1983	26	31(0)	84	43
1984	31	37(1)	84	47
1985	36	46(1)	78	55
Mean	23.7	32	74	44

[a] Two-year-old ewes were included only if they were lactating.

[b] Includes all ewes and yearlings.

[c] Number of lactating 2-year-old ewes included.

Annual lactation rates better reflect actual productivity than the number of lambs observed. These values (Table 3) indicate a very high rate of breeding in adult ewes with only a few being barren each. In 1985, there were more barren ewes (7) present than in any previous year.

During aerial surveys, separation of yearlings (male and female) and non-productive 2-year-old ewes is difficult and usually not done. In order to compare productivity on Ram Mountain with other herds in which yearlings and 2-year-olds were not distinguished, production was also calculated as lambs per 100 "ewes". Although percent productivity fell in 1985, lambs per 100 "ewes" indicated an increase in productivity.

Rocky Mountain bighorn ewes normally do not breed until they reach 30 months of age (Geist 1971, Buechner 1960), but at Ram Mountain breeding has been recorded in ewes 18 months old. The annual incidence of yearling breeding based on lamb production at 24 months of age has varied from 0% (N = 6) in 1979 to 82% (N = 11) in 1980. In 1984 and 1985, only one 2-year-old ewe produced a lamb in each year. It appears that the frequency of yearling breeding has declined in the last 3 years when compared with the peak years, 1977-1982 (except 1979 when no yearling breeding was recorded).

Table 3. Annual lactation rates of adult (3+ years) ewes from Ram Mountain (1975-85).

Year	Percent Lactating	Number Barren
1975	81 (27)[a]	5
1976	91 (24)	2
1977	86 (22)	3
1978	95 (21)	1
1979	89 (28)	3
1980	95 (22)	1
1981	91 (23)	2
1982	96 (29)	1
1983	93 (31)	2
1984	94 (36)	2
1985	84 (45)	7

[a] Sample size.

Horn Growth

As a measure of realized horn growth, annual increment lengths of 1 and 2-year-old rams were compared between years. Significant differences were found between some years in both yearling ($F = 9.89$, $N = 8$, $\underline{P} < 0.001$) and 2-year-old rams ($F = 6.22$, $N = 8$, $\underline{P} < 0.001$). Average third increment lengths were less than second increments in all years except 1977 (Fig. 4). Generally, the same annual pattern of increment growth was observed for 1 and 2-year-old rams (except 1977 and 1979). The shortest and longest second increments were grown in 1982 and 1979 respectively (Fig. 4). Since 1981 there appears to be a trend developing towards shorter horn increments for yearling and 2-year-old rams.

Fecal Crude Protein Analysis

Significant fecal nitrogen relationships have been established with plant protein, protein intake, dry matter digestibility and body weight change (Hebert 1973). Fecal nitrogen values can conveniently be converted to crude protein and such fecal crude protein indices for plant protein intake have

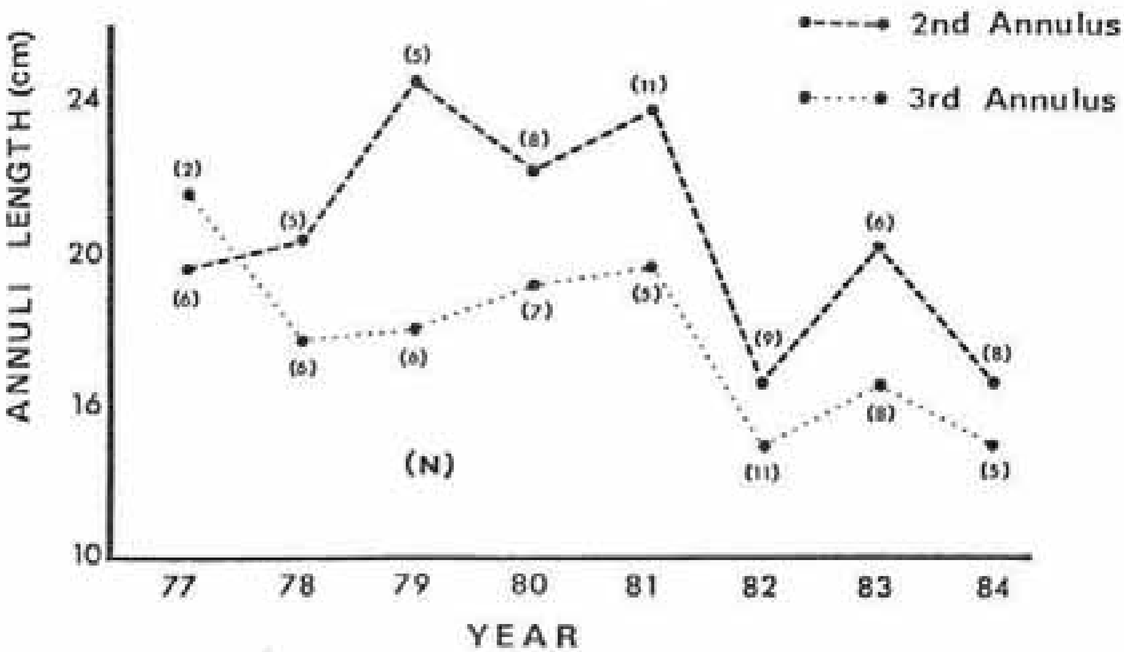

Fig. 4. Annual horn increments from yearling and 2-year-old rams (1977-85).

been established for the Ram Mountain bighorn herd. The annual cycle of fecal crude protein illustrates a typical spring rise in late May-early June followed by a slow steady decline until late November. Levels remain consistently low throughout the winter. In some years, a short fall green-up occurred. The greatest difference between years was in the timing and magnitude of the spring rise. In 1984 and 1985, the rise was later in the year and an overall depression in summer and fall values was noted when compared to previous levels (Fig. 5).

Lungworm Levels

Annual monitoring of fecal lungworm levels has continued since 1977. Larval outputs in 1984 and 1985 (1985 results only up until October) continued the cyclical pattern of high winter and low summer larval shedding observed over past years (Jorgenson and Wishart, 1983). Inter-annual comparison of larval output are best made from winter samples, since this is when output is at the maximum. Summer counts generally tend to be quite low (many negative samples) and often highly variable. Relative annual comparisons indicate a high increase in output in 1985 (Table 4). The 1985 count (median = 1328 larvae per gram of dry feces [LPG] was higher than from any previous year.

Table 4. Late winter larval output from bighorns on Ram Mountain (1977-85).

Year	$\bar{x}$ Larvae/gm[a]	Median	Range	N
1977	101	129	20-189	5
1978	1138	1232	170-2260	13
1979	694	569	293-1169	19
1980	565	543	49-1472	22
1981	670	596	26-1664	15
1982	912	847	366-1500	8
1983	917	731	311-1768	9
1984	802	631	46-2536	19
1985	1676	1328	314-5352	13

[a] The highest count during February, March or April.

DISCUSSION

Data collected in 1984 and 1985 field season indicate a decay in a number of parameters which could be used as measures of population quality of the Ram Mountain bighorn herd. These changes have arisen as the number of animals on the study area has increased. Since most of the evidence, pointing toward a decline was first observed in 1985, conclusions are preliminary and more years of data are required to confirm any trends.

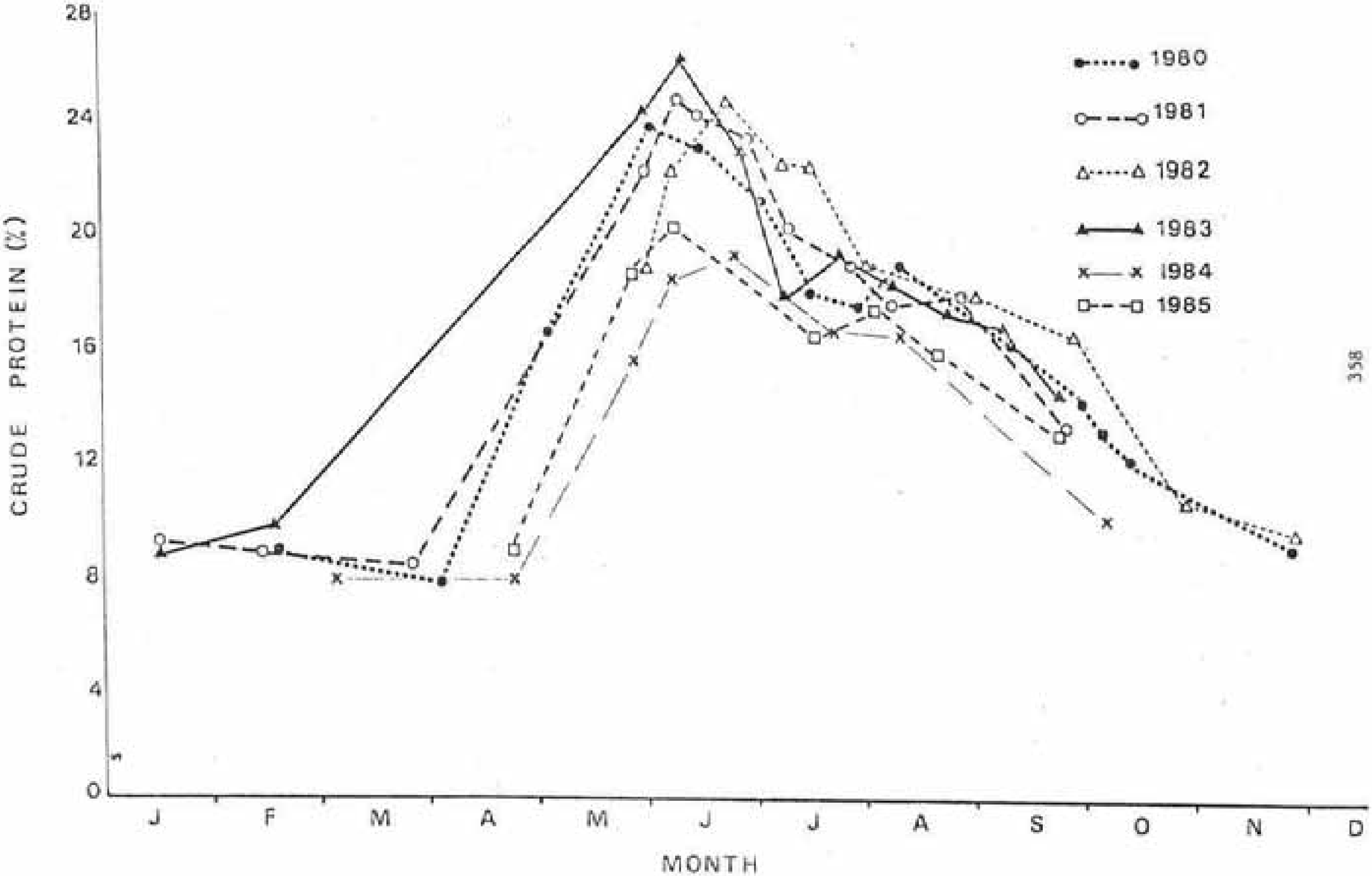

Fig. 5. Annual combined fecal crude protein values from Ram Mountain (1980-85).

Mortality Patterns

Overwinter mortality of lambs, particularly males, may have begun to increase as of 1984-85. Winter severity which directly effects juvenile survival and winter weight loss (Jorgenson and Wishart 1984) was relatively mild in 1984-85 and not considered a factor. High mortality among juvenile males relative to juvenile females has been noted for several mammal species (Trivers and Willard 1973, Clutton-Brock et al. 1982). The theories for such differential mortality range from expression of deleterious recessive alleles on the x chromosome (Myers 1978) to Trivers and Willards (1973) hypothesis that differential mortality occurs postnatally and is a reflection of parental investment.

Another theory suggested by Clutton-Brock, et al. (1984) and Myers (1978) is that higher mortality rates among male juveniles are a consequence of a greater susceptibility of males to food shortage associated with a faster growth rate and requirements for increased nutrition. As the population on Ram Mountain increases and food resources decrease, increased mortality of lambs, and in particular male lambs, would be expected. Mortality of lambs is predominantly winter related on Ram Mountain and while most growth takes place over the summer, lambs naturally gain some weight over winter (Jorgenson and Wishart 1984). Competition for food resources at that time would be of greater consequence than during the summer. Rate of summer weight gain is only slightly greater for (lamb and yearling) rams compared to ewes. It is not until age 2 that differential summer weight gain dramatically increases for rams (Jorgenson and Wishart 1984). Overwinter survival rates of adult ewes has not significantly changed with the increasing population but survival of adult rams has significantly decreased.

Changes in Age Structure

The Ram Mountain population has grown older due primarily to an increase in the number of older females. Previously, these older ewes were removed from the population to simulate a non-trophy hunting season. However, the greatest number of ewes actually harvested are generally from the 2.5-3.5 year age groups (Alberta Fish and Wildlife hunter statistics) with lambs generally making up less than 10% of the total kill. The effect has been to preserve an older age structure in the ewe population.

The ram age structure at Ram Mountain has not changed greatly with the increasing population. Trophy ram harvests and the continued low survival of rams when compared to ewes prevent this segment of the population from getting any older. The differential mortality rate between rams and ewes has also resulted in a sex ratio strongly biased toward females. With ewes no longer being removed from the population, the bias becomes even greater. Clutton-Brock (1982) obtained similar results with red deer.

Productivity

With the increasing population density, a decline in productivity, as measured by lactation rates, was noted in 1985. It was necessary to distinguish lactation from percent productivity because percent productivity takes into account neonatal mortality which was highly variable between years. An increase in the number of barren females with increasing density has also been observed in red deer (Clutton-Brock 1982, Staines 1978), Himalyan tahr (Caughley 1970), white-tailed deer (Marburger and Thomas 1965), and African buffalo (Sinclair 1977). Since the changes in productivity at Ram Mountain are small and not statistically significant, more years of data are required. Studies in red deer (Mitchell and Brown 1974), domestic sheep (Drymundson 1973), Peary caribou (Thomas 1982), and moose (Saether and Haagenrud 1983) have related fecundity to body condition weight. If fecal crude protein is a good measure of relative forage quality (Hebert 1973, Seip 1983), the results from 1984 and 1985 indicate a decline in the quality of forage on Ram Mountain which could lower the condition of breeding ewes and reduce productivity.

Though actual productivity showed a decline in 1985, the lambs per 100 "ewe" ratio indicated an increase. The reason for this was the relatively low number of yearlings and 2-year-old ewes present in 1985 which, when included in the ewe component brought the lamb:100 "ewe" ratio up when compared to 1984. This gave the false impression of improved productivity in 1985. Generally yearlings and 2-year-olds are non-producers, but distinctions between yearlings (males and females) and 2-year-old ewes are not made during aerial surveys and most of the literature reports productivity in bighorn sheep as lambs per 100 "ewes". Caution must, therefore, be used when interpreting lamb production recorded in this fashion.

Annual Horn Growth Patterns

Studies on red deer and other cervids have demonstrated a negative relationship between antler growth and population density (Clutton-Brock 1982). Food shortages can also have marked negative effect on antler growth (Roseberry and Klimstra 1974, McCullough 1979). Food shortage and high density are interrelated. As the bighorn population has risen on Ram Mountain, second and third annual increments have shown a decrease in length over the last 3 years. Since increment growth would depend both on seasonal horn growth rate and the length of the growing season, changes in annuli length could reflect differences in those variables rather than any variable associated with increasing population density. One would expect declining forage resources to negatively impact horn growth rates more than growing season, however, growing season could be affected if energy supplies were directed away from horn growth at an earlier date. Allocation of food resources towards such a low growth priority item as horn growth could occur later than normal and end earlier than when supplies were more abundant.

Lungworm Levels

The high larval outputs in late winter infers that either reproductive activity of adult lungworms was at a peak or that large numbers of larvae stored in the lungs were suddenly released. Sheep are in their poorest body condition in late winter and the body's defense mechanism would be operating at less than optimal performance. At that time lungworm activity could peak and large numbers of larvae would be shed in the feces. Presumably, the poorer the condition, the higher the winter larval output. A combination of wet springs promoting an increase in the snail intermediate host population and hard winters should produce very high larval outputs.

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QUESTIONS AND ANSWERS

Wayne Heimer, Alaska: I would just like to make an apology and comment, more so than asking a question, it might lead to a question. Your comments on the shape of the mortality curve for rams, its my impression that there is a fair amount of data from desert bighorns and Stone sheep and other things that seem to fit the interpretation of Mary's data rather well. And going along with that, if the age structure of the rams on Ram Mountain is such that the older rams are about five years old, our conclusion would be that the population had been pretty well smoked, and you could expect this higher mortality of juveniles. That seems in our work to have gone along with the removal of the old age class of rams. I don't know that I'd ask you to respond to that, its a comment I'd like to make. The other thing I need to say and that is if Tom Thorne isn't going to do this, I have to make an apology for ever bringing up this idea of alternate year reproduction. Two years ago Thorne made me take that back and I did. I've written several times that this was a distraction and a mistake, and we probably shouldn't be paying too much attention to it. Out technique was biased. We were emphasizing alternate year reproduction and the way we gathered our consecutive year reproductive frequency stuff suffered. For that reason we've stopped looking at alternate year breeding as a phenomenon and have concentrated on consecutive year reproductive success, which is influenced by a number of things, weather being at least one. I talked about that the other day, but I don't want Tom Thorne to be jumping on my case because people are still saying alternate year breeding when he made me straighten that out a couple years ago. Is that right, Tom?

Tom Thorne, Wyoming: Its just fine. OK I won't comment on the alternate year breeding. As far as the ram portion of it goes, I believe in your Dry Creek herd you're removing all of your older rams or most of them anyway. At Ram Mountain, hunters are not taking all that are available. There's still a good 50% of the older rams that are left up there. Now the lack of older rams is influencing the survival of these younger rams, that kind of situation is only going to happen when you're cropping all your old rams. There's still 4 - 5 mature rams, that are five years old and older that are there every year so that's effecting the survival of the juveniles. Old rams have got to be older than 5 - 6 years of age or else there needs to be more of these older rams than we have got.

Heimer: We don't know what the cropping rate is exactly, but we figure its something over 50% and probably approaching 75%. That doesn't allow for very many actually mature rams in our situation. There's some out there, and if I've mislead you on that I apologize also. We think, a Dall and bighorn sheep differ. If you're considering a five year old Dall ram mature, you're probably making a mistake. I don't know what it would be with bighorn.

Thorne: That does probably apply for Dall sheep. Bighorn rams just don't live very long. By the time ten years of age rolls around, there aren't any rams left. Now in the next few years I'd really like to look at this ram mortality business and try to determine what's happening to these rams. We're definitely losing them. They just disappear. One thing that might be happening is that there could be wounding and crippling losses occurring during the hunting season. It doesn't have to amount to very many rams in order to give me this kind of survivorship curve. I've seen instances of wounding, and I see hunters shoot rams and the ram staggers off into the trees and bush or down onto a piece of cliff. Hunters have no idea where he's gone and that ram is found a couple days later by somebody else. I've also seen hunters flock shooting at groups of rams. The odds on some kind of wounding going on in situations like that is pretty high, and it might just be possible that that kind of loss of rams is higher than we expected or we've ever thought it might be. That's something that needs a lot more looking into and hopefully I can do that in the next few years because I'd really like to try to resolve this issue and find out what's happening to these rams.

Jon Jorgenson: We've come to look more at the socials trends involved with young ram participation as a predisposing factor to predation. There are changes that hopefully will be apparent when you see our paper in print. The predator control had quite on influence on survival of rams and didn't make that much difference for ewes.

Thorne: I can't comment on that. I don't know what sort of predation levels are going on in some of these individuals. John?

John Stelforth, Alberta: My question, Jon, deals with matter of horn growth in relation to population density. An interesting thing from your study indicates when you let the population go from 100 up towards 140-150 that certain unfavorable situation arise as far as decreased horn growth, increased lungworm output and what not. I'm just wondering about that population in relation to what you'd consider suitable or the likely carrying capacity of that range. You know Shakelton's work in Banff and Kootenai after the population declined about 75%, there were tremendous increases in horn growth related to that low population. Your information relating it to spring greenup, certainly has an influence, but I guess my main question and Bill might want to respond to this, is that from a management standpoint, what would happen if you brought this population down to say 60 or 80 animals, if the objective was to produce large trophy rams, you should get better annual growth rates on those rams from a smaller population. Their health should be better. Also, have you been thinking in terms of your long term objectives as far as the population size you want, and how you're going to be cropping those, and how that relates to your carrying capacity for that herd?

Jorgenson: Our plans right now are just to let the population go, at least a bit further, and keep monitoring these things. Last year was the first year we started getting any sort of indications that we might be getting a bit of a decline in the quality. Admittedly, we've only gone from a hundred animals to a hundred forty which isn't very much, only about 40%, but already we're starting to see a bit of a difference. Now as far as the horn growth goes, I showed that growth rates are still going up at Ram, yet the actual horn sizes were going down and that was related to this problem of length of the growing season. You can't regulate that at all. You might be able to do something about forage quality that might increase growth rates, but if you reduce your population, you'd expect that your quality should maintain when you've got a good early green up, and you've got a good chance to jump onto that horn growth then you're going to produce... you're going to lay down an increment during that year. As far as the carrying capacity at Ram Mountain goes, we maintained that population at about 100 animals representing a density of about 2.8 animals per square kilometer. At that 100 population level we feel that we were just below the carrying capacity or just below that maximum sustained yield level. We got our high lamb production, we got our good growth rates, we got our high survival rates, we got our yearlings producing. But there's other factors, like predation isn't that big a problem at Ram, and I haven't mentioned that much about winter as far as winter influences on these parameters go. We've had mild winters, nothing but mild winters in Alberta for the last 10 years. Now, how much of a factor would severe winters have on this? I suspect they'd have the greatest influence probably on survival rates and that big influence would probably influence it much greater at this high density level then it would when we maintained it at 100 animals.

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Bi-Level Analysis of Habitat Selection by Mountain Goats in Coastal Alaska

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ABSTRACT

Habitat selection by mountain goats (Oreamnos americanus) was studied on a 400 km^2 area in south coastal Alaska from 1981- 84 using radiotelemetry. Twenty marked goats were relocated a total of 1,052 times from fixed wing aircraft. Each relocation was assigned to a 2.6 ha grid cell on the study area for which elevation, aspect, slope, distance to cliff, vegetation type, and timber volume were measured. The same attributes were measured for a random sample of 1,526 grid cells. Analysis of availability vs. utilization were made at the level of selecting a home range from the overall ridge-and-valley complex and at the level of selecting winter habitat within the home range. At the level of selecting a home range, goats avoided lower elevations, slopes < 30° and commercial volume forest; generally included aspects in proportion to availability; and showed strong preference for areas within 0.4 km of cliffy terrain. Conversely, within the home range in winter, goats preferred lower elevations and commercial forest habitat, favored south aspects, and showed no preference for proximity of cliffs. Reasons for these seemingly contradictory results are discussed and the importance of bi-level analysis of selection is demonstrated. Implications for habitat selection studies and forest habitat management are identified.

INTRODUCTION

Numerous authors have published descriptive accounts of habitat types used by mountain goats throughout their native and introduced range (Klein 1953, Brandborg 1955, Hjeljord 1971, Chadwick 1973, Rideout 1974, Smith 1976, Kuck 1977, Hebert and Turnbull 1977, McFetridge 1977, Chadwick 1983). These reports provide information on the general character of terrain and vegetation used by goats. In more recent studies, most authors have attempted to assess availability of habitat features, as well as their use, to provide insight into the species' pattern of habitat selection (Thompson 1980, Adams and Bailey 1980, Foster 1982, Fox et al. 1982, Schoen and Kirchhoff 1982, Smith 1986). Fox (1983) conducted a thorough analysis of several hypotheses to explain the observed patterns. However, most previously reported studies have employed direct observational techniques, so results contain undetermined biases toward open habitat types where observability is high (Foster 1982).

In addition to observability bias, previous studies of mountain goat habitat selection may contain bias associated with arbitrary decisions as to habitat availability. Johnson (1980) demonstrated that researchers' decisions regarding what is considered "available" can have profound effects on the outcome of commonly-used analyses of preference. He also suggested that animals may make habitat selection decisions at more than one operative level.

In an attempt to avoid these biases, habitat selection by mountain goats in southcoastal Alaska was studied using radiotelemetry and a bi-level analysis of availability vs. use. Habitat preference was evaluated at the level of selecting a home range from the overall ridge-and-valley complex of the study area and at the level of selecting winter range within the overall home range.

STUDY AREA

The Upper Cleveland Peninsula (UCP), approximately 80 km north of Ketchikan, Alaska, was chosen as being typical of areas occupied by coastal mountain goats (Hebert and Turnbull 1977). Elevations range from sea level to over 1,500 m; topography is complex; steep, broken terrain predominates. Vegetation below 700 m is primarily old-growth forest of Western hemlock (*Tsuga* heterophylla), Sitka spruce (*Picea sitchensis*), and cedar (*Thuja plicata* and *Chamaecyparis nootkensis*) with sedge (*Carex* spp.) muskegs in poorly drained areas and alder (*Alnus rubra*) on steep slide zones. Above 700 m alpine heath/tundra areas are interspersed with rock, scree and limited permanent snow fields.

METHODS

Mountain goats were captured during July 1981 and 1982 using standard helicopter darting techniques (Schoen and Kirchhoff 1982) with 4 mg. of M-99 etorphine hydrochloride (Lemmon Co., Sellersville, Pa.). Captured goats were fitted with radio collars (Telonics, Mesa, Az.) and were relocated at approximately 7 day intervals from the air using twin 2-element Yagi antennae mounted on a Piper PA-18-150 Super Cub as described by Nichols (1982).

An independent grid overlay system was developed for the study area with a 10 x 10 matrix providing 100 grid cells per section on USGS topographic and USDA Forest Service timber type maps at the scale of 1:31,680. Each cell contained approximately 2.6 ha of land. This cell size was considered large enough to permit accurate mapping of goat radio-locations, yet fine enough to permit a single point sample of habitat attributes to describe the cell. Each time a goat was located, its position was recorded on a map as being within 1 grid cell identified by the coordinates of the southwest (lower left) corner.

Habitat features were determined for each occupied cell and for a 10% random sample (N = 1,526) of cells on the study area. Elevation, aspect, slope, and distance to the nearest cliff (i.e. area of measurable slope > 50°) were taken at the grid line intercepts on topographic maps. Vegetation type and timber volume were determined at the same point from standard USDA Forest Service forest cover maps. Details of methodology for habitat measurements are provided in Fox et al. (1982).

The procedure described by Marcum and Loftsgaarden (1980) using chi-squared and Bonferroni Z statistics (Neu et al. 1974) was used for statistical analyses. Individual confidence intervals were determined at the 98% level; the confidence level for the combined "family" of intervals was 90% for all features except vegetation type where the use of 6 categories resulted in an 88% overall confidence level.

For this study, elevations were grouped into 250 m categories. Aspects were grouped at Flats (i.e. no slope), North (including NW and NE), East and West combined, South (including SE and SW), and Ridgetop. Slope categories were 0-20°, 31 - 50°, 51 - 65°, and 66°+. Distance to cliffs was measured in 0.4 km units. Vegetation types were grouped as commercial forest, muskeg forest, subalpine forest, brush/slide, alpine, and rock/cliff. Standard Forest Service timber volume classes (0, <8, 8-20, etc. thousand board feet per acre (mbf/a)) were used.

For the 1st level of selection, minimum convex polygon home ranges for individual goats were plotted on the study area overlay, and habitat features within the home range were compared to those of the overall study area. Only those goats for which use-area curves had reached an asymtote, indicating complete mapping of the home range (Bekoff and Mech 1984), were included in analyses. "Availability" was based on data from the 10% random sample of grid intersection points on the study area. "Utilization" was based on a random sample of at least 75 points within goat's home range, or all points within the home range for goats with home ranges smaller than 1.9 km^2.

The 2nd analysis of availability vs. utilization was made at the home range level. The frequency distribution derived from the random points in the home range were considered "availability" data, and those from cells occupied by relocated goats were considered "utilization" data. Because the number of relocations during other seasons was limited, and in view of the importance of winter habitat to northern ungulates, only winter relocation cells were used in this analysis.

RESULTS

Twenty mountain goats (13 females, 7 males) were included in analyses for this study. Home ranges of the females averaged 11.7 km^2 (range 1.9 to 22.0 km^2), and those of males averaged 44.9 km^2 (range 5.1 to 90.1 km^2). Due to the limited sample size, results for the sexes were combined. Their selection of the habitat parameters was as follows.

ELEVATION

Chi-squared analyses revealed that 90% of the goats were selective ($P < 0.05$) with respect to elevation in establishing their home range on the study area (Table 1). Sixty-five percent of the goats were selective ($P < 0.05$) regarding use of elevation within the home range during winter (Table 1).

Bonferroni Z analysis indicated that of the 5 elevation classes, all goats avoided the 0-250 m zone in establishing their home ranges, but only 40% avoided this zone within their home range in winter (Table 2). In fact, 7% of the goats preferred this lowest elevation zone in winter.

These results indicate that although goats generally avoid lower elevation areas in the course of their annual movements, those areas below 500 m that do fall within a goat's home range may often be used, or even preferred, during winter months. The opposite is true of the highest 2 elevation categories.

The 750-1,000 m elevation zone was preferred by 45% of the goats and used proportionately by the other 55% in selecting their home ranges, but the majority (65%) of goats avoided this zone in winter (Table 2). The 1000 m elevation zone was also preferred or used proportionately by most goats (65% overall) in establishing their home ranges, but 57% of the goats avoided these areas within their home range during winter (Table 2).

This analysis of use of elevation zones demonstrates that goats may be making habitat selection decisions at 2 levels. At the primary level, they elect to utilize areas on a year-round basis which represents preference for higher

Table 1. Percent of mountain goats ($N = 20$) demonstrating significant ($P < 0.05$) selection with respect to 5 habitat features in establishing home ranges (HR) on the Upper Cleveland Peninsula (UCP) study area and in utilization of winter range (WR) within the home range based on Chi-squared analyses of random points and radiolocations, 1981-84.

Comparison	Elevation	Aspect	Slope	Distance to Cliff	Vegetation Type	Timber Volume
HR vs. UCP[a]	90	90	70	95	95	75
WR vs. HR[b]	65	45	75	10	45	55

[a] Analyses based on comparison of frequency distributions of measurements at >75 random points within a goat's home range and 1,526 random points on the UCP.

[b] Analyses based on comparison of frequency distributions of measured values at November-March relocations for each goat ($N = 10$ to 31) with 75 random points within the goat's home range.

Table 2. Percentage of mountain goats (N = 20) showing preference (+) proportional use (0) and avoidance (-) of elevational zones in selecting year-round home range areas (HR) on the Upper Cleveland Peninsula, Alaska (UCP) study area and in selecting winter ranges (WR) within their home range, 1981-84.

	ELEVATION									
	0 - 250 m		250 -500 m		500 - 750 m		750 - 1000 m		1000 m	
	HR vs. UCP	WR vs. HR[a]	HR vs. UCP	HR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR[b]
+	0	7	0	15	20	20	45	5	20	0
0	5	53	45	80	80	75	55	30	45	43
-	95	40	55	5	0	5	0	65	35	57

[a] N = 15 Sample size reduced as this zone did not occur within each goat's home range.
[b] N = 14 Sample size reduced as this zone did not occur within each goat's home range.

Table 3. Percentage of mountain goats (N = 20) showing preference (+), proportional use (0) and avoidance (-) of aspects in selecting year-round home range (HR) areas on the Upper Cleveland Peninsula, Alaska (UCP) study area and in selecting winter ranges (WR) within their home range, 1981-84.

	Aspect									
	NW/N/NE		E/W		SE/S/SW		Flat		Ridgetop	
	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR[a]	HR vs. UCP	WR vs. HR
+	20	5	5	0	20	55	5	0	0	0
0	75	50	75	80	70	45	25	50	100	90
-	5	45	20	20	10	0	70	50	0	10

[a] N = 16; Flat terrain did not occur within 4 home ranges.

elevations than are generally available in the ridge-and-valley complexes which they occupy. During the critical winter period, however, their selection is reversed and they demonstrate preference for the lower elevation portions of their home range. This dichotomous pattern is also evident with respects to other habitat features.

ASPECT

Chi-squared analyses revealed that 90% of the goats were selective ($P < 0.05$) with respect to aspect in establishing their home ranges on the study area, but less than half were selective regarding use of aspect within their home range during winter (Table 1).

Bonferroni Z analysis indicated that at the level of selecting a home range from the UCP study area most ($\geq$ 70%) of the goats included proportional amounts of all slope aspects and ridgetops, but strongly avoided flats (Table 3). Within their home ranges during winter, however, there was a distinct preference for south-facing slopes and 45% of the goats avoided northerly aspects (Table 3).

SLOPE

Seventy percent of the goats were selective ($P < 0.05$) with respect to inclusion of various slope angles in their home ranges and 75% were selective regarding use of slopes within their home ranges during winter (Table 1). Bonferroni Z analyses revealed that 50% of the goats avoided slopes of less than 20° (Table 4). Most ($\geq$ 75%) of the goats included proportionate amounts of steeper slopes in their home range (Table 4).

Winter relocations compared to availability within the home range indicated even more pronounced selection in favor of steep (>30°) slopes (Table 4). For example, even though half of the goats had already avoided slopes of less than 20° in establishing their home range, all goats except 2 females (which used these slopes proportionately) were found to have further avoided what small amount of this low slope angle did occur within the home range during winter. In addition, 60% of the goats avoided the 21-30° slopes and 70% preferred slopes of 31-50° in winter (Table 4). Use of the steepest category was also more pronounced in winter (Table 4).

DISTANCE TO CLIFFS

All goats except 1 male were selective ($P < 0.05$) with respect to distance to cliffs in establishing their home range on the study area (Table 1). Conversely, only 1 goat of each sex was selective regarding distance to cliffs within their home range during winter. This seemingly

Table 4. Percentage of mountain goats (N = 20) showing preference (+), proportional use (0) and avoidance (-) of slope categories in selecting year-round home range (HR) areas on the Upper Cleveland Peninsula, Alaska (UCP) study area and in selecting winter ranges within their home ranges, 1981-84.

	Slope Category									
	0 - 20°		21 - 30°		31 - 50°		51 - 65°		66°	
	HR vs. UCP	WR vs. UCP	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR[a]
+	5	0	0	0	20	70	5	15	0	6
0	45	10	100	40	75	30	95	75	85	94
-	50	90	0	60	5	0	0	10	15	0

[a] N = 17; Slopes over 66° were not available in 3 home ranges.

Table 5. Percentage of mountain goats (N = 20) showing preference (+), proportional use (0) and avoidance (-) of areas at various distances to cliffs in selecting year-round home range (HR) areas on the Upper Cleveland Peninsula, Alaska (UCP) study area, and in selecting winter range (WR) within their home range, 1981-84.

	Distance To Cliffs									
	< 0.4 km		0.4 - 0.8 km		0.8 - 1.2 km		1.2 - 1.6 km		>1.6 km	
	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	WR vs. UCP	WR vs. HR[a]	WR vs. UCP	WR vs. HR[b]	HR vs. UCP	WR vs. HR[c]
+	80	40	5	0	0	8	0	0	0	0
0	20	60	35	60	15	77	15	75	5	0
-	0	0	60	40	85	15	85	25	95	100

[a] N = 13 No area over 0.8 km from a cliff occurs within other home ranges.
[b] N = 4 No area over 1.2 km from a cliff occurs within other home ranges.
[c] N = 1 No area over 1.6 km from a cliff occurs within other home ranges.

counter-intuitive lack of selection in winter is merely an artifact of radical selection at the home range level. Virtually all goats spend their entire lives within 0.4 km of cliffy terrain so their home ranges consist almost completely of cliffs and nearby slopes. Since only 1 distance to cliff dominates the home range, it is impossible for goats to be selective. The exceptions to this pattern in this study, male No. 26 and female No. 29, had the largest home ranges for goats of their sex (90.1 and 22.0 km^2, respectively) thus enabling them to select from an array of categories within their home ranges during the winter.

Bonferroni Z analysis (Table 5) supports the foregoing explanation. In selecting a home range, 80% of the goats preferred areas less than 0.4 km from cliffs and at least 85% avoided areas over 0.8 km from cliffs. Conversely, only 40% were found to prefer areas within 0.4 km of a cliff in the hone range during winter, and fewer than 30% avoided areas over 0.8 km from cliffs.

VEGETATION TYPES

All goats except 1 female were selective ($P < 0.05$) with respect to inclusion of various vegetation types in their home range on the study area (Table 1). However, less than half were selective regarding use of vegetation types within their home range during winter (Table 1).

Selection of vegetation type parallels selection for elevation. In establishing their home ranges, goats more often avoided commercial old-growth and muskeg forest (i.e., lower elevations) and used subalpine, alpine, and brush/slide areas (i.e., higher elevations) proportionately (Table 6). Conversely, in winter the open subalpine, alpine, and brush/slide types were less preferred or even avoided, while preference for commercial old-growth forest was increased (Table 6).

TIMBER VOLUME

Seventy-five percent of the goats were selective ($P < 0.05$) with respect to inclusion of various timber volume classes in their home range on the study area (Table 1). However, only 55% were found to use timber volumes selectively within their home range during winter.

Bonferroni Z analysis indicated that nonforested areas were used proportionately by 55% of the goats, preferred by 40% and avoided by only 5% in establishing their home ranges (Table 7). However, within the home range during winter, 75% of the goats avoided nonforested areas, and none preferred nonforested habitat during winter.

Table 6. Percentage of mountain goats (N = 20) showing preference (+), proportional use (0) and avoidance (-) of vegetation types in selecting year-round home range (HR) areas on the Upper Cleveland Peninsula, Alaska (UCP) study area, and in selecting winter range within their home ranges, 1981-84.

	Vegetation Type									
	Old-growth forest		Muskeg forest		Subalpine forest		Brush/slide		Alpine	
	HR vs. UCP	WR vs. HR	Hr. vs. UCP	WR vs. UCP[a]	HR vs. UCP	WR vs. HR	HR. vs. UCP	WR vs. HR[b]	HR vs. UCP	WR vs. HR[c]
+	5	35	5	6	20	0	10	0	35	0
0	55	65	25	75	80	85	75	78	35	36
-	40	0	70	19	0	15	15	22	30	64

[a] N = 16; Muskeg forest did not occur in other home ranges.
[b] N = 18; Brush/slide did not occur in other home ranges.
[c] N = 14; Alpine did not occur in other home ranges.

Table 7. Percentage of mountain goats (N = 20) showing preference (+), proportional use (0) and avoidance (-) of timber volume classes in selecting year-round home range (HR) areas on the Upper Cleveland Peninsula, Alaska (UCP) study area, and in selecting winter range (WR) within their home ranges, 1981-84.

	Timber Volume Class									
	Nonforested		<8 mbf/a		8-20 mbf/a		21-30 mbf/a		30+ mbf/a	
	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs. HR	HR vs. UCP	WR vs HR[a]
+	40	0	10	5	0	5	0	30	0	8
0	55	25	60	90	45	95	45	70	50	84
-	5	75	30	5	55	0	55	0	50	8

[a] N = 12; 30+mbf/acre did not occur in other home ranges.

While noncommercial forest lands were also used proportionately by over half (60%) of the goats, only 10% preferred these stands and 30% avoided them in establishing their home range (Table 7). Within the home range during winter, only 5% of the goats either preferred or avoided noncommercial forest, and 90% used these stands proportionately.

All 3 commercial-volume timber categories were avoided by 50% to 55% of the goats, and were preferred by none in establishing their home ranges (Table 7). Conversely, no goats avoided 8-20 or 21-30 mbf/acre timber, and only 1 goat avoided 30+ mbf/acre stands, within their home range during winter. Thirty percent of the goats preferred 21-30 mbf/acre stands at this time.

Thus, as was shown for other habitat features, goats appear to be making selection decisions regarding timber volume at more than 1 level. Lower-elevation, commercial-volume forests are generally avoided in establishing the home range, but those stands of commercial volume timber that do occur within the home range are highly preferred during winter.

DISCUSSION

The criteria an animal uses in determining its overall home range may be quite different from those it uses in making decisions regarding seasonal or day-to-day activity areas. The degree of difference between the 2 operative levels should reflect, among other things, the variability of seasonal weather and the degree of heterogeneity of habitat types within the species' range.

By examining habitat selection at two different levels it may be possible to reduce bias associated with arbitrary decisions regarding availability. This approach should produce results which are more realistic in biological terms and provide insights into habitat selection that otherwise might not be revealed.

In this study, at the level of selecting a home range, mountain goats were found to prefer areas at high elevations with generally steep slopes, spent most of their time in close proximity to cliffs and avoided commercial forest stands. This would be expected based on the general model of goat habitat selection (Schaller 1977, Chadwick 1983, Fox 1983). However, analyses at the level of selecting winter habitat within the home range revealed that during the critical winter months, goats made preferential use of the lower elevation portions of their home ranges including commercial forest cover.

Without the partitioning applied here, it is likely that evaluation of availability vs. use of timber volume by goats in winter would have indicated that goats avoid commercial timber stands. This might lead resource managers to conclude that timber harvesting will not adversely affect goat habitat. However, results presented here and elsewhere (Schoen and Kirchhoff 1982, Fox et al. 1982, Fox 1983, Smith 1986) clearly indicate that certain commercial forest stands are highly preferred by coastal mountain goats in winter. Given the nature of winter weather in this region with abundant, high density snowfall, and the effect of weather on goat population dynamics (Smith 1984), it is not surprising that old-growth forest is a critical component of winter range for coastal mountain goats. Thus, land use planning decisions must reflect the need to protect these areas to maintain goat populations.

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QUESTIONS AND ANSWERS

Questions not recorded regarding old growth forest and mountain goat winter survival.

Scott Brainard presented this paper for Christian Smith

Scott Brainard: Well, when I worked for Chris we did some helicopter surveys, so we had the chance to get down on the ground and collected pellets and looked at goat feed. We found they were eating the branches off of cedar hemlock, its been five years now. I don't think goats forage on these trees to the extent that its damaging the timber, but they do utilize those commercially important species to subsist. We had a goat that was wintering almost 3,000 feet elevation in southeast Alaska. He stuck out the whole winter in a place that was so desolate you couldn't believe it, and he was subsisting in an area where there was no understory, nothing but cedar. He was eating cedar. I don't know if Chris has presented this in the other papers or not. I don't want to get a little ahead of his game, but, yes, we did find that goats ate cedar but as far as damage to old growth forest, I don't think there's a problem.

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FOOD HABITS AND HABITAT USE OF PUTORAN SNOW SHEEP, (OVIS NIVICOLA BOREALIS).

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Abstract: Data from the central Putoran Plateau during May-June 1983 are presented along with data from other researchers. Food habits were determined from analysis of rumen contents and feeding sites. In May-June, graminaceous plants and lichens were the predominant forages and comprised 70 and 20-25% of the diet, respectively. The diets of males and females differed due to vegetational availability differences related to differential habitat use. Following green-up, legumes became the preferred forage. During late summer and early fall, snow sheep used a wide variety of forage plants. As the season progressed, cured forages again became dominant. The proportion of the winter diet made up by lichens was inversely related to the amount of grasses and reflected the declining forage quality of grasses during the winter. Snow sheep feeding sites during May-June were usually on the south slopes and therefore snow-free. When snow was present, sheep fed by pawing through the snow and occasionally digging into the soil to uncover roots and rhizomes. The actual manner of feeding is described.

Various authors have reported on different aspects of snow sheep ecology (Michurin and Mironenko 1966, Pavlov 1977, Borzhonov et. al. 1979, Larin 1983, Fedosenko 1985). Despite that, knowledge of Putoran snow sheep (Ovis nivicola borealis), habitat use and food habits are limited.

In general, females occupy the upper parts of the slopes during and in the first weeks following lambing. Males use the lower slopes and high river terraces at this time. During green-up, females occupy the entire slope.

Larin (1983) observed that females with lambs and subadults occupy sites within the 900 to 1100m zone during summer and early autumn. The animals feed on mountain tundras in close proximity to rocky outcrops which are used as escape cover and protection from foul weather. Adult males occurred at elevations above 1400m at that time.

Winter habitat use data are very limited. Borozhonov (1979) found tracks and feeding sites on lower slopes in dense larch forests in the middle fork of the Kholokit River.

The purpose of this report is to describe the food habitats and habitat use during May-June 1983 in the Central part of the Putoran Plateau and to bring together the results of other similar studies.

STUDY AREA

The Putoran Plateau is situated in the southern part of the Taimyr Peninsula. The boundary of the plateau is dissected by narrow canyon-like gorges with steep rocky slopes. The primary study area was in the central part of the plateau near Ayan lake.

Snow sheep occur here as small, scattered bands the occurrence of which is determined by the distribution and availability of those steep, rocky slopes.

RESULTS

Food Habits

Food habits of Putoran snow sheep were determined from examination of rumen contents and sheep feeding site analysis (Fedosenko et. al. 1985, Michurin and Mironenko 1966, and Larin 1983). A list of the various foods consumed is given in Table 1.

Cured grasses and sedges and lichens were the most important foods in rumen samples of males in early May, comprising 70 and 20-25% of the rumen contents, respectively. Cottongrass and sedges were the predominant graminaceous foods. Cladonia and Cetraria were the more important lichens. Shrubs and mosses were relatively unimportant, 4-5% by volume of rumen contents.

Examination of feeding sites of males in early May showed similar trends. Important grasses were Cobresia simplicuscula, Festuca rubra, Trisetum spicatum, Luzula sp., and Carex rupescens. Lichens included Cladonia deformis, Thamnolia vermiculatus, and Stereocaulon alpinum. The main forbs in the diet were Silene pauciflora, Oxytropis spp., and, rarely, Arnica iljinii. Oxytropis was eaten by digging the roots along road cuts.

The food habits of male and female snow sheep in early May were quite different, reflecting availability based on differences in habitat use. Because males occupy the lower slopes near or in the forest border, lichens played a more important role in their diet.

Snow sheep food habits change markedly with green-up in early June and leguminous species, especially Astragulus and Oxtropis, were favored. During summer and early fall, a wide variety of graminaceous plants, forbs, and shrubs were used (Table 1). Lichens and green mosses were lightly used during that period.

Cured grasses, sedges and cereals predominated in the rumen contents of a male killed in early September (54.5%) (Larin 1983). Forbs and shrubs comprised 33 and 10%, respectively, of the rumen contents. Lichens, mosses and fall green-up were relatively unimportant.

The rumen contents of two males, killed in November, were examined (Michurin and Mironenko 1966). Over 80% of the diet was cured forages. Shrubs, shrub willow, birch and lapland willow comprised 10% of the diet, and 5% of the diet were lichens.

Salt licks were used in spring and summer.

Feeding Behavior

The pattern of feeding varied seasonally and females generally spent more time feeding than males. In early May and June, snow sheep fed throughout the day with feeding periods alternating with rest periods. Initially, about 2/3 of the time is spent feeding and 1/3 is spent resting. As the season progressed, the relative amount of time spent feeding decreased, although they always spent more time feeding than resting.

Table 1. Food Habits of Putoran snow sheep (various authors).

Food	May R S[1]	May F S[3]	4	Sept R S[5]	Nov R S[6]
Grass/Sedges	47%			54.5%	85%
Grasses				31.4%	
Eriophorium spp.	xx[2]				
Cobresia simplicuscula		xx			
Festuca rubra		xx			
Hierochloe alpina			xx		
Poa spp.			xx		
Trisetum spicatum		xx			
Sedges/Rushes				22.0%	
Carex rupescens		xx			
C. spefuscidula			xx		
Lazulu spp.		tr			
Forbs	tr			33.0%	
Arnica iljinii		xx			
Astragulus spp.					xx
Drias octopetela			xx		
Hedysarum spp.					xx
Oxytropis nigrescens			xx		
Oxytropis spp.		xx			
Pachypleurum spp.					xx
Polygonum bistorta			xx		
Silene pauciflora		xx			
Trees/Shrubs	4-5%			10.0%	10%
Betula nana			xx		xx
Cassiope tetragona			xx		xx
D. punctata					xx
Salix polaris			xx		
S. pulchra			xx		
S. spp.					xx
Vaccinium uliginosum			xx		xx
Cowberries					xx
Lichens	35%			2.4%	5%
Alectoria nigricans			xx		
Cetraria nivalis			xx		
C. cacullata			xx		
C. spp.	7-9%				
Cladonia arbusus			xx		
C. deformis		xx			
C. spp.	25%				
Parmelia spp.	tr				
Peltigera aphtosa			xx		
P. spp.	tr				
Stereocaulon alpinum		xx			
Thamnolia vermiculatis		xx			
Green Mosses				1.1%	
Aulacomnium turgidum			xx		
Hylocomium splendens			xx		

*1 Early May rumen samples, Fedosenko et. al. 1985.
*2 xx = occurred in diet, no frequency/volume implied
*3 Early May feeding site analysis, Fedosenko et. al. 1985.
*4 Late summer-early fall, Larin 1983.
*5 September rumen samples, Larin 1983.
*6 November rumen samples, Michurin and Mironenko 1966.

The manner of feeding was similar to that of the Siberian ibex (Fedosenko 1983). Prior to green-up, sheep fed in a small area. After green-up, they used the whole slope while feeding.

Snow was usually absent from the feeding sites in May-June. When it did occur, sheep were forced to dig for food, which they did by pawing with the forelegs. Females usually dug without raising their muzzle and generally pawed 2-9 times between bites (x=3.5). The animals rake snow rather intensively for an average of 30 seconds per period. The diggings of two adult males were 22 to 28 cm deep and covered areas of 30x50 and 100x250 cm. Different foods were found in each hole.

From early May on, as the soils thaw, sheep, especially males, dug for roots and rhizomes. Four to 7 strokes (one serial) were made between bites and two males were observed to make 9 and 13 serials, respectively, in 6 minutes.

Seasonal nutrition varied from fall and winter to spring, especially for males. The decrease in use of cured grasses and the resultant increase in use of lichens reflected the declining nutritional quality of the graminaceous plants. Putoran snow sheep nutritional characteristics were similar to those of Yakut and Chucotka snow sheep (Egorov 1965 and Zhelezhov 1981) which switch from Icelandic moss to lichens. Only on Koryak is the role of lichens felt to be unimportant (Chernyaviski 1963).

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ANIMAL CONDITION-A COMPARISON OF FECAL NITROGEN AND DIAMINOPIMELIC ACID

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ABSTRACT:
Fecal nitrogen (N) was initially used to determine condition in domestic animals and more recently has been used for bighorn sheep, deer, elk and moose. Mould & Robbins (1981) indicated that ingested phenolics significantly increased fecal N excretion and Nelson et al (1972) suggested that diaminopimelic acid (DAPA) may be used instead of fecal N as an indicator of digestible energy levels. This paper suggests a strong correlation between fecal N and DAPA annual curves but does not indicate a strong relationship between DAPA and digestible energy. Fecal N curves among studies were significantly related even though the diet varied from 92% grass to 64% browse.

Fecal nitrogen (N) techniques have been utilized to determine changes in animal condition in several species (Hebert et al 1984). The fecal N index is related to changes in nitrogen intake and weight change in sheep (Hebert et al 1984), to changes in digestibility and weight change in elk (Janz 1983, Gates 1980, Leslie & Starkey 1982) and to changes in nitrogen intake and dry matter digestibility in moose (Renecker and Hudson 1985). Recently, Mould and Robbins (1981) suggested that plant species with high phenolic levels significantly increased fecal nitrogen excretion when fed as a single species diet or in simple mixed diets where species with supposedly high phenolic levels composed as much as 33 percent of the diet. Thus, it has recently been suggested that diaminopimelic acid (DAPA), an indigestible and unabsorbed by product of rumen fermentation, could be used as an indicator of digestible energy level in diets of ruminant animals(Nelson et al 1982). Initial trials were conducted on domestic sheep. This study reports on annual fecal nitrogen curves for wild bighorn sheep utilizing a wide range of diets.

Although, most ungulate species utilize a wide range of forage species on a seasonal basis, thus reducing the influence of phenolics, it appears useful to compare the shape of fecal N and DAPA curves and their relationship with other nutritional indicators.

METHODS:

The collections of data from the three bighorn sheep research studies (Hebert 1973 and Hebert et al 1984) has been described in previous publications. In this paper, correlation coefficients were established between fecal N, DAPA and a range of nutritional indices such as plant nitrogen, plant energy, digestible protein and energy and seasonal weight change.

Similarly, correlation coefficients were developed for annual fecal N curves over a wide range of dietary composition. Tests of significance at the 0.05 level identified the important relationships. Comparison of data resulted from the analysis of the same samples for both fecal N and DAPA.

RESULTS:

The annual curves of fecal N and DAPA exhibit a similar decline throughout the period April through December (Fig. 1). The curves differ at two points. The fecal N curve declines gradually during the sampling period, with a slight increase during September - November as a result of fall greenup. The DAPA curve declines sharply during this period. The DAPA curve shows a sharp increase in May, paralleling somewhat, the change in plant gross energy (Hebert 1973).

As a result of this similarity to the plant gross energy curve, the DAPA curve was compared to the digestible energy curve in Kcal/day and in Kcal/gm dry matter intake, (Hebert 1973) as shown in Figure 2. Although gross and digestible energy are significantly related ($r=.621$, $P<0.10$), the DAPA and digestible energy curves appear to differ during the early growth stages in May and June. Although digestible energy (Kcal/day) increases from April through June, digestible energy (Kcal/gm) declines in May as root and photosynthetic carbohydrates exchange and as the rumen adjust to high quality spring growth. It is during this period that forage quality and forage intake often do not show consistent changes, depending on the magnitude of effect of low quality winter diets.

Both fecal N and DAPA are significantly related to changes in seasonal plant protein (Table 1). Thus, the curves for DAPA and fecal N are significantly related ($r=.943$). Neither fecal N or DAPA are related to plant or digestible energy.

As a result of the similarity between the fecal N and DAPA curves both are significantly related to seasonal weight change and digestible protein (Table 2).

Since Mould and Robbins (1981) suggested that phenolic activity may reduce the digestion of nitrogen and influence the annual fecal N curve, fecal N curves were compared through a range of studies and food habits (Table 2). In the three studies examined, fecal N curves were significantly related to each other. All herds were non-migratory in nature and subsisted on forage from the winter range year around. The fecal N curves of the Junction and O.K. studies were not significantly related until adjustments were made for latitude (Phenology) and fall greenup. The Junction study, being 500 km further north, was adjusted by one month, to accommodate the earlier phenological growth of the southern PH.D and O.K. studies. Similarly, the wet fall months (1982 and 1983) of the Junction were compared to an earlier year(1978) of the O.K. study to standardize fall greenup.

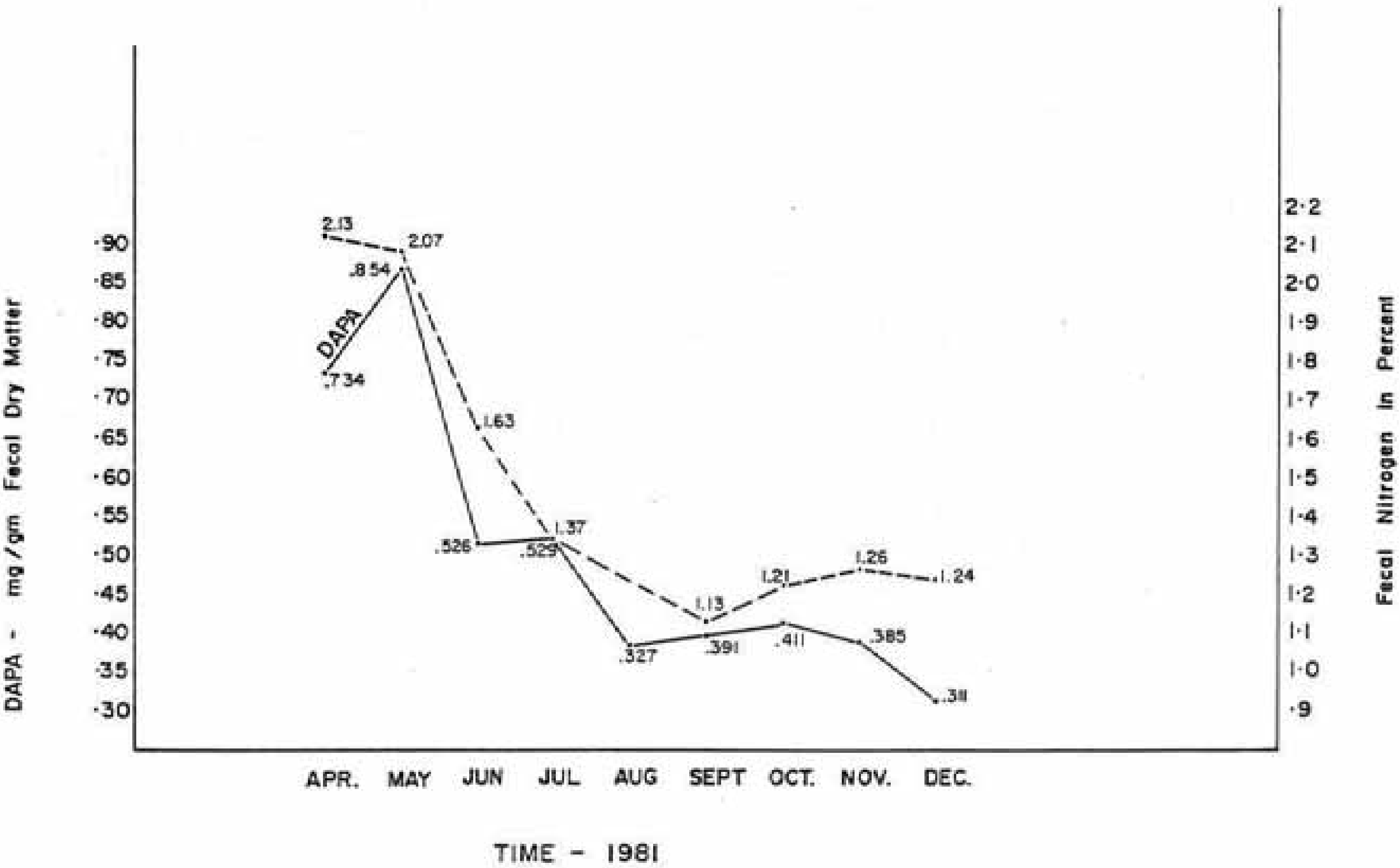

Fig. 1 : A comparison of the Annual Curves for Fecal Nitrogen and DAPA during 1981.

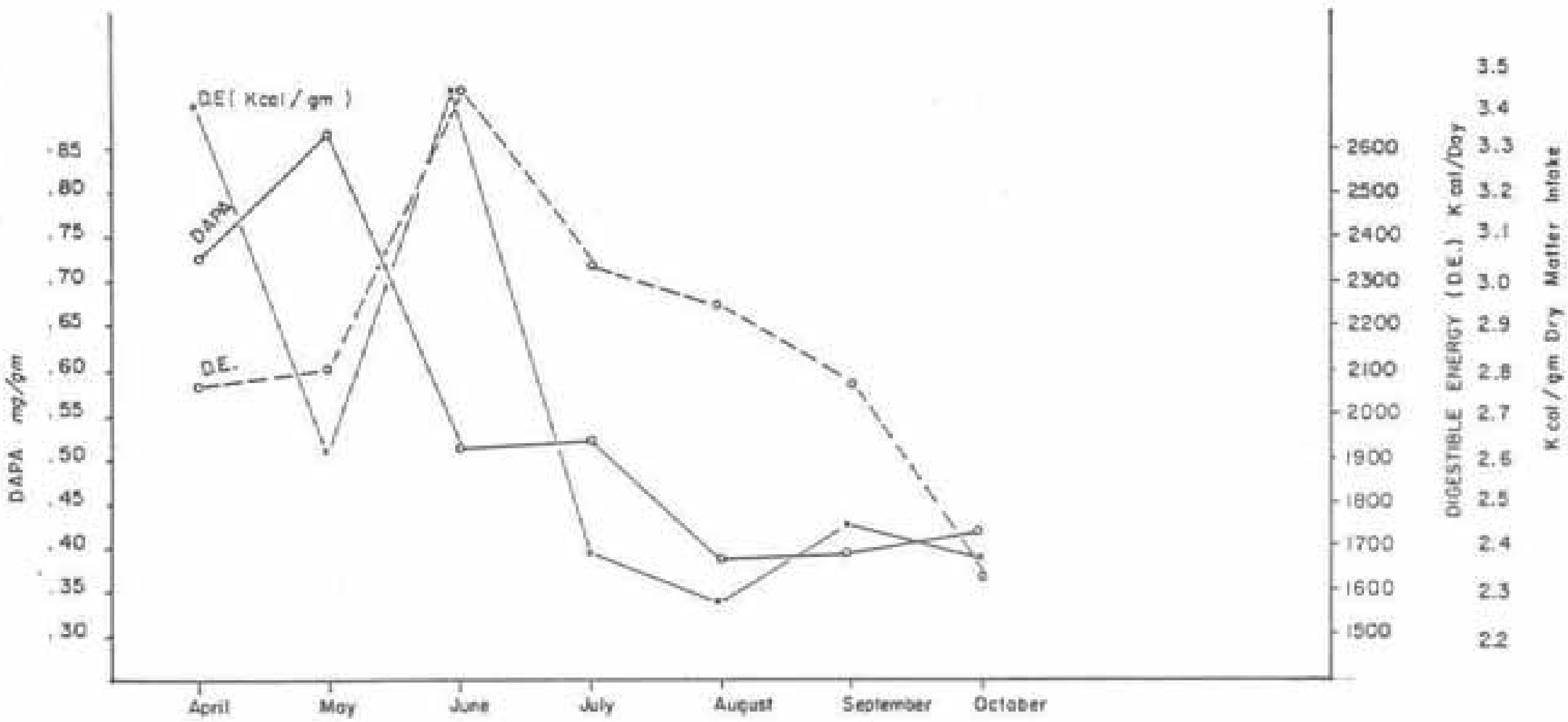

Figure 2. A comparison of the Annual Curves for DAPA and Digestible Energy.

The data suggests that even though diet composition differed dramatically from 92 percent grass to 64 percent browse (largely pasture sage), fecal N curves were similar and reflected diet quality and animal condition. Phenolics present in the higher browse plants (dicots) (Levin 1976) did not appear to alter nitrogen digestion.

DISCUSSION:

Fecal N has been shown to be a consistent indicator of diet quality and animal condition over an extremely wide range of forage composition. Similarly, DAPA has been shown to be significantly related to fecal N, plant and digestible protein and is also a valid indicator. Although Nelson et al 1982, suggests that DAPA is related to digestible energy (Kcal/gm) in domestic sheep, it did not appear to be related to the digestible energy components of wild sheep forage. The gross and digestible energy component of wild forage follows a marked set of changes from greenup, to root reserve - leaf carbohydrate exchange to winter dormancy. Hebert (1973) has shown that digestible energy can change from 3.40 Kcal/gm in spring growth winter range forage to 3.5 Kcal/gm in alpine forage to 1.8 Kcal/gm in low quality winter range forage. Energy changes in tame pasture undergo considerable less change (2.20 Kcal/gm to 2.75 Kcal/gm) due to the constancy of growing conditions. Thus, it appears that the degree of change, including carbohydrate exchange is relatable to changes in DAPA rather than the energy component itself. Nelson etal (1982)indicated a significant increase in non-DAPA bacteria simply by increasing the feed intake from maintenance to ad libitum. In this case there is no change in species composition or diet quality. When wild ungulates change from maintenance diets of winter range forage to ad libitum or growth diets, there is a change in species composition, forage quality and associated forage intake. These changes produce different digestible energy curves as shown in Figure 2.

Similarly, it appears that phenolics are less an inhibitor of N digestion than was originally suspected. Mould and Robbins (1981) fed single species or simple mixed diets supposedly high in phenolics. Since their elk were probably on a staple diet of grass or alfalfa prior to the digestion trails, it is possible that the drastic change in species and quality alone (maple =3.8% protein) could have produced the slight deviation in fecal N-dietary N relationship. Inclusion of his mixed rations in the relationship would probably have changed the r2 value very little. Most food habit studies indicate that ungulates select a wide range of forage species. In association, it is likely that ungulates have evolved to select forage species low in phenolics if digestion can be improved as a result. Recent work on mule deer (Langin pers comm.) suggests that mule deer in the central interior of B.C., which require mature Douglas fir as winter range, select mature fir branches in their diet (80% Douglas fir) which are four times lower in phenolics than younger aged fir.

Levin (1976) suggests that the higher plants contain complex mixtures of phenolics. The phenolic compounds appear to have evolved to serve as resistance to attack, especially from microbes or herbivores. In general, herbivores have learned to avoid them, or can degrade, recycle or respire them.

Recent work on browsing ungulates (Gates 1980, Janz 1983, Renecker and Hudson 1985) suggests that fecal N is related to a variety of nutritional indicators (weight change, digestibility, etc.) with no apparent negative effects from phenolics. In general, there appears to be no selective advantage for herbivores to use plants with phenolics which affect them negatively.

TABLE 1. Correlation coefficients established with fecal nitrogen and DAPA to examine nutritional condition.

Parameter	Study	Parameter	Study	N	Correlation coefficient	Sig .05
Fecal N	OK[1]	Plant N	OK	7	.920	Y
DAPA	OK	Plant N	OK	7	.81	Y
Fecal N	PhD[2]	Plant N	PhD	7	.994	Y
Fecal N	OK	Plant N	PhD	7	.952	Y
DAPA	OK	Plant N	PhD	7	.832	Y
Fecal N	OK	DAPA	OK	9	.943	Y
Plant N	PhD	Plant En.	PhD	7	.634	N
Fecal N	PhD	Plant En.	PhD	7	.625	N
Fecal N	OK	Plant En.	PhD	7	.447	N
DAPA	OK	Plant En.	PhD	7	.520	
Dig.Prot.	PhD	Dig.En.	PhD	7	.486	N
Fecal N	PhD	Dig.En.	PhD	7	.310	N
Fecal N	OK	Dig.En.	PhD	7	.149	N
DAPA	OK	Dig.En.	PhD	7	.069	N
DAPA	OK	Dig.En.[3]	PhD	7	.464	N
Fecal N	OK	Wt.Change	OK	7	.986	Y
DAPA	OK	Wt.Change	OK	7	.923	Y
Fecal N	PhD	Dig.Prot.	PhD	7	.949	Y
Fecal N	OK	Dig.Prot.	PhD	7	.923	Y
DAPA	OK	Dig.Prot.	PhD	7	.813	Y

1 Okanagan Game Farm Study (Hebert et al 1984)
2 PhD study (Hebert 1973)
3 Digestible Energy in Kcal/gm Dry Matter Intake

TABLE 2. A comparison of differences in fecal N with differences in food habits.

FECAL N COMPARISON

	n	Correlation Coefficient	Sig .05
PhD vs OK(81)	7	.920	Y
OK(81) vs Jct[1](82)	8	.552	-
OK(81) vs Jct(83)	6	.672	-
OK(81) vs Jct(82) (Adj. for Phenology)	8	.603	-
OK(81) vs Jct(83) (Adj. for Phenology)	5	.900	Y
OK(78) vs Jct(82) (Adj. for Phenology & Fall Greenup)	9	.724	Y

FOOD HABITS COMPARISON

	Grass	Forbs	Browse
PhD	91.8	6.0	3.2
OK[2] (May-Aug)	56.1	31.3	12.6
OK(82) (Jun-Mar)	86.8	9.75	3.25
Jct(82)	44.1	6.2	64.0

[1] Junction Sheep Range
[2] Pit & Wikeem, 1978

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QUESTIONS AND ANSWERS

Marco-Festa Bianchet: Did you look at ash values in the fecal samples and did the ash as a component affect the nitrogen values?

Daryll Hebert: I haven't looked specifically at ash values in these cases, although Dale Seip has in Stone sheep. Certainly in the work that we've done, the ash values are not being affected by salt licks or any large ingestion of any nonorganic materials. With the data we have and the correlations as we've established to date, there's no problem from that end as far as I'm concerned. But again, its another component that people could examine further because it may play a role in some cases.

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WINTER FOOD HABITS AND SEXUAL MONOMORPHISM IN JAPANESE SEROW

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Abstract: Rumen contents of Japanese serow (Capricornis crispus, N = 253) were obtained in central Japan during the winter of 1982-82. Botanical composition was similar for males and females, as predicted by their lack of sexual dimorphism. Male and female serow are similar in body size and length and shape of horns, though there are slight differences in their skeletons. Sexual dimorphism is greater in their northern-adapted relative, the mountain goat (Oreamnos americanus).

A recent project on Japanese serow (Fig. 1), once an "animal of mystery", has revealed many aspects of its biology, including reproduction, morphology, diseases, age-determination, food-habits, nutrition, genetics, population dynamics and management (Sugimura 1985). The authors reported food habits analyses in a previous paper (Takatsuki and Suzuki 1984). Serow is a browsing animal, at least in winter. Browse leaves formed as much as 57% of the diet; dwarf bamboos (Sasa spp.) were also important (27%). Food habits could be a factor determining the distribution of serow, which corresponds with that of deciduous broad-leaved forests.

Figure 1. A male Japanese serow in northern Japan (photo by R. Kishimoto)

Here we compare the food habits of males and females, based on a larger sample size. In ungulate species with a high degree of sexual dimorphism, differences in food habits can be a factor in habitat segregation (Geist, 1974a, b). However, Japanese serow appear to have little sexual dimorphism, and we can predict that this would be reflected in their food habits. The objective of this study was to compare the botanical composition of the rumen contents of male and female Japanese serow.

METHODS

A total of 253 rumen samples of Japanese serow (132 males and 121 females), excluding kids (0.5 year old), was collected from Nagano Prefecture, central Japan, during November 1982 - February 1983. About 500 ml of each contents were sampled and stored in ethyl alcohol (over 60%). Samples were washed through a 2-mm mesh screen, and residues were analyzed by the point-frame method (Leader-Williams et al. 1981). Plant fragments were uniformly spread over a laboratory dish with 5-mm grid, and the points covered by plant fragments were scored. Four hundred points were counted for each sample. Plant fragments were assigned to 6 forage categories: (I) browses, (a) conifers, (b) broad-leaved browses, (c) unidentified browses; (II) graminoids, (a) dwarf bamboos, (b) grasses, sedges and others; (III) others such as forbs, ferns, mushrooms and unidentified materials.

Forage availability may vary among winter months, depending on snow conditions (Takatsuki and Suzuki 1985), and therefore, data were partitioned by months.

RESULTS

In 1982-83, winter diets of Japanese serow (Table 1) were similar to those recorded in 1979-80 (Takatsuki and Suzuki 1984). "Browses", including coniferous and broad-leaved woody plants, were most important, occupying 50-70 percent of the diet. There were compensating relations between coniferous and broad-leaved woody plants; the former increased and the latter decreased through the sampling period. Among the browse species, the leaves of Chamaecyparis obtusa, a coniferous tree, were most important both in percent composition (around 15% in most cases) and in frequency of occurrence. Graminoids accounted for 20-30 percent in most cases, among which dwarf bamboos (Sasa spp.) were important (10-20%). Miscellaneous forages accounted for about 15 percent of the rumen contents except in February when they accounted for less than 10 percent. Major constituents in this category were ferns and mushrooms, but their occurrence was irregular.

No significant differences were recognized between males and females, for any food category or in any month (Table 1).

DISCUSSION

Since competition for limited resources is most intense within a species, it can be predicted to be adaptive for animals to segregate forage resources between males and females (Geist 1974a, b). Despite this prediction, there seem to be few studies of ungulates in which the food habits of males and females are compared, though there are some for species with well developed sexual dimorphism; red deer (Cervus elaphus, Ahlen 1965, Harper et al. 1967), Sika deer (Cervus nippon, Takatsuki 1980) and bighorn sheep (Ovis canadensis, Shank 1982).

Table 1. Percentage composition of rumen contents of Japanese serow.

Month	Nov.		Dec.		Jan.		Feb.	
Sex	M	F	M	F	M	F	M	F
N	32	32	62	55	28	22	10	12
Browses	73.5	64.3	58.9	56.1	49.3	56.5	68.7	67.8
conifers	9.0	12.2	19.1	16.4	26.6	25.5	36.0	28.9
broad-leaves	63.2	50.1	36.9	37.2	21.4	28.6	29.6	35.6
unidentified	1.3	2.0	2.9	2.5	1.3	2.4	3.0	3.2
Graminoids	11.8	20.4	25.6	19.9	34.0	27.0	22.0	27.3
dwarf bamboos	7.6	14.2	16.4	12.6	24.9	20.4	13.4	16.6
others	4.2	6.2	9.2	7.3	9.1	6.7	8.6	10.7
Others[1]	14.8	15.3	15.5	24.0	16.7	16.5	9.4	4.9

[1] Forbs, ferns, mushrooms and other unidentifiable materials.

A lack of intersexual differences in food habits of Japanese serow can be attributed to their physiological and morphological similarities. There are no physiological studies comparing male and female serow, and there are no significant intersexual differences in their external measurements (Table 2).

Table 2. External measurements of Japanese serow and mountain goats.

	Japanese serow[1]			Mountain goat		
	Male	Female	M/F	Male	Female	M/F
Body weight (kg)	35.2	37.7	0.93	79.5	61.3	1.30[2]
				69.9	53.1	1.32[3]
				75.7	49.0	1.54[4]
Body length (cm)	78.0	79.9	0.98		No data	
Horn length (cm)	15.0	14.9	1.01	23.2	22.8	1.02[5]
				23.6	21.1	1.12[4]
Horn spread (cm)		No data		15.9	14.8	1.08[5]

[1] Sugimura (1985), 10 of each sex, [2] Klein (1953), [3] Brandborg (1955), [4] Richardson (1971), [5] Hibbs (1966).

Among 99 measurements from serow skulls, vertebral columns, and thoracic and pelvic limbs, there were only 13 differences between the sexes (Sugano et al. 1982, Tsuchimoto et al. 1982). Males were larger than females in 5 of the measurements and smaller in 8, but these differences were small, none more than 1.2 cm. Thus it is very difficult to distinguish the sexes especially in the field, without checking the primary sexual characteristics, even for well-experienced observers (Kishimoto, personal communication).

Further evidence of sexual monomorphism, relating more directly to food habits, has been recognized in the serow's tooth wear (Miura 1985). There were no significant differences between sexes in degree of tooth wear, which is in contrast to some cervid species such as mule deer (*Odocoileus hemionus*, Erickson et al. 1970), elk (*Cervus elaphus*, Flook 1970) and caribou (*Rangifer tarandus*, Miller 1974).

Sexual monomorphism in Japanese serow becomes more apparent when serow are compared to their northern-adapted relative, the mountain goat. Though this species is considered less sexually dimorphic than the mountain sheep (Ovis spp. Geist 1974b; 213), differences between sexes are apparent (Table 2). Body weight differences between sexes are greater in mountain goats, where the male/female ratios are 1.3 to 1.5 while this ratio is 0.9 in Japanese serow. Intersexual differences in horn length are slight in mountain goats, but Hibbs (1966) has recognized that the horns of males are more massive and continuously curved backward. These comparisons suggest that the mountain goat has increased in sexual dimorphism through recent evolution. We need comparable studies on the food habits of mountain goats, focused on comparing the sexes.

Other differences between serow and mountain goats occur with their habitats and social behavior. Japanese serow inhabit forests and are territorial, living in groups of 1-3 individuals (Akasaka and Maruyama 1977, Sakurai 1981). In contrast, mountain goats inhabit cliffs and more open habitats; they are not territorial and form larger groups of 3-6 to even 60 individuals (Hibbs 1966, Richardson 1971, Chadwick 1977, Adams and Bailey 1980, J. A. Bailey personal communication). These differences may relate to food habits, and should be reconsidered from the socio-ecological standpoint (Geist, 1974a, b).

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QUESTIONS AND ANSWERS

Dale Reed, Colorado: Are you familiar with the controversy, or is there any controversy concerning the population of Japanese serow and forestry products?

Seiki Takatsuki: Yes, there is a very serious problem, they eat most of the trees planted.

Reed: Do you have an idea for a solution to this problem?

Takatsuki: Well, its hard to answer. I am just a biologist. The agency is beginning to control the populations, but they have no plans to hunt the animals, but there is a movement to use some repellant or plastic net around on the young saplings.

Joseph Hamr, Ontario: I was wondering if there is any information on the movements of the animals in the course of the year?

Takatsuki: Well, they are basically solitary, but mother/kid units are common. They are territorial against the same sex. Male are territorial against males only, and a territorial male and female are overt. They do not migrate, they just move several kilometers up and down depending on snow conditions. We have no information on the composition of groups over five individuals. Most of them occur in groups of two and three. A group is usually composed of a male and female pair during the rut, and later a group of three includes the newborn kid.

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HABITAT IMPROVEMENT FOR TAYLOR RIVER BIGHORN SHEEP HERD

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Abstract: This paper reports on past and present habitat conditions of a bighorn sheep (Ovis canadensis) range in central Colorado along Taylor River. Hibbs and Woodard (1969) analyzed habitat conditions. The Colorado Division of Wildlife (DOW) have made winter counts of the herd since 1940 (Fig 1). These counts show a cycling population usually crashing when the population nears 100. Both summer and transitional range have become overgrown with conifers due to lack of fires within the past 80 years. The U.S. Forest Service (USFS) has started a program of habitat improvement to improve the range thru a variety of manipulation techniques. This program and future plans are discussed.

AREA DESCRIPTION

The Taylor River bighorn herd uses a 25 km long segment along the Taylor River from the town of Almont north to Taylor Reservoir. The winter range consists of steep Mesozoic rock formations with loose shale slides along the Taylor River. The winter range is approximately 8 km in length and .5 km in width. Ponderosa pine (Pinus ponderosa), Douglas fir (Pseudotsuga menziesii), and juniper (Juniperius scopulorum) are scattered along the east and south facing cliffs. Understory is dominated by fringed sagebrush (Artemisia frigida) big sagebrush (Artemisia tridentata) and rabbitbrush (Chrysothamnus spp.). The most common grasses include Indian ricegrass (Oryzopsis hymenoides), mountain muhly (Muhlenbergia mountana), needle and thread grass (Stipa comata), and sedges (Carex spp.).

At the top of the cliffs the terrain changes to big sagebrush flats with a minor understory of rabbitbrush . Grasses in the understory include western wheatgrass (Agropyron smithii) and junegrass (Koeleria cristata).

The summer range, some 15-20 km up river, is dominated by an overstory of lodgepole pine (Pinus contorta) and Engelmann spruce (Picea engelmannii). Only 20% of the entire summer range area is nonforested, with a majority of this nonforested area being barren. The openings which are present near timberline are dominated by Thurber fescue (Festuca thurberi), vetch (Vicia spp.), and sedges.

VEGETATIVE HISTORY

Since the early 1900's, the habitat has progressively converted to a timbered stand through natural succession and the lack of any large fires. The available summer range is becoming increasingly isolated with heavy stands of timber forming barriers between these "island habitats".

Risenhoover and Bailey (1980, 1985) and Bailey (1980) point out the importance of visibility in grazing areas and along migration corridors. Visibility for the Taylor River bighorns has decreased to the point where abandonment of the summer range in the future is a possibility.

The winter range, while not as heavily timbered, is showing the same trend towards reforestation.

HERD HISTORY

Herd size has been cyclic, starting from a low of 25 and gradually building up to around 100 when a crash usually occurs (Feuerstein, et. al. 1980 and USFS 1940-1985). The herd is infected with lungworm though not at an epidemic stage. In comparing with other herds in Colorado, the Taylor River herd appears quite healthy (Bear and Jones 1973). Some sheep are now starting to remain on the winter range yearround however and speculation is this is due to the migration routes closing in with trees. The USFS is concerned that the migration pattern may be lost.

There has been only one transplant into this herd. In 1969 10 sheep were brought in.

HABITAT HISTORY AND MANAGEMENT

At The turn of the century, the Taylor River drainage experienced extensive wildfires. The summer range and transitional range was almost totally inundated with fire during this time. Lodgepole pine has since invaded this range to its present dense condition.

In 1976, the USFS became concerned with conflicts between sheep and people. Consequently, since 1976 the winter range has been officially closed to all human use from December 1 to March 31.

Actual habitat improvement for the bighorn sheep began in the spring of 1983. A 50 acre sage flat in the upper winter range was burned to test response of both vegetation and the sheep to the burn. A herd of 22 sheep immediately moved into this burned flat and grazed throughout the summer and fall on the _Stipa_, Kentucky bluegrass (_Poa pratensis_) and Thurber fescue which came up after the burn.

Since then, approximately 1,800 acres have been burned. Burns on the winter range have resulted in a large increase in grasses and sedges. Seventy acres on the winter range were reseeded with timothy (_Phleum_ spp), smooth brome (_Bromis inermis_) and sweet clover (_Melilotus officinalis_). Three native plants in the burn area (_Stipa_, _Carex_ and _Wyethia_), have been lightly utilized since the burn.

In May and June of 1985, the first large fire was completed in the summer transitional range. Over 1,200 acres of lodgepole timber were burned by ground crews using driptorchs and by using the helitorch, an aerial ignition device. This burn received considerable attention from the local and national media. The media coverage was all positive and displayed the needs for habitat improvement for the sheep.

PUBLIC RELATIONS

An intensive public relations campaign was initiated prior to and during these burns. All landowners in the canyon were individually notified and the project was explained. Ground patrols talked to the public during the burns and distributed information sheets on the objectives.

In addition, the USFS erected information signs where burns were visible from the Taylor Canyon road. These signs described what the USFS was trying to accomplish and why.

FUTURE MANAGEMENT PLANS

The entire range for the sheep was analyzed in 1985 using the Ram 1 computer model (Hoover and Wills 1984). Present habitat capability for bighorn sheep after the 1,200 acre burn is 26% of potential with a summer population capability of 64 sheep.

The document which establishes management direction for USFS in this area is the approved Land and Resource Management Plan for the Grand Mesa, Uncompahgre and Gunnison National Forest. Minimum standards for bighorn sheep habitat quality are described in this document. Habitat for bighorn sheep will be maintained at least at 40% or more of potential. In order to meet the 40% level, 5,000 acres need to be returned to early successional stages. Following determination of the need, the USFS analyzed locations and potential projects. Listed below are project plans resulting from our analysis:

1. Proposed burning of 10,000 acres within the next ten years. (Past burns have shown that you need to double the burn acreage you want in order to achieve your goal. Some acres won't burn no matter what you do, due to a lack of carrying fuels.)

These burns would be predominantly in lodgepole and are considered 2 stage burns. The first burn's objective is to kill as many mature trees as possible. Following the burn, there will be a large amount of seed released from burned cones. For the next 20 years, there will be a buildup of regeneration as the dead and dying timber falls down. The second burn will attempt to burn the regeneration and slash resulting from the first burn.

This burn should be much more extensive as the fuels will be more continuous.

2. Seeding of areas which experience intense fires. If the prescribed fires are hot enough, the cones will be burned up, resulting in a single stage burn. At this time it will be worthwhile to seed desirable grasses.

3. Clearcut, burn and seed spruce stands within the summer range. Part of the summer range has gentle topography where logging is possible and the timber present makes the sale financially feasible. The cutting units would be designed to imitate natural snowchutes.

Because of the burning and seeding, we anticipate these units to be very slow (20 years or longer) in reverting back to spruce. All roads would be obliterated following completion of the sale.

4. Create openings in the migration corridor. This would be via small timber sales where possible, and felling and burning where timber or topography make the site unfeasible for commercial harvest.

5. Maintain herd population at 100 sheep through trapping and hunting. The Colorado DOW has agreed to keep the population at this level in hopes of keeping down stress and maintaining the quality of the winter range. Transplanting will continue to be the major management technique as the DOW is attempting to restock the historic sheep ranges and supplement existing herds state wide.

DISCUSSION

The Taylor River bighorn sheep herd is at peak population levels. The USFS is attempting to improve the range thru burning and logging. These improvements will hopefully put the sheep in better physical condition where they will be able to withstand the winter. Trapping for trannsplant by Colorado DOW should keep the population down to a point where winter carrying capacity is not exceeded.

The burns which have been completed were used by sheep within 1 growing season. The seed mixture used in reseeding has proven to be very successful.

To date, 1,800 acres have been burned with 3,100 acres planned for 1986. Public response has been very positive despite the immensity and visibility of the program. Much of this can be attributed to the intense public relations campaign intitiated to inform the public.

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SUMMER HABITAT USE BY BIGHORN EWES AND LAMBS

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Abstract: Habitat use by bighorn sheep (Ovis canadensis) ewes and lambs in Custer State Park, South Dakota was determined. Six habitat types were classified based on a combination of topograpy and vegetation. Radio-telemetry was used to monitor sheep movements and habitat use. Availability of each habitat was determined from aerial photographs. Availability of habitats within the home range (HRAH) of the bighorn sheep was compared to the total availability of habitats (TAH). Highly significant differences existed between HRAH and TAH indicating that determination of actual available habitat can influence apparent habitat selection. Bighorn sheep selected steep rocky habitat with a ponderosa pine overstory and avoided dense stands of ponderosa pine saplings. Habitats selected by bighorn sheep occurred in greater proportion within the home range than the total available habitat. Sheep avoided habitats having reduced visibility, but once a minimum threshold of visibility had been exceeded other factors influenced use. Bighorn sheep were never located further than 80 m from escape terrain and all locations were within 1 km of water.

The Black Hills and Badlands of South Dakota were traditional range for Audubon's bighorn sheep (Ovis canadensis auduboni) until this subspecies became extinct by 1916 (Buechner 1960). Rocky Mountain bighorn sheep (O. c. canadensis) were introduced to the Black Hills in Custer State Park (CSP), a 29,250 ha park, in 1964. The population increased to 100-150 animals by 1975 (Trefethen 1975), but has failed to increase above this level with a population estimated at 100 animals at present.

Most studies on Rocky Mountain bighorn sheep report distinct summer and winter ranges with traditional migration routes. Migration is often an elevational shift (Martin 1981, Erickson 1972) or a seasonal shift to different plant communities (Deming 1964, Bradley 1964). However, introduced bighorn sheep populations often fail to establish traditional migration patterns and remain restricted to the site of introduction (Geist 1971).

Several researchers have demonstrated the importance of steep, rocky terrain to bighorn sheep (Welch 1969, Geist and Petocz 1977, Morgantini and Hudson 1981). These areas provided increased protection from predators during lambing and lamb rearing (Irvine 1968). Bighorn sheep summer activity centers also showed proximity to water in addition to precipitous terrain (Graham 1968, Hinkes 1978), with sheep remaining close to permanent water resources during dry periods, but utilizing their entire range during wet periods (Irvine 1968).

This study was designed to determine which specific habitats were selected by bighorn ewes and lambs in CSP during summer, based on observed use and proportional availability of these habitats to the sheep.

ACKNOWLEDGMENTS

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STUDY AREA

This study was conducted in CSP, which is situated in the southeast corner of the Black Hills of South Dakota (Fig. 1). Bighorn sheep are resident in the French Creek Natural Area, which is located in the central portion of the park. French Creek Natural Area encompasses French Creek Canyon, which is approximately 19 km long, 800 m wide, and ranges from 140 to 270 m in depth. French Creek Canyon represents a typical canyon in the southern Black Hills with exposed granite cliffs and a predominantly ponderosa pine (Pinus ponderosa) cover interspersed with steep, grassy slopes. These canyons typically have a narrow riparian zone adjacent to semi-permanent streams.

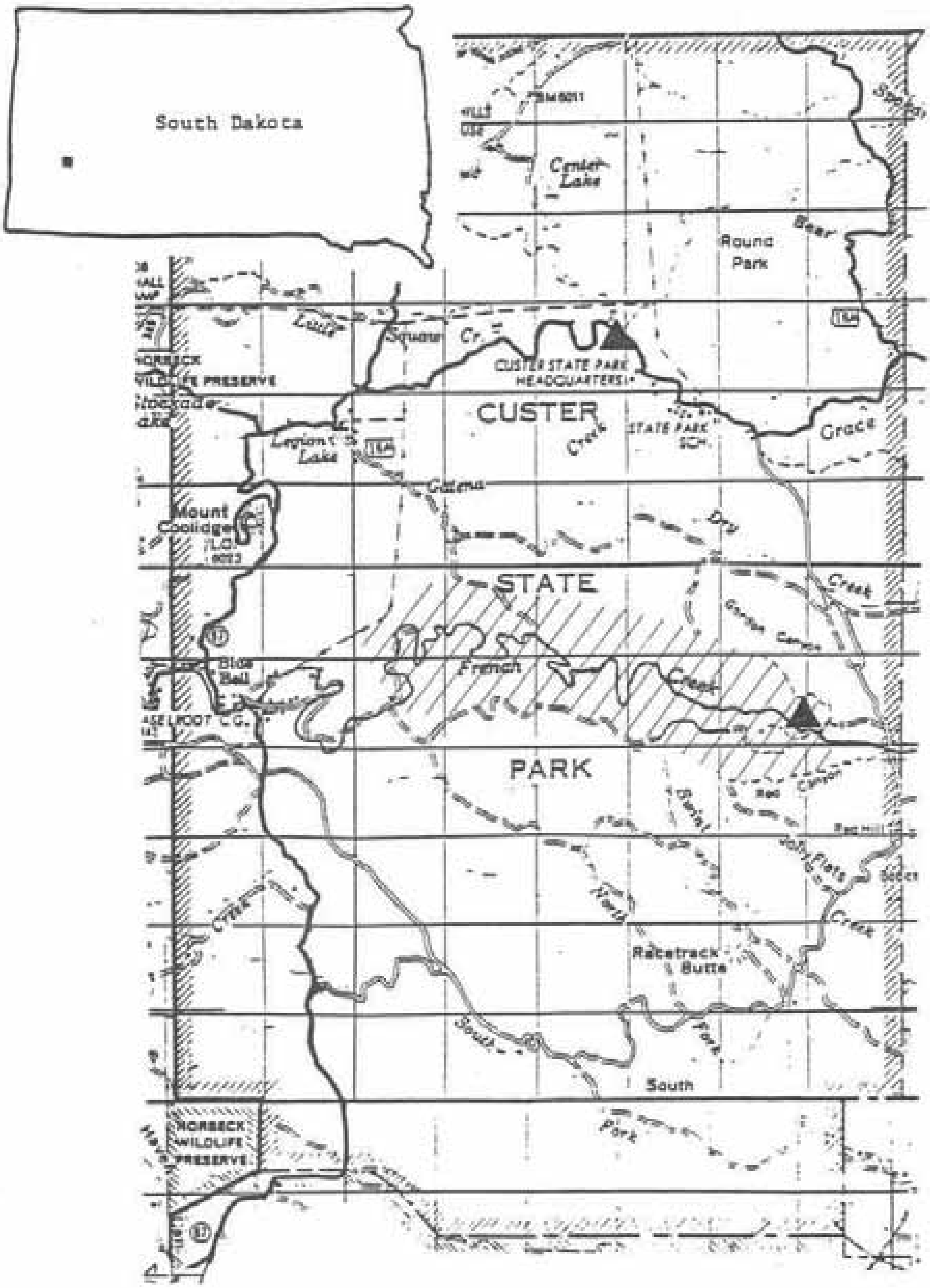
METHODS

Movements

Bighorn sheep movements were monitored using radio-telemetry from early May through August, 1984. Sheep were baited with alfalfa hay and apple pomace, and trapped with a drop net (Schmidt et al. 1978). Fourteen ewes were marked, 10 of which also were equipped with color-coded radio-transmittered collars (Advanced Telemetry Systems Inc., Bethel, MN). Radio-collared ewes were monitored until visual verification of location could be established.

To insure random relocation sampling throughout the diurnal period, fixes were taken during 8, 2-hour time periods starting at 0500 h and ending at 2100 h. Telemetered sheep were assigned a number 0 through 9. Numbers were randomly selected for each of the 8 time periods and the corresponding sheep was located during that time frame. No sheep was located twice in the same time period until all sheep had been located

Figure 1. French Creek Canyon study area in Custer State Park, South Dakota, and bighorn sheep trap sites.



in all time periods.

Information recorded for each observation included time, location (UTM coordinates), percent slope, exposure, position on slope, distance to escape cover, and habitat type.

Habitat Sampling

Six habitat types were visually delineated based on a combination of topography and vegetative cover. Habitats were characterized as mixed grass-forb meadows with no overstory (mxgr/forb), riparian with several deciduous overstory species (ripr), ponderosa pine stands with a grass-forb ground cover (pipo/grfb), steep rocky canyon sides with a grass-forb understory and a ponderosa pine overstory (stro/pipo), steep rocky canyon sides with a grass-forb understory but no overstory (stro/grfb), and dense stands of ponderosa pine (dest/pipo).

Habitat understory charactertistics were then sampled using a 20 x 50 cm frame to define a sample plot (Daubenmire 1959). Four sites were randomly selected within each habitat type for placement of 30 m transects which were aligned parallel to the contour within the habitat to be sampled. At 1.5 m intervals along the transect, a left or right perpendicular direction was randomly selected (coin toss) and the plot was placed at 1 of 6 randomly chosen (die roll) incremental marks on a 1.5 m pole at 0.25 m intervals.

Overstory characteristics were sampled using 10, 0.01 ha sampling sites randomly located in each habitat type. All trees greater than 2 m in height were counted and diameter at breast height (dbh) measured. Canopy cover was estimated from 4 readings of a spherical densiometer (Lemmon 1956, 1957) placed on the site center, 1 in each compass quarter. Horizontal obstruction was determined from 4 readings at 10 m of a density checker board, 1.5 m x 1.5 m, placed in the center of the site. One reading was taken from each compass dirction.

Habitat Availability and Selection

To determine habitat availability, sheep locations were plotted and home range was determined using the modified minimum polygon method (Harvey and Barbour 1965). Maximum distance sheep traveled between areas of use was determined and this distance was then added around the home range perimeter to encompass total available habitats (TAH). Habitats within the home range were considered home range available habitat (HRAH).

Habitat availability within these areas was determined by stereoscopy using color photographs (1:24000 scale) and a point grid overlay. TAH and HRAH frequencies were recorded from 3,958 point observations. To ascertain whether HRAH was characteristic of TAH, proportions of habitats within the home range were tested against proportions of total habitats using contingency table analysis.

Selection and avoidance of habitat by bighorn sheep was calculated from the proportion of observations of sheep in each habitat and the proportional availability of each habitat type (Neu et al. 1974, Byers et al. 1984). Preference ratios were calculated from percent use and percent availability (Risenhoover and Bailey 1985).

Habitat understories were analyzed using discriminant analysis of species composing at least 4% total cover in any 1 habitat. Overstory characteristics were analyzed using analysis of variance.

RESULTS

Habitat

Discriminant analysis discriminated, with 100% accuracy, among all habitats based on understory vegetation with the exception of the 2 steep, rocky habitats (75% accuracy). Steep, rocky habitats had the same 2 dominant species, little bluestem (Andropogon scoparius) and side-oats grama (Bouteloua curtipendula) (Table 1), however, stro/grfb had greater total ground cover than stro/pipo (32% vs 19%). In addition, these 2 habitats differed in overstory, stro/pipo with a dominantly ponderosa pine overstory and stro/grfb without any overstory.

Overstory characteristics were not significantly different ($P < 0.05$) between habitats except dest/pipo (Fig. 2). Dest/pipo stands were composed of ponderosa pine trees with an average dbh of 7.5 cm and a mean of 14,340 stems/ha as compared to average dbh of 19.9 - 23.4 cm and average stem densities of 840 - 880 stems/ha in all other types of overstories. Riparian habitat, although very similar to other habitats in overstory structural characteristics, was composed of deciduous trees with very few ponderosa pine trees. All other overstories were composed almost exclusively of ponderosa pine. Burr oak (Quercus macrocarpa) was the only other tree species encountered in any habitat but riparian.

Dest/pipo also had a significantly ($P < 0.05$) greater canopy cover (74.3%) than any other habitat (49.2% to 56.6%). Horizontal obstruction was significantly ($P < 0.05$) greater in dest/pipo stands at 52.4% than the other habitats (18.3% to 23.0%).

HRAH was significantly different from TAH ($X^2 = 133.14$, df = 5, $P < 0.001$). The most available habitat, pipo/grfb, occurred less than expected in the home range (Table 2), as did dest/pipo and mxgr/forb. However; both steep rocky habitats and riparian habitat were more abundant than expected within the home range.

Hatitat Selection

Bighorn sheep used habitats in different proportions than present in TAH ($X^2 = 16.7$, df = 5, $P < 0.01$). Sheep selected stro/pipo and avoided dest/pipo and pipo/grfb (Table 3). Other habitats were used in proportion to their availability. Selection of habitats by the bighorn sheep in HRAH was similar, to their habitat selection in TAH, however, bighorn sheep used pipo/grfb in proportion to its availability and

Table 1. Percent ground cover composition in each of 6 habitats in Custer State Park bighorn sheep range (standard deviation).

Habitat type	Andropogon gerardi	Andropogon scoparius	Bouteloua curtipendula	Bouteloua gracilis	Poa species	Psoralea tenuiflora	Rhus radicans	Scirpus atrovirens	Non-vegetation
Ponderosa pine/ grass forb	1.3 (1.4)	2.3 (3.0)	5.4 (5.1)	1.6 (1.9)	9.2 (6.9)	0	0	0	55.7 (13.2)
Steep rocky/ ponderosa pine	1.9 (1.7)	5.9 (4.5)	4.0 (3.9)	0	0	0.1 (0.2)	1.3 (1.8)	0	81.0 (5.3)
Steep rocky/ grass forb	3.5 (2.5)	9.3 (5.7)	7.4 (6.0)	1.6 (2.0)	0	0.1 (0.2)	0.5 (0.9)	0	67.9 (10.6)
Doghair	0	0	0	0	0	0	0	0	97.5 (0.0)
Riparian	0	0	0.2 (0.4)	0	1.8 (2.1)	0	14.1 (7.6)	16.3 (5.6)	24.8 (11.9)
Mixed grass/ forb	6.2 (2.8)	5.0 (5.4)	2.1 (4.0)	8.3 (8.2)	12.7 (5.3)	4.0 (5.4)	0	0	11.6 (10.4)

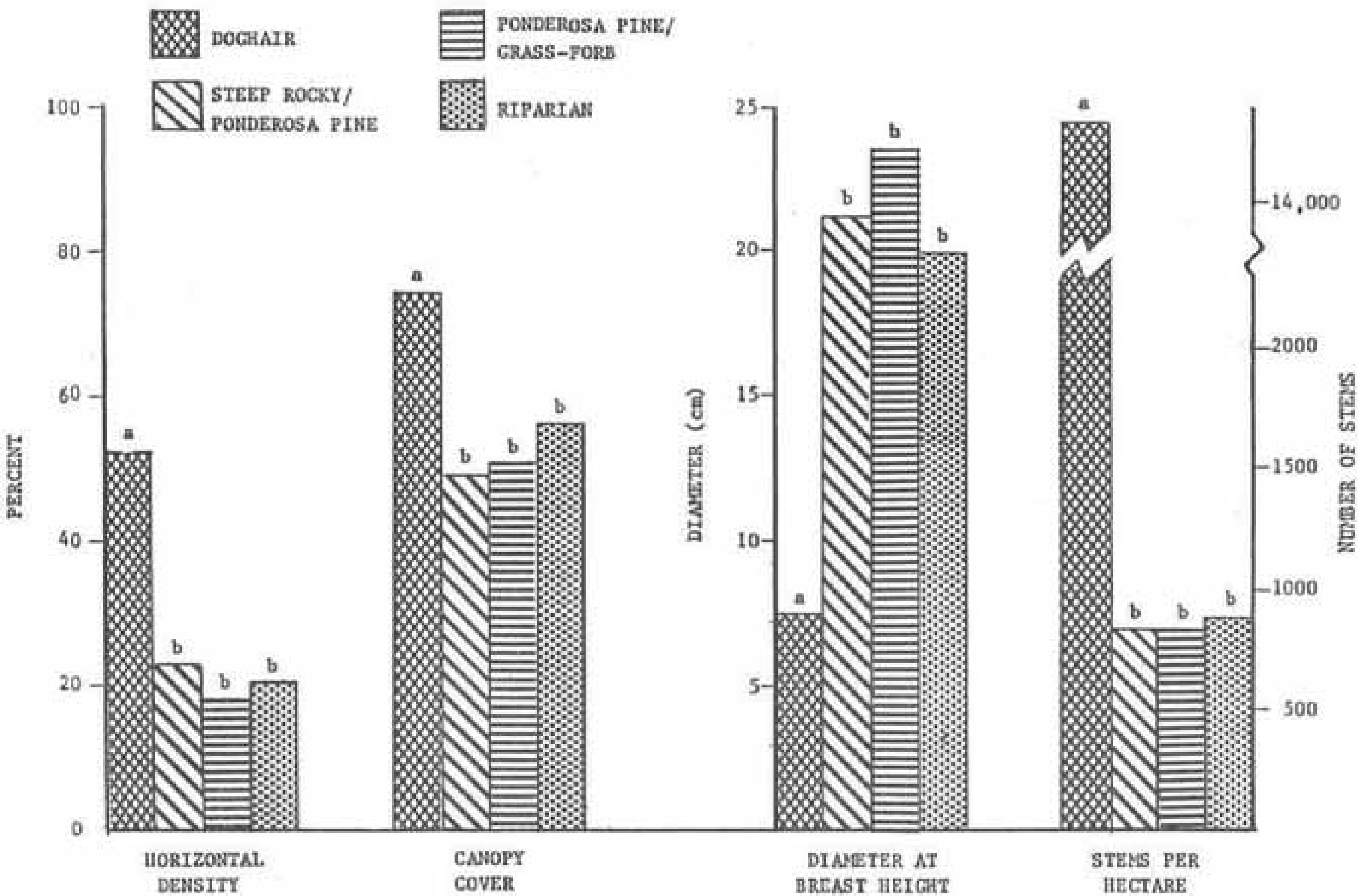


Fig. 2. Characteristics of habitat overstories in Custer State Park bighorn sheep range (characteristics with the same letter are not significantly different $\alpha = .05$).

Table 2. Availability of 6 habitat types within the modified minimum home range of bighorn sheep in Custer State Park, South Dakota, compared with total habitat availability in 1984.

Habitat Type	Total Availability (TAH)	Home Range Availability (HRAH)	
Ponderosa pine/ grass forb	39.4%	30.8%	*
Steep rocky/ ponderosa pine	20.1%	34.2%	*
Steep rocky/ grass forb	4.0%	8.7%	*
Doghair	23.2%	17.6%	*
Riparian	2.2%	3.8%	*
Mixed grass/ forb	11.2%	4.8%	*

* Indicates significant difference at $P \leq 0.05$

Table 3. Habitat selection by Custer State Park bighorn ewe-lamb groups, May-August 1984.

Habitat Type	Proportion availability (total)	Proportion availability (home range)	Proportion observations (P_i)	Preference ratio*	Confidence interval for proportion of use P_i
Ponderosa pine/ grass forb	0.394	0.308	0.273	0.69	$0.174 \leq P_1 \leq 0.371$ [a]
Steep rocky/ ponderosa pine	0.201	0.342	0.545	2.75	$0.443 \leq P_2 \leq 0.662$ [ab]
Steep rocky/ grass forb	0.040	0.087	0.042	1.06	$0.000 \leq P_3 \leq 0.086$ [b]
Doghair	0.232	0.176	0.000	0.00	$0.000 \leq P_4 \leq 0.000$ [ab]
Riparian	0.022	0.038	0.042	1.95	$0.000 \leq P_5 \leq 0.086$
Mixed grass/ forb	0.112	0.048	0.091	0.81	$0.027 \leq P_6 \leq 0.154$

* Preference ratio = use divided by total availability

[a] Indicates significantly different use than total availability at $P < 0.05$

[b] Indicates significantly different use than home range availability at $P < 0.05$

stro/grfb slightly less than its availability in HRAH.

Bighorn sheep were never located farther than 80 m from escape terrain, which was defined as areas having greater than 100% slope with large rock outcrops. Sheep were observed on the middle third of the slope 44% of the time, while only 27% of the observations were off the slope either at the top or bottom. Over 90% of the locations were within 0.5 km of available water, with no sheep being located farther than 1 km from a water resource.

DISCUSSION

Risenhoover (1981, in Risenhoover and Bailey 1985) reported that bighorn sheep avoided areas with tall, dense vegetation but would use these areas when visibility was increased through thinning. Peek et al. (1979) and Riggs and Peek (1980) also reported that bighorn sheep will move into ranges that were recently burned to clear vegetation. Once a threshold of visibility has been exceeded, forage density becomes more important in determining habitat selection (Risenhoover and Bailey 1985). This is the case in CSP. There was a slight negative correlation ($r = -0.46$) between preference ratio (habitat use divided by total availability) and horizontal obstruction. Sheep used all areas with horizontal obstructions less than 25%, but totally avoided dest/pipo with horizontal obstruction over 50%.

MacArthur et al. (1979, 1982) have reported that heart rates increased when sheep enter forested areas with reduced visibility. Heart rate is a sensitive indicator of arousal, the first stage of an alarm reaction to stress (Jenkins and Kruger 1975). The added cost of excessive arousal may interfere with health, growth, and reproductive fitness (Geist 1979). Sheep in CSP may avoid dest/pipo stands because of the stress involved and the very limited forage available.

Foraging efficiency of bighorn sheep was negatively associated with distance from escape cover and positively associated with habitat visibility (Risenhoover and Bailey 1985). Bighorn ewe and lamb groups in CSP have restricted their activity to steep, rugged canyons with permanent water supplies. Although forage density was higher in some available habitats than the stro/pipo selected by the sheep, the added security of close proximity to escape terrain together with an acceptable forage density and access to water in this habitat could have led to this selection.

Home range, which is determined by the movements of an animal or group of animals, is influenced by habitat selection. Thus, home range must reflect habitat use. This is indicated by the differences in availability of habitats within the home range of the sheep compared to total habitat availability. Selection for stro/pipo and the close proximity to both water and escape terrain indicated that CSP bighorn ewes and lambs required rugged slopes or canyons near permanent water supplies.

Recommendations

Dest/pipo stands in the French Creek Canyon should be thinned or burned. Clearing these areas would increase available range which would otherwise remain unused. Carrying capacity also could be increased due to increased forage production stimulated by opening the canopy. Finally, when habitat selection studies are undertaken, the method by which available habitat is determined can influence apparent selection. If only the home range is considered to contain available habitats, true selection may be masked by the fact that home range already reflects this selection.

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ALPINE HABITAT SELECTION IN SYMPATRIC MOUNTAIN GOATS AND MOUNTAIN SHEEP

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Abstract: Observations enhanced with use of a prescribed route and radiotelemetry, were used to estimate fall, winter and spring (Sept-May) habitat selection of sympatric mountain goats (*Oreamnos americanus*) and mountain sheep (*Ovis canadensis*) in alpine areas near Mount Evans of central Colorado. Based on instances of use and not frequency or intensity of use, mountain goats and mountain sheep selected 15 and 17 of 25 identified habitat types, respectively, during September through May 1981-85. Six habitat types were not used by either species. Mountain goats tended to occupy more habitats within months than mountain sheep. Based upon tests of pooled observations, mountain goats used alpine habitats disproportionately to their availability. Dissimilarly, mountain sheep used alpine habitats proportionately to their availability. Although mountain goats and mountain sheep did not use the same habitats in toto, at least 2 habitats were used frequently be each of the species and not always at different times. Sixty-nine instances of direct interaction were noted between the 2 species. Of these, 41% involved interference competition where mountain sheep were deterred from use of some resource. Observations of seasonal differences in interference competition were consistent with competition theory. Whether habitat selectivity in this case has been influenced by interspecific competition is uncertain.

QUESTIONS AND ANSWERS

Daryll Hebert, BC: Dale, you mentioned 69 agonistic interactions that you recorded between sheep and goats, is that correct?

Dale Reed: Yes

Hebert: Did you have any measurements as a result of the agonistic interactions that there was any detrimental effect on the sheep? Were they actually displaced out of an entire habitat or did they remain within that habitat but select a different feeding site for example?

Reed: I would say almost exclusively they remained in that habitat, but they were displaced from a given feeding area, a given resource such as a salt lick, a bedding area and so on. The extreme we had was where one adult goat literally chased a group of about twelve sheep for one hundred meters. That's extreme, but that was still in the same general habitat as identified.

Hebert: If you're hypothesizing some interference, how do you think it would manifest itself in sheep, poorer nutrition, larger energy expenditure?

Reed: Larger energy expenditures to some degree, less preferable resources to some degree. We were monitoring populations aspects as well as feeding habits, but I think our measurements were too crude to detect a response.

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A SOLAR RADIATION MODEL FOR IBEX RELOCATION PROGRAMS

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This paper is dedicated to the memory of our friend
Gerbrandt Wiersema, who died in the Gran Paradiso National Park
while on field work for his "Project Ibex".

ABSTRACT

A SUN/LAND program (solar radiation calculated from a digital elevation model) was tested as a practical and time-saving means of evaluating suitability of mountain slopes as wintering sites for the establishment of new ibex colonies. The test site was a protected area on the Italian Western Alps, harbouring old, numerically stable ibex population. Actual wintering areas regularly overlapped well defined patches of territory receiving high incoming solar radiation (minimum value: 1800 Wh/m^2 on January 15 map); habitat corridors for late spring migration were also represented. Limitations and management implications of this method are discussed.

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INTRODUCTION

In 1821 Alpine ibex (Capra ibex ibex L. 1758) were close to extinction with only 100 animals surviving in the Massif of Gran Paradiso in Northwestern Italy (Couturier, 1962). After 160 years of protection and reintroductions carried out in the 7 Alpine countries (natural recolonization by ibex is limited), the present stock is over 18,000 head (Tosi 1983).

However, historical distribution of this ungulate (Couturier 1962) and the human cause of its former local extinctions (uncontrolled hunting), suggest that much unexploited habitat remains. Consequently, the demand to establish new colonies is still high.

On the other hand, ibex reintroductions are expensive and delicate operations; a third of the colonies harbour stagnant or declining small stocks (Wiersema 1983a) and complete failures are also frequent (4 out of 9 on the Italian side of the Western Alps).

Recently, habitat evaluation models were developed so future reintroductions could be planned on a more objective ecological basis (Elsner-Schack 1982; Wiersema 1983b; Apollonio and Grimod 1984; Tosi et al. 1985; Rossi et al. 1986). According to these studies, the presence of suitable winter ranges appears to be the main factor for the success of an ibex colony. Habitats with high incoming solar radiation and steep slopes allow access to forage through fast snow melting/sliding, giving ibex the possibility of surviving during the harsh Alpine winter. As such sites are usually localized and difficult to reach in winter, their identification over a large territory, through field searches and/or low level flights, would require high personnel involvement and economic cost.

The aim of this study is to test whether the computing and mapping of solar radiation, using a procedure already developed for other purposes, may facilitate detection of suitable wintering areas and habitat evaluation for ibex relocation programs [2].

STUDY AREA

The 42,000 ha study area is encompassed by the following coordinates:
NE angle latitude 45°51' longitude 5°00'
SW angle latitude 45°38' longitude 5°35'.

It comprises the middle and high Orco Valley (Italian Western Alps), with a major east-west orientation. The head and north side of Orco Valley

(2) When the research was over, we knew that a similar survey, though performed with different methods, was carried out by Stefanovic and Wiersema. Their paper is in press in the ITC Journal (1985-3).

represent the southernmost part of the Gran Paradiso National Park (G.P.N.P.). Wide lateral valleys obliquely entering the main glacial valley characterize the landscape. Altitudes range from 650 to 3,642 m (Mt. Ciarforon).

Ground cover is generally poor on the south slopes with broadleaf trees at low elevation and larches (Larix decidua) higher up. Rich and dense spruce (Picea picea) and larch forests exist on the exposed northern side. Alpine grassland extends as far as 2,800-3,200 m.

The climate is of the continental type (highest precitipitation rates occur in summer and are minimal in winter) and is typical of the xeric inneralpine valleys. Total annual precipitation reaches 997.5 mm in the heart of the study area (Ceresole Reale, 1,582 m).

Ibex living in the study area belong to the only autochthonous population of this ungulate. On average 250 ibex have been observed since 1950 during summer ground counts; winter stock is higher (585 ibex in winter 1984-85) because of migration from the neighbouring valleys.

The long term stability of this protected population suggests that the carrying capacity of the study area has likely been reached, supporting the hypothesis that all or at least most of the suitable wintering areas have been colonized.

METHODS

Ibex winter distributions (Fig. 1) were compared with thematic maps of daily solar radiation (Fig. 2-6).

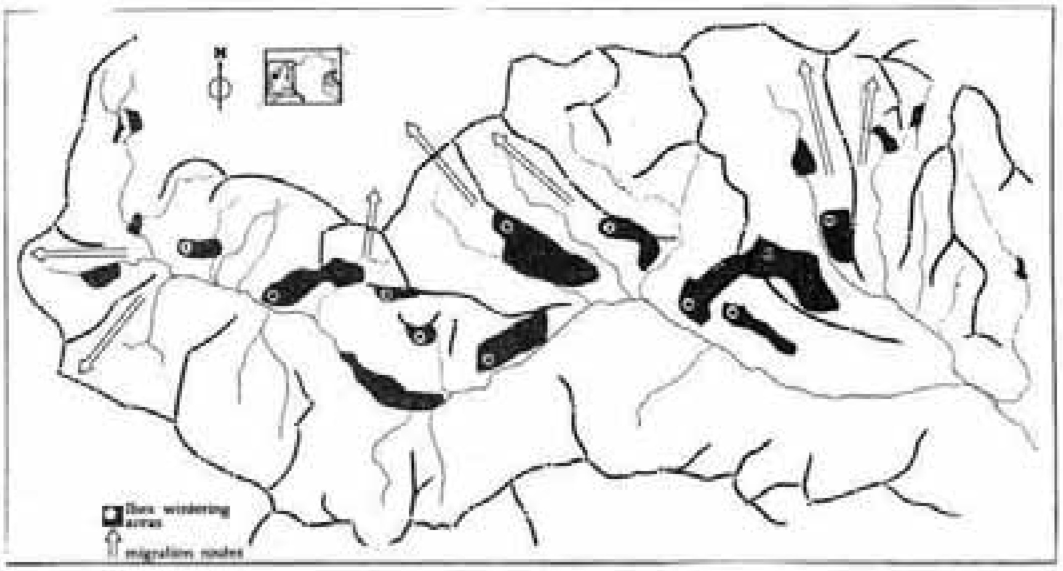

Fig. 1 - Winter distribution and main migration routes of ibex in the middle and high Orco Valley.

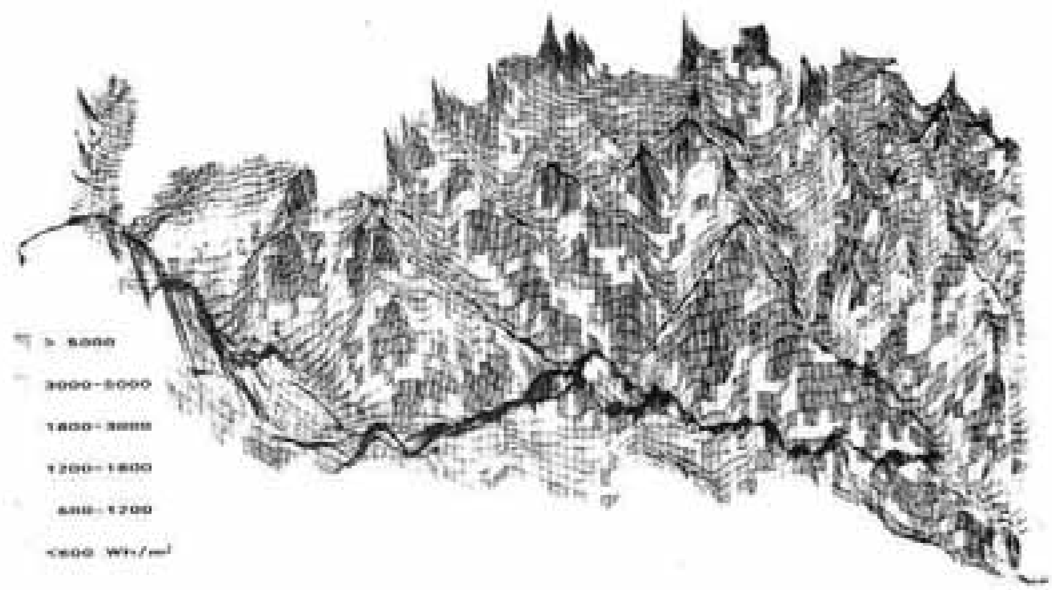

Fig. 2 - Solar radiation map of the middle and high Orco Valley on January 15 (isometric view).

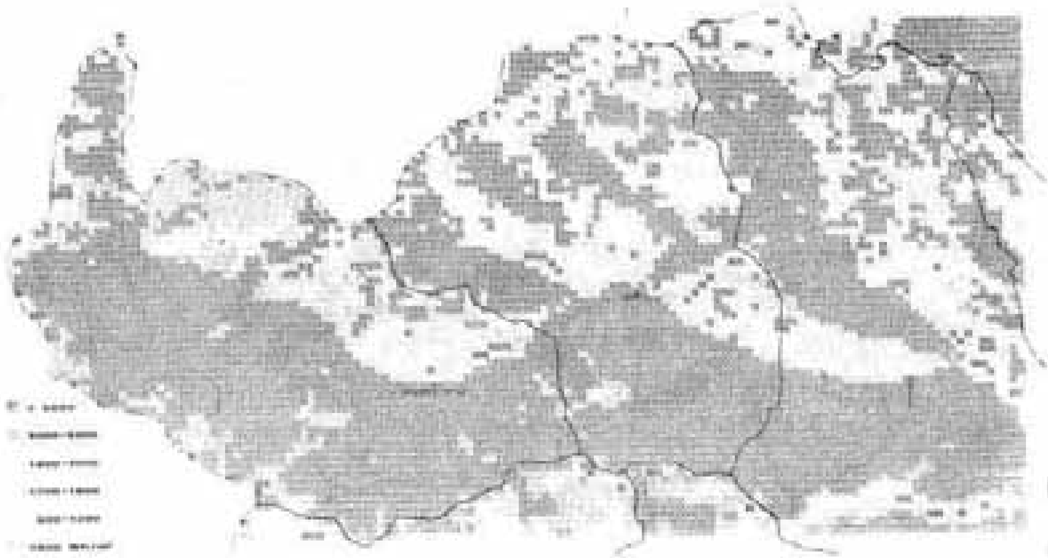

Fig. 3 - Solar radiation map of the middle and high Orco Valley on January 15.

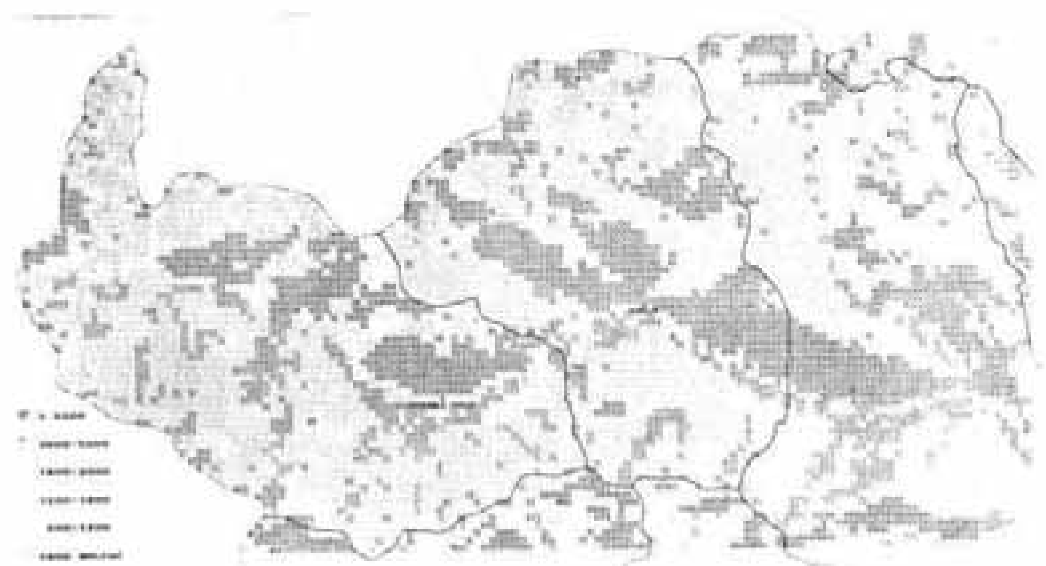

Fig. 4 - Solar radiation map of the middle and high Orco Valley on February 15.

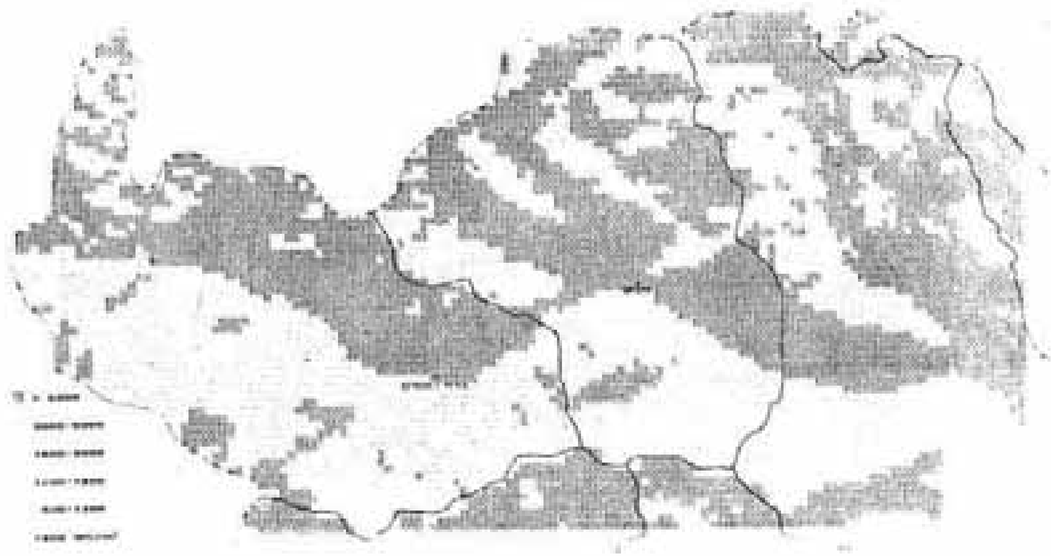

Fig. 5 - Solar radiation map of the middle and high Orco Valley on March 15.

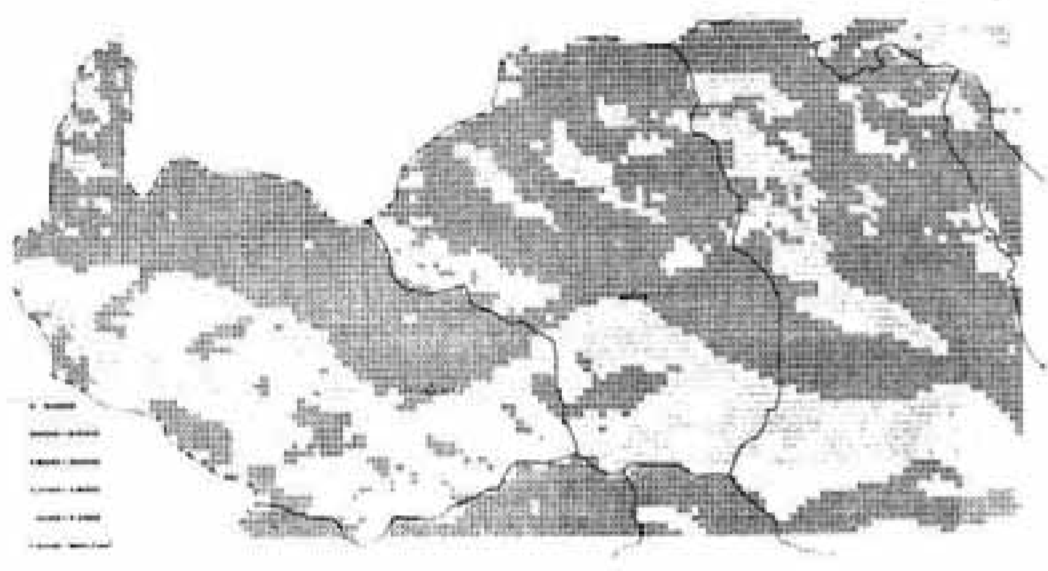

Fig. 6 - Solar radiation map of the middle and high Orco Valley on April 15.

Figure 1 was drawn from observations of the wardens of the G.P.N.P., collected over a 5-year period. Data were recorded on a 1:50,000 scale map. Eleven wintering sites were mapped (Table 1).

Moreover, main migration routes of some ibex herds from their wintering sites were drawn (Fig. 1).

Table 1 - Topographic features of actual wintering sites of ibex in the middle and high Orco Valley.

wintering area	elevation (meters)	average slope	aspect
1	2400 - 2000	30°-45°	S
2	2600 - 1700	30°-45°	S
3	3000 - 2400	30°-45°	S
4	2500 - 2200	30°-45°	S
5	2200 - 1500	30°-45°	S
6	2700 - 1400	30°-45°	S
7	2700 - 1600	30°-45°	S
8	2900 - 1400	30°-45°	SW
9	2200 - 1700	30°-45°	SW
10	2900 - 1500	30°-45°	E
11	2700 - 1900	30°-45°	SW

Solar radiation was mapped using software (SUN/LAND) developed by Grosso et al. (1983). This program, supplied by C.S.I.-Piemonte (a public service documentation and computing Center), is available on request.

Briefly, the SUN/LAND is made up of the following stages:

- constructing a digital elevation model representing the outline of the sample area;
- computing insolation through a model giving the instantaneous and daily evaluation of sunlit and shaded zones;
- computing ground position;
- computing solar radiation through a model based on unitary radiation values on the horizontal plane and including the instantaneous and daily radiation values for each node of the elevation model.

The study area was digitally represented by a 200 x 200 m grid (7,418 meshes total) to optimize the 1:100,000 plotted orographic data stored in the CSI-Piemonte archives.

Seven thematic colour maps were drawn [3], representing solar radiation on January 15, February 1 and 15, March 1 and 15, April 1 and 15 (Figs. 3-6). An isometric solar radiation map was also drawn for January 15 (Fig. 2). Mapping was started on January 15, because by this time regular rutting is over and ibex have reached their winter range.

Solar radiation values (Wh/m^2) were grouped in six classes (Table 2); the percentage of grid meshes in each class were determined from the thematic maps (Table 3).

Table 2 - Solar radiation classes used and their associated solar radiation values.

Class	Wh/m^2
1	> 5000
2	3000-5000
3	1800-3000
4	1200-1800
5	600-1200
6	< 600

Table 3 - Distribution of solar radiation values on the thematic maps of the middle and high Orco Valley.

	% of grid meshes from each energy class						
Class	Jan 15	Feb 1	Feb 15	Mar 1	Mar 15	Apr 1	Apr 15
1	2.3	11.0	22.0	35.7	48.4	56.7	59.5
2	8.8	10.1	9.8	9.1	7.1	7.3	9.5
3	8.0	8.1	8.2	6.3	5.7	6.4	7.8
4	5.7	5.7	5.0	5.2	5.2	7.5	17.7
5	15.8	34.6	45.7	42.1	33.6	22.1	5.5
6	59.4	30.5	9.3	1.6	0	0	0

(3) Following Editor's instructions, black and white prints of original colour maps are presented.

Ten man-days of a CSI computer operator were needed to adapt the SUN/LAND program to our requirements and to check the results. Each thematic map required approximately 30 minutes of CPU time on a OH 5560 computer with an operative system MVS/TSO and 45 minutes on a Calcomp 1039 plotter. Total cost of the operations was about 2 million Italian Lire (~1,300 US$).

RESULTS

Comparison of ibex winter ranges and thematic solar radiation maps showed that:

- presently utilized wintering sites overlap areas characterized by daily solar radiation values $\geqslant$1800 Wh/m^2 (except for site number 10);
- Class 1 values were found in 9 out of 11 wintering sites from the beginning of the mapping period;
- wintering sites are better recognizable on the January 15 map because on this day the ratio between the surface of areas with a daily solar radiation 1800 Wh/m^2 and the surface of known wintering sites reaches its minimum value (Table 4);
- two of the main late spring migration routes, connecting the high Orco Valley with Maurienne and Tarantaise regions, in the Vanoise National Park (westernmost arrows on Fig. 1), are clearly represented on the maps. These routes are drawn by the progressive appearance of Class 1 values along south to south-east slopes situated in a very poorly irradiated part of the sample area. The other known migration routes were not so clearly recognizable in the northern part of the study area where the high solar radiation had been homogeneously distributed since the beginning of March.

Table 4 - Predictability of ibex wintering sites location on different solar radiation maps of the middle and high Orco Valley.

Day	surface of areas with solar radiation values $\geqslant$1800 Wh/m^2 / surface of known wintering areas
Jan 15	4.62
Feb 1	7.08
Feb 15	9.74
Mar 1	12.42
Mar 15	14.85
Apr 1	16.89
Apr 15	18.68

DISCUSSION

Within the study area, which is densely populated and likely to be saturated with ibex, the solar radiation map for January 15 identified 10 out of 11 known wintering areas. These results are similar to those obtained by analysis of satellite images, which are able to furnish direct printouts of snow-free vegetation sites (Wiersema 1983b). In fact, the areas found through false colour composite of Landsat winter scenes overlap most of the sites defined on the January 15 map by a solar radiation level ≥ 1800 Wh/m^2 (Fig. 7).

Fig. 7 - Patches of snow-free vegetation found by Wiersema (1983b) through false colour composite of a Landsat winter image of the middle and high Orco Valley (above) compared with sites of the same area receiving high solar radiation (≥ 1800 Wh/m^2) on January 15 (below).

Of course, not all sites with a high solar radiation harbour ibex herds for the following reasons:

1 - most of these sites are located at extremely high elevations (above 3,000 m);
2 - some sites are lacking necessary landscape features (steep slopes, rocky terrain interspersed with grassland, no thick forest, etc.) that can be found on topographic maps and by photointerpretation in known wintering areas (Rossi et al. 1986);
3 - a few sites have been subjected to heavy poaching in the recent past and have not yet been spontaneously recolonized.

The sensitivity of this technique could be improved by reducing the scale of the grid which defines the sample area. Consequently, this would mean input of cartographic data referring to a scale smaller than 1:100,000.

We agree with Stefanovic and Wiersema (1985) that the use of a smaller grid scale (e.g. 100 x 100 or 50 x 50 m) is advisable, at least in areas with complex topography, because in this way the computer can detect small areas that may adequately support overwintering ibex herds.

For example, as far as the study area is concerned, the exact morphology of the wintering area number 10 was seriously misrepresented due to the computer interpolation of input topographic data. This site, which actually comprises 3 narrow valleys with major east-west orientation, appeared to have a uniformly east to north-east aspect on the digital elevation model. Therefore, none of the south slopes was represented, so daily solar radiation probably had been strongly underestimated. These slopes appear as snow-free vegetation patches on the false colour composite of Landsat winter images (Wiersema 1983b).

CONCLUSIONS

Mapping of daily solar radiation, using the procedure developed by Grosso et al. (1983), can be defined as an interesting, economic and time saving possibility for dealing with the problem of planning ibex reintroductions. The screening of territory for this determining factor, not only supplies data that are valuable on their own, but also enables more detailed scale evaluations (e.g. photo-interpretation and vegetation survey) to be carried out on smaller areas through "a priori" rejections of unsuitable overshadowed sites (80.9% in the study area, though one of the most favourable for ibex).

Further studies are necessary before widespread application of this technique. In particular, a 1800 Wh/m^2 solar radiation level will be tested as the minimum requisite for predicting the locations of ibex wintering sites in homogeneous macro-climatic conditions. Thus the analysis of solar radiation will be extended to other areas harbouring:

- stable ibex colonies
- increasing ibex colonies spontaneously spread

- increasing ibex colonies recently reintroduced.

Also, an ibex reintroduction will be carried out in May '86 in an area located by the described method.

Other management implications may be foreseen through the planned development of this method. For example, recognizing possible late spring migration routes could influence the choice of the reintroduction sites, depending on the individual situations. Indeed, a policy to increase ibex on a regional level would select sites connected by corridors facilitating pioneering of vacant habitat. On the other hand isolation could control the animals' dispersal, enabling a faster establishment of the colony, and thus lower operational costs.

Finally, an analysis of the relationship between solar radiation, pasture productivity and animal biomass, could reveal interesting data correlated to the carrying capacity of an area.

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